

**FACTORS INFLUENCING PREDATION ON RUFFED GROUSE  
IN THE APPALACHIANS**

by

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**ABSTRACT**

Predation accounts for the majority of ruffed grouse mortality beyond the brooding period throughout grouse range. Most studies of ruffed grouse ecology have taken place in the central portion of the species range including the Great Lakes states and southern Canada where aspen (*Populus tremuloides*) is dominant. Populations in the central range of grouse distribution exhibit 10-year cyclic patterns of decline that have been associated with the invasions of boreal predators such as great horned owls and northern goshawks during crashes in small mammal populations.

I completed an accuracy assessment of field sign to determine the role of scavenging as it related to diagnosing causes of proximate mortality. Potentially large numbers of grouse are scavenged after death, which can alter or completely falsify the reported cause of death.. My results indicated that stand-level and micro-site habitat variables did not influence scavenger detection of ruffed grouse carcasses ( $P \geq 0.05$ ). Scavenging was limited to 24 of 64 carcasses and was entirely attributed to mammalian species. Scavenging behavior was related to the

condition of the carcass following death ( $P = 0.003$ ) and the ambient temperature ( $P = 0.01$ ). As the temperature increased and as a carcasses entrails and muscle became more exposed, the probability of being scavenged increased. Nineteen percent of whole carcasses placed in the field were scavenged and would have been attributed to mammal predation based on the field sign; 56% of 32 mock avian kills were scavenged would have been attributed to mammal predation.

I related indices of predators and weather patterns to trends in ruffed grouse predation. Using data collected at 10 study sites between February, 1997 and December, 2000, I compared predation rates, and animal and weather indices to predation rates, across sites, years, regions, seasons and month combinations pooled across years. Avian predators were the primary predators of ruffed grouse in the Appalachian region (50% of all predation). Predation rates on ruffed grouse were highest in fall (8.3%), due to high predation on juveniles, and spring (7.4%) in association with raptor migration and pre-breeding activity of grouse. Predation patterns and predator abundance did not indicate the occurrence of predator invasions during the years of this study. Predation rates on ruffed grouse were positively related to the presence of rain and negatively related to the average low temperature and number of rabbits and squirrels observed per hour. Observations of owls and Cooper's hawks per hour were correlated with predation rates on grouse while those of red-tailed, red-shouldered and broad-winged hawks were not.

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## **Chapter 1- SCAVENGING OF RUFFED GROUSE CARCASSES IN SOUTH-WESTERN VIRGINIA; INFLUENCES AND IMPLICATIONS**

**Abstract:** Scavenging is often neglected as a source of bias when diagnosing sources of mortality and collecting mortality related habitat information. The use of mortality-sensing radio transmitters has greatly increased our understanding of animal survival. However, the potential of lag-time in recovery of carcasses and subsequent diagnoses of cause of death are seldom addressed. Motion created by feeding predators and scavengers can delay pulse switchover and prolong recovery. This study sought to determine the influence of temperature, forest stand type, overhead cover, and carcass condition on scavenging rates, displacement patterns and habitat sampling biases at perceived kill sites for ruffed grouse (*Bonasa umbellus*). We documented carcass disturbance, scavenger species and displacement distances for 64 carcasses. Mammalian scavengers disturbed 42 of 64 grouse carcasses. Scavenger species identified included mice (*Peromyscus sp.*), flying squirrel (*Glaucomys sp.*), cottontail rabbit (*Sylvilagus floridanus*), Virginia opossum (*Didelphis virginiana*), raccoon (*Procyon lotor*), long-tailed weasel (*Mustela frenata*), bobcat (*Lynx rufus*), eastern coyote (*Canis latrans*) and common raven (*Corvus corax*). Air temperature and carcass condition were the dominant factors associated with scavenger disturbance of grouse carcasses. Mammal scavenging activity increased during warmer temperatures, and mock avian kills were scavenged more frequently than whole carcasses. Potential overestimation of mammalian-caused mortality may result from scavenging especially when ambient air temperature is warmer and carcasses have been previously fed upon.



## INTRODUCTION

The impact of scavenging on estimates of cause-specific mortality has been poorly addressed in upland gamebird literature. Investigations of scavenging trends have applied mainly to lead poisoning in waterfowl (Stutzenbaker et al. 1986, Pain 1991), power line collisions (Faanes 1987), and carrion use by various vertebrate communities (Hewson 1981, 1995; Wallace and Temple 1987, Travaini et al. 1998). To our knowledge, this is the first study that incorporates radio telemetry and passive-infrared cameras to document scavenging on upland gamebirds as a means of assessing the accuracy of proximate mortality diagnoses and habitat relationships. Conclusions may provide information about the accuracy of cause-specific mortality estimates and reliability of habitat data at perceived kill sites.

Radio telemetry is one of the most commonly used methods for monitoring survival, and contributes greatly to carcass recovery and estimates of cause-specific mortality (Hine 1973, Small et al. 1991, Samuel and Fuller 1994, Gormley 1996, Johnson et al. 1997, Pace 2000). Survival studies reporting cause specific mortality frequently use carcass condition and marks on transmitters to make diagnoses (Hine 1973, Pace 2000). Some researchers imply a great deal of certainty when reporting causes of death yet, there is often little mention of scavenging as a potential source of error. Carcass longevity, defined as the period between death and the commencement of scavenging is seldom >1 week and is often only minutes or hours (Hewson 1981, Stutzenbaker et al. 1986, Faanes 1987, Pain 1991, Hewson 1995, Travaini et al. 1998). Estimates of carcass longevity can provide information on how quickly scavengers leave evidence on or near bird carcasses. Further, mammalian and avian scavengers can transport carcasses considerable distances from the kill site, affecting the timeliness of recovery for animals equipped with motion sensing mortality transmitters. Movement of carcasses by

scavengers may result in misleading habitat data when relationships between mortality and habitat are of interest. Motion-sensing transmitters on dead ruffed grouse have been observed switching from mortality mode to active while investigators monitored them (G.S. Haulton, SUNY-ESF, personal communication). The objectives of this study were to identify scavenger species, estimate carcass longevity, measure carcass displacement from scavenging, and determine the role of temperature, forest stand type, overhead cover, carcass condition, and micro-site habitat variables in scavenging behavior on ruffed grouse carcasses.

## METHODS

### *Study Site*

Our study was conducted on Clinch Mountain Wildlife Management Area (WMA) (36° 94' N, 81° 83' W), near Saltville, Virginia. Clinch WMA is a 10,343 ha parcel in the ridge and valley province of the Appalachian Mountains consisting of mature oak-hickory (*Quercus spp.* - *Carya spp.*) forest with 2 - 5% herbaceous and clearcut cover types (Fearer 1999). The vertebrate scavenger community on Clinch Mountain WMA is composed of, but not limited to Virginia opossum, raccoon, red fox (*Vulpes vulpes*), gray fox (*Urocyon cinereoargenteus*), eastern coyote, domestic dog (*Canis familiaris*), weasel (*Mustela spp.*), mink (*Mustela vison*), striped skunk (*Mephitis mephitis*), bobcat, black bear (*Ursus americana*), mice, red-tailed hawk (*Buteo jamaicensis*), common raven, American crow (*Corvus brachyrhynchos*) and blue jay (*Cyanocitta cristata*). The topography is rugged and diverse with elevations ranging between 600 - 1,400 m. This study was conducted as part of the Appalachian Cooperative Grouse Research Project (ACGRP) which was established to describe ruffed grouse ecology, population dynamics and the effects of hunting in the Appalachian Region.

*Study design and execution*

The sampling unit in our study was a grouse carcass ( $n = 64$ ) placed in a forest stand for a 5-day period using a 3-way factorial design. The treatment factors were forest stand type (mature hardwood or 10-15 year-old clearcut), carcass condition (whole or mock avian kill) and overhead cover (present or absent, Fig. 1.1). Overhead cover was defined as shrub growth or natural structures (e.g., rock overhangs or dead wood)  $\sim 0.5$  m above the ground that impeded detection from aerial scavengers. Within each 5-day sampling period I selected 2 clearcuts and 2 mature forest stands for carcass placement. I paired each clearcut with a mature stand of similar slope, aspect, size and juxtaposition to other landforms such as roads, ridge tops and other clearcuts. All stands were within 250 m elevation of the ridge top largely due to the dispersion of clearcuts across the landscape. I randomly placed 4 carcasses ( $> 100$ m apart) within each of the 4 forest stands during each sampling period based on a point grid in Arc View 3.2. The placement site of each carcass will hereafter be referred to as the deposition site. Within each stand, each carcass was represented by 1 of the combinations of carcass condition and overhead cover. Whole carcasses simulated hunter losses or accidental deaths and mock avian kills represented grouse that had been rendered by a hawk or owl. The latter was reproduced by decapitating carcasses, removing the breast muscle and scattering feathers from the grouse in a 1 m radius around the carcass. All carcasses were stored frozen and allowed to thaw to room temperature ( $4.4 - 10$  C) prior to placement in the field. Rubber boots and gloves were worn to limit the amount of human scent when placing carcasses in the field. The 5-day sampling period was replicated 4 times resulting in a total of 64 grouse carcasses being placed in the field between 6 November and 1 December 2000. I allowed 2 days between sampling periods. Four

new stands (2 clearcut and mature stand pairs) were randomly selected for each sampling period. Stand size ranged from 3.2 – 8.7 hectares.

I placed 16 Cam Trakker™ passive infrared cameras (Cam Trakker, Watkinsville, GA, USA) 1–1.5m above the ground and 3–4m away from carcass (1 camera/carcass) at the deposition site. Cameras were set to monitor during day and evening periods with a minimum 3-minute delay between photographs. Date and time were automatically recorded on photos.

All carcasses were equipped with the standard 11g, necklace transmitter placed on living grouse and an additional 11g transmitter wired internally to the skeleton (ATS Inc., Isanti, MN, USA). Paired transmitters were used to reveal differences between the resting point of the necklace transmitter and the carcass following a scavenging event. Necklace transmitters were placed on mortality mode using a magnet and checked for disturbance by investigators every 2-6 hrs.

Carcasses were recovered when the transmitter was found in active mode (signifying a scavenging event). Disturbance would be instantaneously apparent by the switch from mortality to active mode as opposed to an 8-hr delay observed when changing from active to mortality mode. Thus, the true time to scavenging was estimated as the time between carcass deposition and the time of scavenging based on photo images or transmitter pulse change.

I recovered disturbed carcasses after an 8-hr waiting period to replicate the best case scenario for diagnosing predation. When the recovery time was within 1 hr of sunset or during hours of darkness, I retrieved bird remains the following workday. The latter simulated typical field recoveries, which are not usually attempted during low light conditions. When recovering bird remains, I noted scavenger sign and marks to carcasses and transmitters, and distance to the nearest habitat edge at the deposition site. Recovery site was defined as the location of the

carcass following a scavenging event. Distances were measured between recovery and deposition sites using a tape measure. I also recorded slope, aspect, basal area, stem density at both sites and made a determination of cause-of-death based on the field sign. I established habitat plots consisting of 4, 11.3 m transects radiating from the transmitter in each of the cardinal directions at the deposition and recovery sites. I recorded point intercept data at 2-m intervals along each transect for ground-level dead wood and overhead canopy. I estimated slope using a clinometer, basal area with a 10-factor angle gauge, and stem density (<8 cm) was measured by counting the number of stems within 1 m on each side of the transects, 1.4 m above the ground. I measured straight-line distances between the resting point of the carcass (the recovery site) and the point of initial deposition. When the recovery site was  $\leq 11.3$  m from the deposition site, habitat was considered the same as the deposition site and no data were collected.

Temperature was recorded at 1-hr intervals throughout the study using a StowAway® temperature logger (Onset Industries, Pocasset, MA, USA) located at the center of the study area. I assumed that temperature variations at deposition sites were correlated although not exactly the same, as that at the central location. My analysis was concerned with relative changes in temperature (not absolute temperature). I believe the lack of exact temperature measurements at each site had limited impact on our results. Temperature values used for modeling probability of being scavenged were calculated as the mean hourly temperature leading up to the time of scavenging. Carcasses not disturbed after 5 days were removed from the field.

#### *Data analysis*

I hypothesized that the probability that a grouse carcass was scavenged could be influenced by the treatment factors (forest stand type, carcass condition, cover), by habitat characteristics (canopy cover, wood debris, stem density, basal area, slope, and distance-to-edge)

at the deposition site, or by temperature. I modeled the probability of being scavenged using logistic regression (PROC LOGISTIC, SAS Institute 1999). I fit full models to each variable set and all variables combined, and also used stepwise procedures to select the subset of variables from each set separately and combined, that best predicted the probability of being scavenged. I used Akaike's Information Criterion (AIC) to compare models (Anderson et al. 2000) and selected the "best" model that predicted probability of being scavenged. Due to low sample size I used Multiple Response Permutation Procedure for matched pairs (PTMP) in BLOSSOM, (Midcontinent Ecological Science Center, Fort Collins, CO, USA) to test the hypothesis of no difference between habitat variables at deposition sites versus carcass relocation sites. I compared habitat data at deposition sites for grouse carcasses that were and were not disturbed by scavengers using Wilcoxon Rank-Sum tests for non-normal data. I used PROC GLM (SAS Institute 1999) to test for differences in time to scavenging and distance to edge against treatment and habitat variables. Significance level was set at  $\alpha = 0.05$  for all tests.

## RESULTS

Forty-two (66%) of 64 carcasses were scavenged during this study. Small rodents accounted for 18 (28%) instances of disturbance and larger scavengers accounted for 24 (38%). Sign left on carcasses by rodent scavengers was characterized by small incisor marks and gnawing. Rodent scavenging was visually distinct from that of larger animals and would not alter diagnosis of death. Therefore, rodent scavenging observations were excluded from these analyses. Rodent activity however, was sufficient to change the pulse of the transmitter from morality to active mode. Twenty-three of the 24 carcasses scavenged by larger animals showed signs of mammalian scavenging including chewed bones and feathers. Mean ( $\pm$  SE) time to disturbance was  $68 \pm 7.9$  hr for the 24 carcasses disturbed by larger scavengers. Fifty-eight

percent of carcasses were scavenged within 72 hrs (Fig. 1.2). The shortest time to disturbance was 1 hr and 46 min and was attributed to a bobcat. During the 4 trials 10, 4, 6 and 4 carcasses were scavenged, respectively. The proportion of carcasses scavenged per time block did not substantially differ ( $\chi^2_3 = 4.0$ ,  $P = 0.12$ ).

Relocation distances of grouse carcasses by scavengers ranged from 0.1 - 52.5 m. Seventeen grouse carcasses were moved >1 m ( $\bar{x} = 9.8$  m,  $SE = 2.8$ ) from the deposition site. Movement distances for the 24 mammal scavenged carcasses did not vary among treatment factors or habitat variables ( $F_{13,23} = 1.03$ ,  $P = 0.49$ ). Internal collars were separated from 3 carcasses, resulting in underestimated movement distances. Three carcasses were taken into ground dens: 1 was 1.4 m inside a hollow oak (*Quercus sp.*) log, 1 in an abandoned woodchuck (*Marmota monax*) den and 1 in a weasel den.

Cameras documented disturbance by 3 mice, 1 eastern chipmunk (*Tamias striatus*), 2 eastern gray squirrels (*Sciurus carolinensis*), 4 flying squirrels, 1 cottontail rabbit, 3 Virginia opossum, 4 raccoons, 2 long-tailed weasel, 2 bobcats, 1 eastern coyote and 1 common raven (Fig. 1.3). Photographs of squirrels were thought to be incidental events since they were not photographed feeding on carcasses and the grouse remains were not disturbed. Three false negatives occurred when potential scavengers approached a carcass but left no visible evidence; these included coyote, long-tailed weasel and raven encounters. Camera sensors failed to detect 14 scavenging events. In instances of camera failure, estimates of time-to-disturbance and scavenger identity were generated using radio telemetry and field sign. Time-to-disturbance did not vary by treatment or habitat variables ( $F_{13,23} = 1.03$ ,  $P = 0.29$ ) when data were analyzed across all experimental trials. Temperatures ranged from -2.3 – 14.3 C.

Carcass condition ( $P = 0.003$ ) and temperature ( $P = 0.01$ ) were the variables most closely associated with scavenging probability (Table 1.1). The likelihood of a carcass being scavenged was highest for mock avian kills during periods of warmer temperatures. Wilcoxon Rank Sum test comparing habitat variables at sites where carcasses were and were not scavenged revealed no significant differences (Table 1.2). In 7 of 24 instances, transmitters were moved  $>11.3$  m from the site of deposition. The permutation test for matched pairs indicated that the amount of woody debris at recovery sites may be higher than at initial deposition sites ( $P = 0.06$ , Table 1.3).

Scavenger sign left on carcasses was variable and carcass consumption ranged from minimal to complete. Some scavengers selected breast and leg meat, some selected entrails and others left no scraps whatsoever. Camera failure made it difficult to attribute any consistent species-specific scavenger sign to ruffed grouse carcasses. Impressions on transmitter harnesses and hardware also were inconclusive. Eighteen of 32 (56%) mock avian carcasses placed in the field would have been attributed to mammal predation based on field sign after scavenging. Nineteen percent ( $n = 6$ ) of whole carcasses ( $n = 32$ ) would have been reported as mammalian predation events after scavenging.

## DISCUSSION

A lack of fragmented habitat, indefinite edge boundaries, different landforms and scavenger communities make direct comparisons with other studies difficult (Stutzenbaker et al. 1986, Pain 1991). This is the first study that I am aware of that has looked at scavenging impacts on ruffed grouse carcasses in a forested mountain environment.

Carcasses having the flesh exposed, feathers strewn about and heads removed were scavenged more frequently than birds that were completely intact. Ambient air temperature



appeared to have an influence on scavenging of ruffed grouse carcasses. Temperature and humidity are not addressed in the scavenging literature, however, they are known to affect olfaction in hunting dogs (Syrotuck 1972) and nest predators (Whelan et al. 1994). Warmer temperatures may have increased scent dispersal and scavenger activity, resulting in higher scavenging rates.

Fewer carcasses (38%) were scavenged in this study compared to others (range: 41 to 100%; Grondahl 1958, Dumke and Pils 1973, Stutzenbaker et al. 1986, Pain 1991).

Relationships between scavenging behavior and habitat structure were not found in this study. Pain (1991) found the presence of overhead cover decreased scavenging rates on waterfowl in France, but this was not influential in southwestern Virginia. Twenty of 49 ring-necked pheasant carcasses (*Phasianus colchicus*) were disturbed after 3 days when placed in varying amounts of cover along roads, fence lines and other prominent edges in Wisconsin (Dumke and Pils 1973). Distance to edge and habitat were not significant predictors of scavenging rates on Clinch WMA. The latter suggests habitat effects on scavenging are important in fragmented landscapes but less in contiguous forests.

Carcass temperature, though not addressed in the literature, may also influence scavenging rates. Peak temperature of carcasses prior to deposition in the field in this study was ~ 10°C, far less than the average body temperature (41.6°C) of live ruffed grouse (Bump 1947). The olfactory stimulus produced by a freshly killed grouse would likely be greater than a thawed carcass and may result in higher scavenging rates. Grouse carcasses having exposed viscera and plucked feathers likely provide greater visual and olfactory stimulus and were scavenged in greater numbers than whole carcasses.

Marks to the transmitter harness were uncommon suggesting that punctures and bite marks to transmitter harnesses are created during the dispatch of a bird by the predator and not from scavenging. Bird predators tend to focus on the head and neck when killing avian victims (Darrow 1938, Einarsen 1956, Davis 1964) therefore marks on transmitter hardware can be important diagnostics to determining cause of death. Although carcasses may display predator related sign; those not recovered for extended periods will likely exhibit signs of mammal feeding.

Separation of collars from carcasses can make finding remains and predator sign difficult and can lead to faulty diagnoses of proximate mortality cause. Though separation of the necklace transmitter and carcass occurred in only 12.5% of scavenged carcasses, this may be more common during actual predation events. Thirty percent of 893 recorded mortality events of ruffed grouse in the Appalachians resulted in “collar only,” or “collar and feathers only” recovered at mortality sites (ACGRP unpublished data). Short relocation distances and rigor mortis in the neck may have limited the number of necklace transmitters separated from carcasses in this study.

Our results suggest that habitat analysis of mortality sites could be done without compromising the accuracy of habitat data. I should qualify this statement by noting that our experimental design reflected carcasses that had been deposited by a predator after a kill had been made. Actual predation events can result in carcasses being relocated from the kill site to a deposition location. Habitat data around the deposition sites can be potentially misleading as a result. Our conclusions of habitat at carcass deposition sites only apply to those instances where birds were killed and deposited in the same location.

I observed moderately higher amounts of woody debris at relocation sites as compared to mortality sites. More woody debris at relocation sites may reflect the behavioral response of predators and scavengers to seek out dense, low cover when consuming carrion (Einarsen 1956). In fragmented landscapes, habitat data at perceived kill sites could be biased, depending on carcass movement distances and patch size. I suggest placing high priority on timely carcass recovery and gathering sufficient mortality related sign will improve the accuracy of mortality diagnoses. Quick recovery of carcasses should be highly emphasized during periods of relatively warmer temperatures in circumstances where avian predation is likely.

Scavenging behavior of mammals is common enough to warrant consideration as a source of bias for survival analyses. Although mortality-sensing transmitters do increase the probability of recovering bird carcasses in the field, disturbance by predators and scavengers can prolong the period between death and transmission of a mortality signal by the transmitter. It is possible that mortality attributed to mammal predators may be overestimated in cases where critical time elapses between death and recovery. Grouse that have been killed and fed upon by a predator are more likely to be scavenged than whole carcasses attributed to hunter cripples or other causes. Higher scavenging of partial carcasses is likely due to scenting conditions. All carcasses have a higher probability of being scavenged during periods of higher temperatures. Though mortality-sensing radio transmitters do increase the chances of recovery, they do not ensure correct identification of proximate mortality sources. It is imperative that field investigators place utmost priority on timely recovery of carcasses and that strict attention to detail is paid to carcass remains and surrounding sign. I recommend using radio transmitters with shorter mortality switch delays and shorter monitoring intervals to improve mortality estimates.

## CONCLUSIONS AND MANAGEMENT IMPLICATIONS

### **Major findings**

The objectives of this study were to determine the role of scavenging on ruffed grouse carcasses in a mountain environment. Factors of primary interest were scavenger identity, rate at which carcasses are scavenged, accuracy of habitat data around kill sites and influences on diagnosis of cause-specific mortality on ruffed grouse.

- 1) Twenty-four of 64 carcasses were scavenged by animals that would alter the diagnosis of death.
- 2) The average ( $\pm$  SE) to disturbance for 24 carcasses was 68 hours ( $\pm$  7.9 ) and the fastest scavenging event recorded was 1 hour and 46 minutes.
- 3) Mammals are the primary scavengers of ruffed grouse carcasses having fed on 23 of the scavenged carcasses.
- 4) Habitat did not influence scavenging behavior and habitat at carcass placement sited did not differ from that at recovery sites following scavenging with the possible exception of woody debris being more abundant at recovery sites.
- 5) Temperature and carcass condition were the only variables that affected scavenging. As the average temperature increased and as carcasses were more disturbed ie. Carcasses that had viscera and muscle tissue exposed, had a higher probability of being scavenged.

### **Management Implications / Future Research**

- 1) Emphasis should be placed on recovering carcasses in a timely manner. Radio transmitters with shorter mortality switches provide an option that can assist researchers in reporting more accurate causes of death.

- 2) Proper training of field staff in the methods of carcass recovery, and field sign identification are essential to the collection of reliable data.
- 3) Accumulation of data on species-specific scavenging sign should be recorded in detail whenever opportunities arise. These will add to the collective knowledge on scavenger and predator feeding behavior and improve future investigations.
- 4) Habitat data surrounding rendering sites (where a predator stops to feed on dead grouse) is comparable to the site where a scavenger relocates a carcass. Possible errors can occur if researchers attempt to quantify habitat variables surrounding actual kill sites. It is unclear how far certain predator move killed prey from the point of initial contact.

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Table 1.1. Summary of the logistic regression models developed to predict the probability of a grouse carcass being scavenged at Clinch Mountain during 6 November – 1 December 2000.

Habitat variables included temperature, canopy cover, woody debris, stem density, basal area, slope, and distance to edge; treatment were stand type, carcass condition, and overhead cover.

Parameter estimates are shown only for the “best” model as determined by AIC.

Model	AIC
Habitat variables – all	82.424
Treatment variables – all	82.115
Habitat` variables – stepwise selection	81.702
Treatment variables – stepwise selection	78.745
All variables combined	75.582
All variables – stepwise selection	73.197

Variable	$\beta$	$P$
Intercept	-1.108	0.003
Carcass condition	-0.956	0.003
Temperature	0.149	0.011



Table 1.2. Comparison of deposition site characteristics for carcasses that were ( $n = 24$ ) and were not ( $n = 40$ ) scavenged at Clinch Mountain WMA during 6 November – 1 December 2000.

The significance level is based on a Wilcoxon Rank Sum test.

Variable	<u>Scavenged</u>		<u>Not Scavenged</u>		<i>P</i>
	$\bar{x}$	SE	$\bar{x}$	SE	
Woody debris (%)	23	3	39	2	0.60
Overstory canopy (%)	9	5	14	3	0.51
Stems < 8 cm DBH / ha	5420	895	5860	763	0.74
Basal area (m <sup>2</sup> /ha)	23.9	1.1	20.5	0.1	0.21
Slope (degrees)	16	2	15	1	0.53
Distance to edge (m)	47.0	10.5	37.0	6.8	0.38

Table 1.3. Results of Multiple Response Permutation Procedure for matched pairs comparing habitat at 7 deposition sites and 7 relocation sites for scavenged grouse carcasses moved > 11.3 m at Clinch Mountain WMA during the fall of 2000.

Variable	Deposition Site		Relocation Site		<i>P</i>
	$\bar{x}$	SE	$\bar{x}$	SE	
Woody debris (%)	19.3	6.2	32.1	4.6	0.06
Overstory canopy (%)	12.9	11.2	15.7	11.7	0.20
Stems < 8 cm dbh / ha	5630	1382	7490	1338	0.23
Basal area (m <sup>2</sup> /ha)	21.5	5.9	15.6	1.9	0.14
Slope (degrees)	15.0	4.0	15.6	3.4	0.79

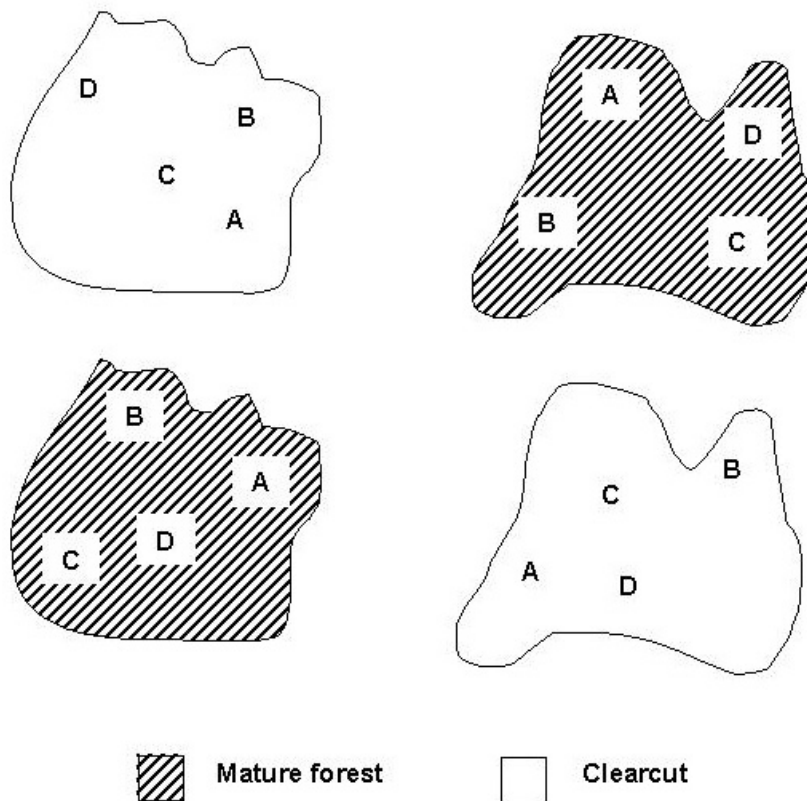


Figure 1.1. Study design for 3-way factorial experiment to determine factors that affect the probability of a grouse carcass being scavenged. Letters [A – D] represent the 4 combinations of carcass condition (whole or mock avian kill) and overhead cover (presence or absence) treatments. This sampling was replicated 4 times in the field between 6 November and 1 December, 2000 at Clinch Mountain WMA, Virginia.

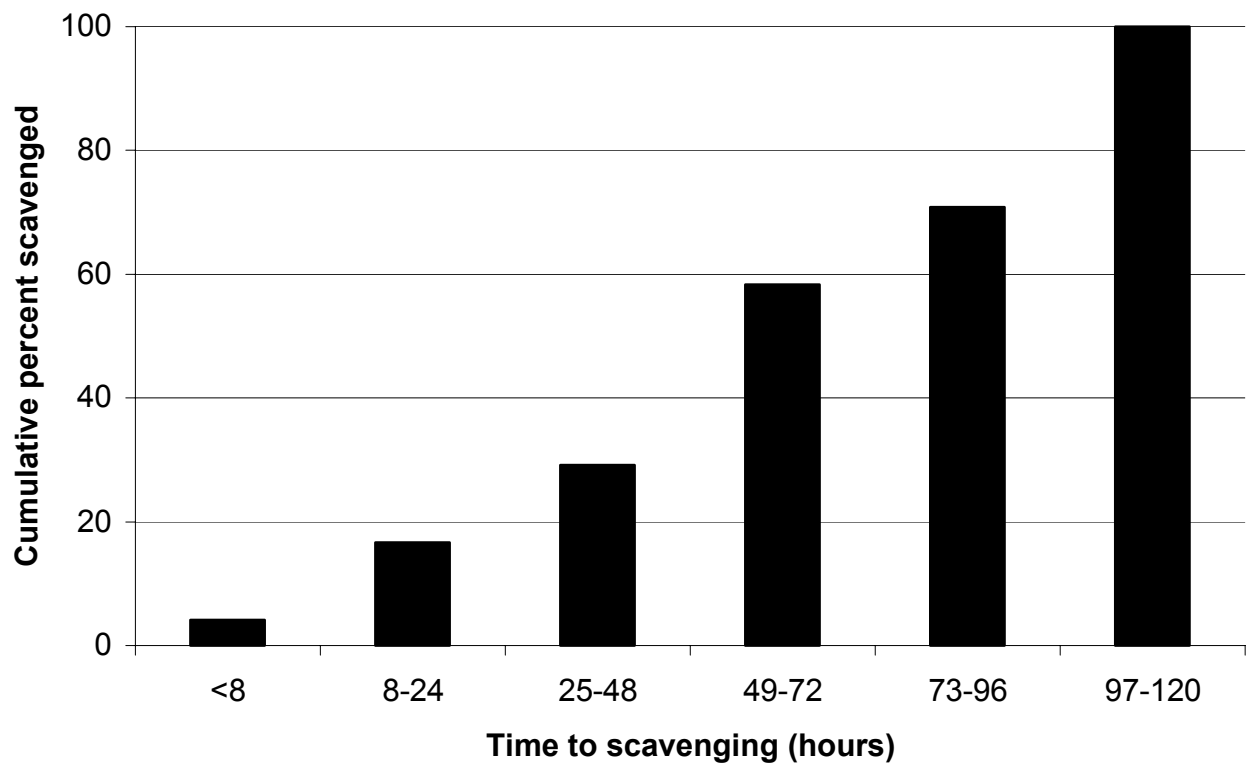


Figure 1.2. Cumulative percent of total ruffed grouse carcasses ( $n = 24$ ) scavenged at time intervals after deposition between 6 November and 1 December, 2000 at Clinch Mountain WMA, Virginia.



Figure 1.3. Examples of remote photographs taken at grouse scavenging sites to assist in determining species of scavenger at Clinch Mountain WMA during the fall of 2000. Shown are a bobcat (left) and Virginia opossum (right).

## **Chapter 2- RELATIONSHIP OF PREDATION ON RUFFED GROUSE TO ENVIRONMENTAL VARIABLES IN THE APPALACHIANS**

**Abstract:** I related indices of predators and weather patterns to trends in ruffed grouse predation. Using data collected at 10 study sites between February, 1997 and December, 2000, I compared predation rates, and animal and weather indices to predation rates, across sites, years, regions, seasons and month combinations pooled across years. Avian predators were the primary predators of ruffed grouse in the Appalachian region (50% of all predation). Predation rates on ruffed grouse were highest in fall (8.3%), due to high predation on juveniles, and spring (7.4%) in association with raptor migration and pre-breeding activity of grouse. Predation patterns and predator abundance did not indicate the occurrence of predator invasions during the years of this study. Predation rates on ruffed grouse were positively related to the presence of rain and negatively related to the average low temperature and number of rabbits and squirrels observed per hour. Observations of owls and Cooper's hawks per hour were correlated with predation rates on grouse while those of red-tailed, red-shouldered and broad-winged hawks were not.

### **INTRODUCTION**

In the center of ruffed grouse range, population declines have been associated with invasions by hawks and owls (Bent 1937, Lack 1954, Grange 1948). Though this phenomenon is well documented in the Great Lakes region and Canada, there is little information on predation patterns on southern grouse populations. Low abundance of goshawks (*Accipiter gentilis*), lack of large scale invasions by other birds of prey, and different climatic conditions such as low

snow accumulations offer the potential for different temporal and spatial patterns of predation in the Appalachian region.

Survival data collected since 1996 on the Appalachian Cooperative Grouse Research Project (ACGRP) have not shown large-scale fluctuations in annual grouse survival; however, peaks in mortality during autumn, early winter and spring have remained constant throughout the period. Seasonal grouse mortality has been attributed to cycles in plant phenology, weather, and life cycles of ruffed grouse in previous studies (Bump et al. 1947, Bergerud and Gratson 1988). Numerous mechanisms underlying seasonal mortality have been proposed, but have not been analyzed in detail. The goal of this study was to determine the relationship of grouse mortality to weather conditions, temperature, phenology of deciduous leaf fall, buffering by alternate prey species, and predator abundance across the Appalachian region.

## **METHODS**

### *Study Sites*

Ten (ACGRP) study sites distributed across 8 states and 3 physiographic regions (Fenneman 1938, Smith 1995; Fig. 2.1) in the Appalachian region were included in this investigation (Table 2.1). Environmental variables were recorded between 21 February 1997 and 31 December 2000. The Ridge and Valley region included 5 study sites (NC1, VA1, VA2, VA3 and WV2), the Alleghany Plateau included 3 study sites (KY1, MD1, WV1) and Northern region sites were PA1 and RI1 (Table 2.1). The Pennsylvania and Rhode Island study areas were grouped together into the Northern region due to the similarity in climate and vegetation characteristics compared to areas in the central range of ruffed grouse. Study areas represented wide variation in ownership, silvicultural practices, and land-use history. Survival data were collected from 10 October 1995 through 12 December 2000.

*Trapping and Monitoring*

We trapped ruffed grouse using a modified lily-pad trap (Gullion 1965) during the fall and spring of each year. Captured individuals were weighed and the age (juvenile or adult) and sex was determined in accordance with previous investigations (Davis 1969, Roussel and Ouellet 1975, Servello and Kirkpatrick 1986, Kalla and Dimmick 1995). Each grouse was equipped with a 10 g necklace-style radio transmitter with an 8-hour delay mortality sensor (ATS Inc., Isanti, MN, USA), and aluminum leg band. Each grouse was monitored for survival and located via radio-telemetry triangulations  $\geq 2$  times each week. Individuals that could not be located due to rugged terrain or other confounding factors were monitored only. Birds with transmitters emitting a mortality signal were located and the cause of death was determined. Carcass condition, marks to transmitters and harness condition were used to assess cause of death.

The observational unit for this study was the monthly predation rate for each site, month, year combination. I calculated monthly predation rates ( $\# \text{ deaths} / \# \text{ alive at start of month}$ ) for age, sex and cause of death for each study site. Grouse that were depredated by mammal, avian or unidentified predators were included in this study. Seasonal trends were summarized for Winter (December through February), Spring (March through May), Summer (June through August) and Fall (September through November). Birds dying  $\leq 7$  days from the date of release were censored from the study. Death date of individual grouse was assumed to be the midpoint between the date a normal signal was last heard and the date the bird was discovered on mortality mode. Grouse censored from the study (without confirmed mortality dates) were assumed to have left the study on the date following that which the last “live” signal was heard. Grouse captured as juveniles were graduated into the adult category on 1 July.



### *Animal and Weather Observations*

I used Animal and Weather Observation (AWO) data to investigate the relationship of grouse predation rates to weather, buffer species, and predator numbers. The AWO data were an observational dataset compiled over multiple years and by many observers. These data were collected daily during routine field research activity on all ACGRP sites. Data reported at each site included observer names, date, distance traveled, time in the field, weather conditions (including wind speed, cloud cover, and precipitation) and sightings of avian and mammalian predators (Appendix A). Sightings of road hunters, automobiles, white-tailed deer (*Odocoileus virginianus*), squirrel (*Sciurus spp.*), rabbit (*Sylvalagus spp.*), wild turkey (*Meleagris gallopavo*) and ruffed grouse also were recorded (Appendix B). Cloud cover was reported in 5 classes: 0%, <25%, 25-50%, 50-75% and >75%. Wind was recorded using the Beaufort wind scale as no wind (< 6.4 km/h), low (6.4-12.9 km/h), moderate (12.9-20.9 km/h) or high (>20.9 km/h; Appendix B). Precipitation was recorded as none, fog/mist, light rain, heavy rain and snow. Snow depth was recorded as none, patchy, light (2.5-10 cm), moderate (10-23 cm), moderate and crusted with ice, heavy (23-46 cm), heavy and crusted with ice and very heavy (>46 cm; Appendix B). These data were categorized by site, month and year. Observation rates of animals were calculated per hour and per kilometer. The proportion of observations for each weather condition category, in relation to all observations made, was summarized by month.

### *Temperature Data*

Temperature measurements were recorded at each study site using Stowaway® temperature loggers (Onset Industries, Pocasset, MA, USA). Hourly readings were taken and used to calculate daily averages. Mean minimum, mean average and mean high temperatures were then calculated for each month on all study sites.

### *Deciduous Leaf Cover*

The timing of leaf-fall was determined on each study site in autumn of 2000. Percent of leaves fallen was estimated at 10-day intervals between 1 September and 15 December (Appendix C). Defoliation patterns from this survey were used to estimate deciduous leaf-drop across all years of the study. Extrapolated leaf-fall dates are assumed to be accurate considering the consistency of autumn leaf-drop (J. Seiler, Virginia Polytechnic Institute and State University, personal communication). Timing for re-growth of deciduous canopy cover was estimated at each site during 3 spring seasons in 1998-2000. Green-up data documented sprouting, leaf-out and flower chronology for 5 herbaceous plants, 4 shrubs and 2 tree species important to ruffed grouse (Appendix D). Leaf fall and green-up data were used to estimate the percent monthly leaf cover at all study sites in the ACGRP.

### *Data Analyses*

Data were collected by multiple observers and are subject to substantial spatial and temporal heterogeneity within and across study sites. Despite inherent variability I assumed that large-scale, persistent trends would become evident through analyses of data from multiple sites and years. My analyses were based on relationships among predation rates and environmental variables. Conclusions from these analyses do not imply causation, but offer hypotheses about correlates of grouse predation that can be tested by others in the future.

I performed principle components analysis (PCA) on the initial set of 27 AWO variables to reduce redundancy and simplify analyses (McGarigal et al. 2000). Variables with absolute factor loadings  $< 0.45$  were eliminated. I performed a second PCA on the remaining variables. Ten variables with the highest factor loadings for the first 3 principle components were retained for modeling (Table 2.2).

I used monthly predation rate as the dependent variable and variables retained from PCA as regressors in stepwise logistic regression (PROC LOGISTIC, SAS Institute 2000). I chose a priori to analyze predator species and snow condition effects separately; hence these variables were not included in the PCA selection process. Alpha for variables to enter models was 0.2 and to stay in a model alpha was 0.1. Comparisons of predation rates across region, site, year, season and month were made using multiple ANOVA tests for binomial response variables (PROC GENMOD, SAS Institute 2000). Main effects and interactions between variables were tested with logistic regression. Interactions between variables were investigated using PROC GLM in SAS due to the SLICE function capability which is not currently found in the LOGISTIC option (SAS Institute 2000). Differences in predation rates between males and females, adults and juveniles, and avian and mammalian were tested for main effects using PROC GLM and paired t-tests. Significance level for tests was  $\alpha = 0.05$  when comparing predation rates and  $\alpha = 0.1$  when I tested the relationship between predation and environmental variables.

## RESULTS

### *TRAPPING*

We captured 1,768 ruffed grouse on the 10 study sites between 7 September, 1995 and 4 December, 2000. Three hundred and eleven grouse died prior to the end of the 7-day conditioning period and were eliminated from the study. Grouse that died prior to the onset of animal and weather data collection ( $n = 126$ ) also were eliminated from my study when testing the relationship between predation and environmental variables. The remaining 1,331 ruffed grouse were used for my final regression analyses (Table 2.3).

## ANIMAL AND WEATHER OBSERVATIONS

Between 21 February 1997 and 31 December 2000, observations were logged during 44,105 hours and 345,553 km of travel on the 10 ACGRP study sites. These data were collected by >120 observers and cumulatively account for 6,581 field days of observation. Observers documented 2,025 predator encounters and sightings of 20,103 white-tailed deer, 9,443 wild turkeys, 6,569 ruffed grouse, and 2,378 sightings of other species (Table 2.4).

### *Predators*

Avian predators tallied in this study were golden eagle (*Aquila chrysaetos*), bald eagle (*Haliaeetus leucocephalus*), Cooper's hawk (*Accipiter cooperii*), sharp-shinned hawk (*A. striatus*), northern goshawk, red-tailed hawk (*Buteo jamaicensis*), red-shouldered hawk (*B. lineatus*), broad-winged hawk (*B. platyperus*), barred owl (*Strix varia*) and great horned owl (*Bubo virginianus*). Mammalian predators tallied were red fox (*Vulpes vulpes*), gray fox (*Urocyon cinereoargenteus*), coyote (*Canis latrans*), domestic dog (*C. familiaris*), house cat (*Felis catus*), bobcat (*Lynx rufus*), raccoon (*Procyon lotor*), mink (*Mustela vison*), weasel (*Mustela spp.*), fisher (*Martes pennanti*), striped skunk (*Mephitis mephitis*), opossum (*Didelphis virginiana*) and black bear (*Ursus americanus*).

The number of avian predators differed by region ( $F_{2, 356} = 1.62$ ,  $P < 0.001$ ) and across years ( $F_{3, 309} = 3.97$ ,  $P = 0.008$ ). The Alleghany Plateau region had the highest rate of avian predators seen/hour (0.11) followed by the Northern region (0.10) and Ridge and Valley (0.06). Difference in avian predator sightings across years was tested in the absence of RI1, PA1, and NC1 study sites since they did not have data for all 4 years. Year 2000 had the highest rate of avian predator sightings/hour (0.099) followed by 1999 (0.082), 1997 (0.082), and 1998 (0.063). Comparisons of avian predator sightings differed across sites ( $F_{9, 349} = 10.29$ ,  $P < 0.001$ ) and

seasons ( $F_{3, 349} = 4.72$ ,  $P = 0.003$ ). KY1 had the highest rate of avian predator sightings/hour (0.171) and VA1 had the lowest (0.039; Fig. 2.2). The highest rate of avian predator sightings/hour was observed during the summer (0.104), followed by the spring (0.089), fall (0.077), and winter (0.063).

The number of mammalian predators did not vary by region ( $F_{2, 356} = 10.79$ ,  $P = 0.20$ ), but did differ across years ( $F_{3, 309} = 3.50$ ,  $P = 0.02$ ). The difference in mammal sightings across years was tested in the absence of RI1, PA1, and NC1 study sites since they did not have data for all 4 years. Year 2000 had the highest rate of mammalian predator sightings per hour (0.037) followed by 1999 (0.021), 1997 (0.018), and 1998 (0.014). Comparisons of mammalian predator sightings differed across sites ( $F_{9, 349} = 4.76$ ,  $P < 0.001$ ) and seasons ( $F_{3, 349} = 2.23$ ,  $P = 0.08$ ). The highest rate of mammal sightings was at RI1 (0.058) and the lowest was at VA1 (0.005; Fig. 2.3). Autumn was the season of highest mammal predator sightings (0.030) followed by summer (0.029), winter (0.018), and spring (0.014).

Study-wide observations for avian and mammalian predators showed an increase during the summer months (Fig. 2.4). The frequencies of raptor observations peaked during the late summer and early autumn (Fig. 2.4) with July being the month of most frequent observation (0.11 observations/hour). Raptor species known to prey on grouse were tallied by month (Fig. 2.5). Red-tailed hawks were the most frequently identified raptor for all months except July, August and September. Unidentified raptor sightings exceeded red-tailed from May to October. Broad-winged hawks were the second most frequently observed raptor and exceeded red-tail hawk observations between July and September. Broad winged hawk sightings peaked during April and July. Cooper's hawks were most frequently seen from August through October with a smaller peak in April. Red-shouldered hawks were observed in roughly equal numbers between

January and June and infrequently during July through December. Observations of unidentified hawks peaked during the months of July and August. Mammalian predators were observed comparatively less frequently than raptors. Mammal observations peaked in August (0.037 observations/hour; Fig. 2.4). Domestic dogs were the most frequently observed mammal predator ( $n = 566$ ) followed by bobcat ( $n = 91$ ) and raccoon ( $n = 43$ ).

### *Prey species*

The number of ruffed grouse seen per hour differed across regions ( $F_{2, 359} = 3.90$ ,  $P = 0.02$ ) and years ( $F_{3, 310} = 2.41$ ,  $P = 0.07$ ). The Ridge and Valley region had the highest frequency of grouse sightings per hour (0.156) followed by the Northern region (0.127) and the Alleghany Plateau region (0.112). Sightings of ruffed grouse per hour increased throughout the study (Fig. 2.6). Sightings of ruffed grouse differed among sites ( $F_{9, 349} = 8.46$ ,  $P < 0.001$ ) and seasons ( $F_{3, 349} = 5.33$ ,  $P = 0.001$ ). NC1 had the highest frequency of grouse sightings per hour (0.316) and RI1 had the lowest (0.012; Fig. 2.7). Seasonal comparisons showed spring to have the highest frequency of grouse sightings (0.169) followed by fall (0.148), summer (0.133) and winter (0.092). Monthly observations of ruffed grouse per hour were highest for March (0.25), April (0.19) and June (0.168) with a second peak of observations occurring in the fall during September (0.171) and October (0.165, Fig. 2.8). Grouse sightings were the lowest in May (during incubation; 0.08) on ACGRP sites.

Rabbit sightings were low from October through March. Peak rabbit sightings were recorded during June (0.07) and July (0.17, Fig. 2.8) as litters were dispersing. Average monthly observations of squirrels showed 2 peaks, 1 in June (0.43) and October (0.51) in association with summer and autumn litter dispersal (Fig. 2.8).

*Additional species of interest*

Observations of white-tailed deer per hour differed across regions ( $F_{2, 359} = 23.27, P < 0.001$ ) but not across years ( $F_{2, 310} = 1.62, P = 0.18$ ). The Northern region had the highest frequency of deer sightings (0.785) followed by the Allegheny Plateau (0.607) and Ridge and Valley region (0.247). Observations of white-tailed deer per hour differed across sites ( $F_{9, 349} = 20.85, P < 0.001$ ) and seasons ( $F_{2, 349} = 5.79, P < 0.001$ ). Spring had the highest frequency of deer sightings (0.527) followed by summer (0.486), fall (0.468), and winter (0.247). PA1 had the highest frequency of deer observation (1.166) and RI1 had the lowest (0.024; Fig. 2.9).

Observations of wild turkey per hour differed across regions ( $F_{2, 359} = 14.81, P < 0.001$ ) and years ( $F_{2, 310} = 4.57, P = 0.004$ ). The Northern region had the highest frequency of turkey sightings (0.617) followed by the Allegheny Plateau (0.290) and Ridge and Valley region (0.154). Turkey sightings peaked in 1999 (Fig. 2.10). Observations of wild turkey per hour differed across sites ( $F_{9, 349} = 8.80, P < 0.001$ ) and seasons ( $F_{2, 349} = 3.53, P = 0.02$ ). Summer had the highest frequency of turkey sightings (0.376) followed by fall (0.247), winter (0.200), and spring (0.174). PA1 had the highest frequency of turkey sighting (0.913) and RI1 had the lowest (0.025; Fig. 2.11).

*Snow accumulation*

The number of reports for various snow depths did not differ across years but did differ among regions. The number of reports for light crusted snow, moderate, and moderately deep, crusted snow were higher in the Northern region ( $F_{2, 354} = 5.38, P = 0.005$ ;  $F_{2, 354} = 6.44, P = 0.002$ , and  $F_{2, 354} = 3.95, P = 0.02$ , respectively). Observations of snow accumulation were reported for the months of October through April on the ACGRP (Fig. 2.12). Patchy and light snow deposition was observed from October through April with the highest proportion of patchy

snow observations in December. The highest proportion of light snow accumulation was recorded in January. Moderate and moderate, ice-crusting snow accumulations were observed between November and April. The highest proportion of moderate and moderate, ice-crusting snow were documented during February. Heavy snow and heavy snow crusted with ice was observed between November and March, and December through March, respectively. In both instances, heavy snow and heavily crusted snow were most frequently reported during the month of February. Records of very heavy snow were present from December through March and were in highest proportion during the month of March.

#### *DECIDUOUS LEAF COVER*

Region-wide, the deciduous leaf-off period extended from November through March (Fig. 2.13). Leaf fall during 2000 began earliest for the northern-most sites (MD1, PA1, RI1 and WV1), starting between the third week in September and the first week of October. The remaining study sites experienced the beginning of leaf-fall during the second week of October. Leaf fall was complete on all sites by the first week in November. The regional pattern in emergence of deciduous foliage was in reverse order of leaf-fall. Southern study sites observed leaf growth of red maple (*Acer rubrum*) and tulip poplar (*Liriodendron tulipifera*) canopies during the first 2-weeks of April. On northern study sites, leaf emergence started between the second week of April and the first week of May.

#### *TEMPERATURE DATA*

Temperature trends followed expected regional patterns, with high and low monthly mean temperatures in July and January, respectively (Table 2.5). Highest average daily temperature during the study was 41.4° C observed at KY1 on 13 August 1999 and the lowest



was  $-24.1^{\circ}\text{C}$  recorded at VA3 on 22 November 2000. Overall mean temperature for the region during this study was  $10.1^{\circ}\text{C}$ .

### *PREDATION*

Five hundred seventy six grouse deaths (82.8% of all mortality) were attributed to predation (excluding hunting and other mortality). Fifty percent ( $n = 291$ ) of predation events were attributed to raptors, 35% to mammals ( $n = 201$ ) and 15% (84) to unidentified predators (Table 2.6). Monthly predation rates differed among years ( $\chi^2_3 = 20.92$ ,  $P = 0.001$ ) and regions ( $\chi^2_2 = 11.24$ ,  $P = 0.004$ ), but no interaction was found between year and region ( $\chi^2_5 = 4.92$ ,  $P = 0.43$ ). Records from 1995 and 1996 were excluded from this analysis because data were not available for all months of those years. Predation rates did not differ among 1997 (6.0%), 1998 (6.0%) and 1999 (7.7%) however, 2000 (4.0%) was significantly lower than all others years ( $\chi^2_3 = 35.53$ ,  $P < 0.001$ ). Regional differences in predation rates were not detected between the Alleghany Plateau (4.5%) and the Ridge and Valley (5.1%) ( $\chi^2_1 = 2.87$ ,  $P = 0.09$ ). Predation rate in the Northern region (13.2%) was higher than both the Ridge and Valley region and the Alleghany Plateau ( $\chi^2_1 = 24.05$ ,  $P < 0.001$  and  $\chi^2_1 = 33.57$ ,  $P < 0.001$ , respectively).

### *Predation by sites and season*

Monthly predation rates on grouse differed by study site ( $\chi^2_9 = 44.38$ ,  $P < 0.001$ ) and season ( $\chi^2_3 = 64.70$ ,  $P < 0.001$ ), and there was an interaction between season and site ( $\chi^2_{27} = 69.83$ ,  $P < 0.001$ ). Interaction between season and study site resulted from differences in predation among study sites in spring and fall ( $F_{9, 381} = 1.89$ ,  $P = 0.05$  and  $F_{9, 381} = 8.65$ ,  $P < 0.001$ , respectively). The difference among sites ( $F_{9, 381} = 17.09$ ,  $P < 0.001$ ) across seasons was due to relatively high avian predation at RI1 (22.0%). Predation was highest in spring (8.3%),

followed by fall (7.5%), winter (5.3%) and lowest in summer (2.1%). Paired comparisons of predation rate showed differences between all seasons ( $P < 0.001$ ) except fall and winter ( $\chi^2_1 = 0.07$ ,  $P = 0.79$ ). Predation rates were different ( $\chi^2_{11} = 100.48$ ,  $P < 0.001$ ) among months (Fig. 2.14). The highest predation rates on grouse were observed in September (12.1%), April (9.8%) and March (8.2%; Fig. 2.14). Months of low predation were August (1.5%), June (2.1%) and July (2.7%). Among individual study sites, RI1, PA1 and VA3 had the highest overall monthly predation rates on grouse (22.0%, 8.1% and 7.2%, respectively; Fig. 2.15). RI1 also had the lowest sample size of all the sites in the study (Table 2.3).

#### *Predation by predator type*

The frequency of avian predation on grouse did not differ among years ( $\chi^2_3 = 3.94$ ,  $P = 0.27$ ) or across regions ( $\chi^2_2 = 2.23$ ,  $P = 0.33$ ), but the interaction between region and year was significant ( $\chi^2_5 = 13.55$ ,  $P = 0.02$ ). Differences among years within the Northern region (0.8%, 19.1 and 6.0 for 1998, 1999, and 2000, respectively) resulted in the interaction ( $F_{2, 381} = 8.66$ ,  $P < 0.001$ ). The frequency of avian predation differed by study site ( $\chi^2_9 = 30.47$ ,  $P < 0.001$ ) and season ( $\chi^2_3 = 54.28$ ,  $P < 0.001$ ). Grouse depredation by avian predators was highest at RI1 (21.3%). When RI1 was removed from the analysis, no difference between sites was found ( $\chi^2_8 = 0.53$ ,  $P = 0.83$ ). The season of highest avian predation on grouse was fall (5.1%) followed by spring (4.7%), winter (2.9%) and summer (0.8%).

Monthly mammal predation rates on grouse differed across regions ( $\chi^2_2 = 7.14$ ,  $P = 0.03$ ) and years ( $\chi^2_3 = 15.87$ ,  $P = 0.001$ ). Mammal predation was the highest in 1998 (2.0%) which was higher than all other years except 1999 ( $\chi^2_1 = 1.16$ ,  $P = 0.28$ ; Fig. 2.16). Grouse depredation rates due to mammal predators differed between the Ridge and Valley (1.9%) and Alleghany

Plateau (1.2%) regions ( $\chi^2_1 = 6.01$ ,  $P = 0.01$ ; Fig. 2.17) only. Monthly mammal predation rate in the northern region (1.7%) did not differ from the Alleghany Plateau and Ridge and Valley regions. Monthly mammal predation rates differed across sites ( $\chi^2_9 = 24.37$ ,  $P = 0.004$ ; Fig. 2.18) and seasons ( $\chi^2_3 = 26.90$ ,  $P < 0.001$ ). Spring had the highest rate of mammal predation on grouse (2.4%) followed by fall (1.7%), winter (1.6%), and summer (0.8%).

Monthly differences between avian and mammalian predation rates remained constant across years ( $F_{3, 373} = 0.60$ ,  $P = 0.62$ ), but differed by region ( $F_{2, 373} = 8.39$ ,  $P < 0.001$ ). Comparatively higher avian mortality was observed in the Northern region than the other 2 regions (Fig. 2.19). The difference between monthly avian and mammal predation rates did not vary by season ( $F_{3, 381} = 1.22$ ,  $P = 0.30$ ) but did differ by site ( $F_{9, 381} = 5.12$ ,  $P < 0.001$ ). RI1 reported only 1 mammal predation event (Table 2.6), and thus the greatest difference between avian and mammal rates. When RI1 was removed from the analysis, no difference among sites was found ( $F_{8, 365} = 0.76$ ,  $P = 0.64$ ). Avian predation rates were significantly higher than mammalian rates during the months of March (paired  $t$ -test:  $t_{30} = 2.47$ ,  $P = 0.02$ ), April (paired  $t$ -test:  $t_{30} = 1.99$ ,  $P = 0.05$ ), August (paired  $t$ -test:  $t_{31} = 2.42$ ,  $P = 0.02$ ) and December (paired  $t$ -test:  $t_{34} = 2.19$ ,  $P = 0.04$ ; Fig. 2.20). Variability within the months of January, September and October was high, thus no statistical differences were detected.

#### *Predation by sex and age classes*

Differences between monthly predation rates on male and female grouse differed across physiographic regions ( $F_{2, 373} = 2.73$ ,  $P = 0.06$ ), but not across years ( $F_{3, 373} = 0.53$ ,  $P = 0.66$ ) or the interaction of year and region ( $F_{5, 373} = 0.44$ ,  $P = 0.82$ ). Sample size effects of RI1 may have resulted in the difference among regions as a less significant result was found once it was removed ( $F_{2, 363} = 2.35$ ,  $P = 0.10$ ). No differences between sex-specific predation rates were

observed across sites ( $F_{9, 373} = 1.57, P = 0.12$ ), but a main effect of season ( $F_{3, 373} = 6.01, P = 0.001$ ) and the interaction between site and season ( $F_{27, 373} = 2.67, P < 0.001$ ) were significant. The interaction of site and season was due to high predation on females at RI1 in spring (11.6%;  $F_{9, 373} = 8.97, P < 0.001$ ). When RI1 was eliminated from the analysis, no differences were detected by season ( $F_{3, 363} = 0.64, P = 0.59$ ) or the interaction of site and season ( $F_{24, 363} = 1.25, P = 0.19$ ). Monthly mortality rates did not differ by sex ( $F_{11, 373} = 0.71, P = 0.73$ ) although, paired *t*-tests of male versus female predation rates did show a significantly higher frequency of female (10.8%) versus male (4.7%) predation in May (paired *t*-test:  $t_{30} = 2.57, P = 0.015$ ; Fig. 2.21).

Monthly predation rates of juvenile and adult ruffed grouse did not differ across regions ( $F_{2, 292} = 0.08, P = 0.93$ ), years ( $F_{3, 292} = 2.20, P = 0.09$ ) and there was no interaction between region and year ( $F_{5, 292} = 0.68, P = 0.64$ ). Differences between adult and juvenile predation rates did not differ by study site ( $F_{9, 292} = 1.15, P = 0.33$ ), but monthly predation rates were higher on juveniles than adults ( $F_{9, 292} = 5.51, P < 0.001$ ; Fig. 2.22). Juvenile predation was significantly higher than adult predation during the months of September (paired *t*-test:  $t_{20} = 2.85, P = 0.01$ ) and October (paired *t*-test:  $t_{30} = 2.20, P = 0.04$ ) only. The months of June and July were eliminated from these analyses due to absence of radio-collared juveniles in the study (Fig. 2.22).

#### *PREDATION IN RELATION TO ENVIRONMENTAL VARIABLES*

Across regions, the probability of a grouse being predated was positively related to rainfall and negatively related to the average monthly low temperature and abundance of alternate prey species observed (Table 2.7). Predation rates in the Alleghany Plateau were positively related to the number of days with high wind speeds, days with rainfall and the number of avian predators seen per hour. Predation was negatively related to the amount of forest canopy leaf cover in the Alleghany Plateau region (Table 2.7). A negative relationship

between mortality rate and high wind was observed in the Northern region (Table 2.7).

Predation rates in the Ridge and Valley region showed a positive relationship with number of overcast days, the occurrence of rain and the number of rabbits and squirrels observed, and a negative relationship to the number of avian predators seen (Table 2.7).

### *Monthly comparisons*

A number of animal and weather variables were related to monthly predation rates (Table 2.8). Mammal predator sightings were positively related to predation rates during March. Monthly observations of avian predators were positively related to predation rates in June, July and December but negatively related in May (Table 2.8). Grouse predation rates were positively related to the number rabbits and squirrels in February (Table 2.8). Predation rates were positively related to the frequency of rainfall during December but negatively in April. Overcast days in October were positively related to grouse mortality but negatively related in March (Table 2.8). Mortality rates during the month of March were also positively related to the presence of snow and the average low temperature and negatively related to the amount of forest canopy cover (Table 2.8).

### *Cause-specific comparisons*

Avian predation rates were negatively related to the average monthly low temperature and positively to the abundance of alternate prey animals (Table 2.9). Mammalian predation rates were positively related to the presence of rain and high velocity winds (Table 2.9). Predation attributed to unidentified predators was negatively associated with mean low temperature (Table 2.9).

*Sex and age-specific comparisons*

Sex-specific mortality showed higher predation on males in association with less forest canopy leaf cover and higher occurrences of rain (Table 2.10). Rate of predation on adult male grouse was negatively related to the amount of forest canopy cover in October when tested alone ( $\chi^2_1 = 4.09$ ,  $P = 0.04$ ). Male mortality was positively related to the number of grouse seen per hour during the months of March ( $\chi^2_1 = 5.18$ ,  $P = 0.02$ ), July ( $\chi^2_1 = 4.93$ ,  $P = 0.03$ ) and August ( $\chi^2_1 = 3.61$ ,  $P = 0.06$ ). Female grouse predation rates were not related to the variables measured (Table 2.10). A positive relationship between the female predation rates and number of grouse seen/hour was observed during January ( $\chi^2_1 = 3.74$ ,  $P = 0.05$ ), July ( $\chi^2_1 = 3.17$ ,  $P = 0.07$ ), August ( $\chi^2_1 = 5.61$ ,  $P = 0.02$ ) and October ( $\chi^2_1 = 5.53$ ,  $P = 0.02$ ).

The probability of a juvenile grouse being predated was positively related to the occurrence of rain (Table 2.10). Predation on adult grouse increased with lower, average low temperature (Table 2.10). The mean number of grouse seen per hour was positively related to predation on adult grouse during March ( $\chi^2_1 = 4.46$ ,  $P = 0.03$ ), August ( $\chi^2_1 = 8.22$ ,  $P = 0.004$ ), and September ( $\chi^2_1 = 2.92$ ,  $P = 0.09$ ). No relationship between grouse observations and juvenile grouse predation rates was observed.

*Snow related comparisons*

Grouse predation rates were observed to change with different snow conditions. Overall grouse predation rates were positively related to heavy, crusted snow during the months of January ( $\chi^2_1 = 3.38$ ,  $P = 0.07$ ) and February ( $\chi^2_1 = 3.01$ ,  $P = 0.08$ ). Avian predation rates were positively related to the number of days in March having moderately deep snow ( $\chi^2_1 = 4.22$ ,  $P = 0.04$ ). Mammalian predation rates were observed to increase during periods of heavy crusted

snow in January ( $\chi^2_1 = 3.16, P = 0.08$ ) and moderately deep, crusted snow in February ( $\chi^2_1 = 3.86, P = 0.05$ ). Alternately, mammal predation on grouse was negatively related to accumulations of heavy, non-crusted snow in February ( $\chi^2_1 = 2.93, P = 0.09$ ).

Predation patterns for adult grouse were not found to be associated with any specific type of snow cover. Juvenile deaths were positively related to moderate snow accumulations in November ( $\chi^2_1 = 5.49, P = 0.02$ ) and moderate, moderately deep and crusted, and heavy, deep crusted snow in February ( $\chi^2_1 = 2.99, P = 0.08, \chi^2_1 = 4.93, P = 0.03$  and  $\chi^2_1 = 4.50, P = 0.03$ , respectively). Predation on juvenile grouse was positively associated with heavy crusted snow ( $\chi^2_1 = 5.49, P = 0.02$ ) in January, but negatively related to moderate, crusted snow ( $\chi^2_1 = 3.99, P = 0.05$ ).

#### *Predator-specific comparisons*

Avian predation was not related to raptor counts when analyzed overall. Comparisons between avian predation and raptor observations by month, did show a negative relationship for unidentified hawks in January ( $\chi^2_1 = 6.07, P = 0.01$ ) and a positive association with Cooper's hawks in February ( $\chi^2_1 = 4.21, P = 0.04$ ). Broad-winged and red-tailed sightings were higher during increased predation on grouse during April ( $\chi^2_1 = 3.51, P = 0.06$  and  $\chi^2_1 = 3.06, P = 0.08$ , respectively) however, Cooper's hawk observations were inversely related to grouse death at this time ( $\chi^2_1 = 3.62, P = 0.06$ ). Avian predation increased during sightings of Cooper's hawks in October ( $\chi^2_1 = 7.55, P = 0.006$ ), red-shouldered hawks in November ( $\chi^2_1 = 6.50, P = 0.01$ ) and Cooper's hawks in December ( $\chi^2_1 = 5.40, P = 0.02$ ).

Results from Chapter 1 led me to believe that significant numbers of avian predation events could be misinterpreted as mammal or unidentified predators due to scavenging activity.

As a result of high depredation rates on grouse by avian predators, I chose to analyze overall predation rates with respect to specific avian predator sightings. Predation rates were compared to sighting frequencies of raptors thought to influence grouse survival including broad-winged, red-tailed, Cooper's, red-shouldered hawks, owls and an unidentified hawk category using logistic regression. Seasonal predation rates on grouse were positively related to the number of Cooper's hawks and owls observed in fall ( $\chi^2_1 = 3.96$ ,  $P = 0.05$  and  $\chi^2_1 = 3.74$ ,  $P = 0.05$ , respectively) but negatively to number of red-tailed hawks observed ( $\chi^2_1 = 3.00$ ,  $P = 0.08$ ). Increased predation on ruffed grouse was coincident with higher frequencies of Cooper's and red-tailed hawk sightings ( $\chi^2_1 = 3.19$ ,  $P = 0.07$  and  $\chi^2_1 = 6.20$ ,  $P = 0.01$ , respectively) in winter and less frequent sightings of red-shouldered and unidentified hawks ( $\chi^2_1 = 3.64$ ,  $P = 0.06$  and  $\chi^2_1 = 4.95$ ,  $P = 0.03$ , respectively). Higher predation rates in spring were associated with lower frequencies of Cooper's, red-shouldered and unidentified hawks ( $\chi^2_1 = 7.34$ ,  $P = 0.007$ ,  $\chi^2_1 = 5.40$ ,  $P = 0.02$  and  $\chi^2_1 = 3.05$ ,  $P = 0.08$ ), but higher frequencies of owls ( $\chi^2_1 = 4.18$ ,  $P = 0.04$ ). Predation on grouse in summer was positively related to the number of red-tailed hawks and owls observed ( $\chi^2_1 = 6.92$ ,  $P = 0.009$  and  $\chi^2_1 = 5.91$ ,  $P = 0.02$ , respectively).

Avian predator sightings and predation rates on grouse were pooled across years and sites and compared using simple correlation. Sightings of unidentified hawks ( $P = 0.29$ ; Fig. 2.23), red-tailed ( $P = 0.93$ ; Fig. 2.24), red-shouldered ( $P = 0.71$ ; Fig. 2.25) and broad-winged hawks ( $P = 0.52$ ; Fig. 2.26) were not correlated with predation rates on grouse. The frequency of owls and the frequency of Cooper's hawks observed did show a correlation with predation rates on grouse. A combination of barred and great horned owl sightings explained a significant portion of the variability in grouse predation ( $P = 0.04$ ; Fig. 2.27). Cooper's hawk sightings were not correlated to predation on grouse ( $P = 0.43$ ) however, when the month of August was removed



from the analysis, Cooper's hawk sightings explained a significant portion of the variation in predation rates on ruffed grouse in the Appalachians ( $P = 0.01$ ; Fig. 2.28).

Female predation rates were observed to increase when broad-winged hawks were observed more frequently ( $\chi^2_1 = 5.44$ ,  $P = 0.02$ ). Seasonal predation on females was positively related to sightings of unidentified hawks in fall ( $\chi^2_1 = 2.73$ ,  $P = 0.10$ ), owl sightings in spring ( $\chi^2_1 = 3.24$ ,  $P = 0.07$ ) and negatively with unidentified hawks in winter ( $\chi^2_1 = 7.45$ ,  $P < 0.01$ ). No relationship between predation on female grouse and raptors sightings was observed in summer. Predation on male grouse was positively related to observation of red-tailed hawks and owls ( $\chi^2_1 = 3.04$ ,  $P = 0.08$  and  $\chi^2_1 = 4.56$ ,  $P = 0.03$ , respectively), but negatively related to the frequency of red-shouldered hawks ( $\chi^2_1 = 3.28$ ,  $P = 0.07$ ). Seasonal predation on males was positively related to owl sighting frequencies in fall ( $\chi^2_1 = 3.14$ ,  $P = 0.08$ ), positively to red-tailed and Cooper's hawks ( $\chi^2_1 = 2.97$ ,  $P = 0.09$  and  $\chi^2_1 = 7.95$ ,  $P < 0.01$ , respectively) in winter but negatively related to red-shouldered counts ( $\chi^2_1 = 4.07$ ,  $P = 0.04$ ). Spring predation on males was negatively related to sightings of red-tailed, red-shouldered, Cooper's, and unidentified hawks ( $\chi^2_1 = 2.95$ ,  $P = 0.09$ ,  $\chi^2_1 = 4.83$ ,  $P = 0.03$ ,  $\chi^2_1 = 10.52$ ,  $P = 0.001$  and  $\chi^2_1 = 9.23$ ,  $P = 0.002$ , respectively). Summer predation on males was positively related to red-tailed and unidentified hawk and owl sightings ( $\chi^2_1 = 4.67$ ,  $P = 0.03$ ,  $\chi^2_1 = 3.66$ ,  $P = 0.06$  and  $\chi^2_1 = 3.12$ ,  $P = 0.08$ , respectively).

Predation rates on juveniles were positively related to owl, Cooper's and unidentified hawk sightings in fall ( $\chi^2_1 = 2.84$ ,  $P = 0.09$ ,  $\chi^2_1 = 5.46$ ,  $P = 0.02$  and  $\chi^2_1 = 2.95$ ,  $P = 0.09$ , respectively) and positively to owl sightings in spring ( $\chi^2_1 = 3.35$ ,  $P = 0.07$ ). Summer predation rates on juvenile grouse were positively related to red-tailed hawk sightings ( $\chi^2_1 = 3.86$ ,  $P = 0.05$ ) and negatively to red-shouldered hawk sightings ( $\chi^2_1 = 3.15$ ,  $P = 0.08$ ). The latter only

included the months of June and September due to the absence of radio-collared juveniles in the population. No relation between predation rates and raptor sightings was noted in winter.

Predation on adult grouse was not related to raptor sightings in fall, but was positively related to Cooper's hawk frequencies ( $\chi^2_1 = 7.52$ ,  $P = 0.06$ ) and negatively to unidentified hawk sightings in winter ( $\chi^2_1 = 4.56$ ,  $P = 0.03$ ). Spring predation rates on adults were negatively related to Cooper's and red-shouldered hawk sightings ( $\chi^2_1 = 3.43$ ,  $P = 0.06$  and  $\chi^2_1 = 3.71$ ,  $P = 0.05$ , respectively) while summer patterns were positively related to owl sightings ( $\chi^2_1 = 6.92$ ,  $P = 0.009$ ) only.

#### *Deer and turkey comparisons*

Concerns over the potential impact of herbivores on forest understory structure and direct competition between grouse and turkeys led to comparisons of deer and turkey sightings to predation on ruffed grouse. Predation rates on grouse were positively related to white-tailed deer sightings ( $\chi^2_1 = 8.44$ ,  $P = 0.004$ ). Concordance was 40.1%. Patterns in deer sightings and grouse predation pooled across years and sites were not related (Fig. 2.29). Observations of wild turkeys were positively related to predation rates on ruffed grouse ( $\chi^2_1 = 11.34$ ,  $P < 0.001$ ).

When data were pooled across sites and years, no correlation was found between grouse predation rates and the frequency of turkey observation (Fig. 2.30). No correlation between deer or turkey sightings and predation rates on grouse were observed across study sites ( $P = 0.58$ ,  $r = -0.20$  and  $P = 0.70$ ,  $r = -0.14$ , respectively).

## **DISCUSSION**

The patterns and estimates of cause-specific predation in this study were similar to those found in other investigations of ruffed grouse (Bump et al. 1947, Gullion 1970, Clark 2000).

Avian predation was the primary cause of grouse deaths and remained relatively consistent across years and regions. Differences among study sites were attributed to small sample size in RI1. Higher mammal predation during spring was probably due to increased vulnerability of male while drumming and females while egg laying and incubating. It is unclear why the Ridge and Valley region had higher mammal predation since higher mammal predator abundance was observed in both Northern and Alleghany Plateau regions.

Differences in predation rates between seasons and months also were in agreement with findings elsewhere in grouse range (Marshall and Gullion 1965, Gullion and Marshall 1968, Rusch and Keith 1971, Small et al. 1991, Gormley 1996). Avian predation appeared to be most important during the spring and autumn. High spring predation could have resulted from heightened activity of grouse during the breeding and egg laying period and raptor migration. At this time male grouse are actively territorial, females are moving greater distances to visit males, and both sexes are engaging in courtship behavior (Gullion and Marshall 1968, Doerr et al. 1974, Boag 1976 and Maxson 1977). Peak counts of ruffed grouse observed along roads and travel routes were coincident with periods of high predation on grouse in spring. This suggests that grouse are more visible to predators during this period and are killed more frequently. Considering that grouse numbers are at an annual low during spring months, this suggests a greater percentage of the population would be exposed to predation at a time when many eastern raptors are migrating northward. Significant positive relationships between grouse sightings and predation rates support this hypothesis. Males have been shown to be more heavily depredated during fall and spring display periods than at any other time (Rusch and Keith 1971, Rusch et al. 1972). Conspicuousness coupled with distraction by breeding activity could contribute to increased predation.

Periods of peak predation rate coincided with raptor migration. Broad-winged hawk migration appears to peak during the 3<sup>rd</sup> week in April in the Appalachian region (C. Kessler New River Valley Bird Club, personal communication) and is supported by ACGRP data. Coopers hawks and broad-winged hawks showed observation peaks during April. Broad-winged and red-tailed hawks were the most commonly observed species of raptors on ACGRP study sites for the month of March. Rusch and Doerr (1972) found ruffed grouse to be the largest component of broad-winged hawk diets by volume in Alberta, Canada. Mueller and Berger (1992) demonstrated that migrating raptors in Wisconsin attacked lures at higher frequencies and of larger size in spring than in fall. Monthly comparisons of predation rates and buteo sightings however, failed to show any relationship. Correlation between predation rates on grouse and the abundance of owls and Cooper's hawks suggests that these species are more important grouse predators in the Appalachian region. If the correlation between predation rates and Cooper's hawk sightings represents a direct relationship, the Cooper's hawk may occupy the role of primary grouse predator of the Appalachians. Further evidence to support this hypothesis is that most fall accipiter migration is in October, after the peak of Cooper's hawk sightings on ACGRP study sites in August and September. This would suggest that Cooper's hawk sightings are not associated purely with migration. This trend may represent heightened levels of activity in Cooper's hawks as they build fat reserves needed for autumn migration.

Ruffed grouse predation mortality was high during early autumn and mid-winter. Several factors may interact during this period. Low numbers of other prey and increased conspicuousness of birds against snow (Bergerud and Gratson 1988) have been proposed as reasons for higher predation rates on grouse. I did find a negative relationship between alternate prey species abundance and predation on grouse overall. Positive relationships between alternate

prey and predation also were observed for certain subsets of data, however. Conflicting results such as this make it difficult to explain the true nature of buffer species abundance in terms of grouse predation rates based on these data. Hibernation, torpor and the natural decline in various alternate prey species may cause predators to switch their efforts towards grouse. I expected to find a decrease in depredation of grouse during the dispersal of squirrel and rabbit litters, but this was not observed in the data. Bump et al. (1947) found a negative relationship between the occurrence of ruffed grouse remains in owl pellets and grouse survival. Periods of low grouse survival were also coincident with periods of low buffer species abundance (Bump et al. 1947). Experimental removal of predators by Bump et al. (1947) however, showed no change in grouse survival, although immigration and emigration of both grouse and predators were not accounted for.

Predation in the absence of migrant raptors in winter suggests that resident predators may be important at this time. Small et al. (1991) reported that over winter mortality was similar between 7 years in Wisconsin despite the occurrence of a great horned owl and goshawk invasion in 1 of the years. Great horned owls, red-tailed hawks, and other birds of prey over winter in the Appalachian region and have been documented to have significant impacts on grouse numbers (Bump et al. 1947, Rusch and Keith 1971, Rusch et al. 1972, Keith et al. 1977).

I hypothesized that predation peaks would also be associated with the decline of deciduous tree canopy. The relationship between leaf cover and grouse mortality in October and the rate of green-up in March support this hypothesis. Male grouse show a minor peak in territorial behavior in autumn accompanied by drumming and confrontations with other grouse (Bump et al. 1947), and are perhaps more susceptible than females to predation at this time.

Fresh leaf litter may also result in higher delectability. Grouse walking in fresh leaf litter may be heard at greater distances by predators using auditory cues.

Age was an important factor affecting grouse survival in autumn. Predation on juvenile grouse exceeded predation on adults for all months; September and October showed significant disparity. September is the first month for which juvenile mortality estimates were available. This trend was likely a result of continued chick loss observed by Haulton (1999) due to inexperience (Small et al. 1993) and the costs of juvenile dispersal (Godfrey 1967, Small et al. 1993). Male and female predation rates differed during May. Higher predation rates on female grouse were likely related to nesting activity (Rusch and Keith 1971).

The apparent importance of snow, though occasionally present during the fall and early winter months, did not become evident until winter and early spring. Predation was positively related to instances of crusted snow and negatively related to snow accumulations that would allow birds to snow roost. Grouse in the southern range have been shown to remain active and travel greater distances during the winter as compared to the northern range (Neher 1993, Hewitt 1994). In winter, southern grouse subsist on low quality forage (Norman and Kirkpatrick 1984, Servello and Kirkpatrick 1987) and may remain active to overcome energetic stress. Risk of predation has been shown to increase for grouse with higher rates of movement (Godfrey 1967, Thompson and Fritzell 1989). The limitation imposed by an impermeable snow pack would both limit access to ground forage and elevate exposure to the elements and foraging predators (Larsen and Lahey 1958, Kubisiak et al. 1980). Heavy to moderate snow is sufficient to allow grouse to snow roost (Gullion 1970) and therefore reduces energetic demands brought on by heat loss and reduces the need for extended periods of foraging and exposure to predation (Thompson 1987). Deep, non-crusted snow was inversely related to both avian and mammalian predation

rates. Light or patchy snow was hypothesized to reduce grouse survival by increasing the visibility of birds against snow while not providing sufficient roosting cover. My data supported this for juvenile birds during the month of December. It is unclear whether adult grouse suffer similar difficulties or whether learned behavior has enabled them to cope with unfavorable snow conditions. Nonetheless, Appalachian grouse have been observed to snow roost whenever snow is present (D. Whitaker, unpublished data) as opposed to potentially less advantageous tree roosts (Bump et al. 1947, Bergerud and Gratson 1988, Ott 1990).

Temperature has been considered a factor affecting grouse populations (Bump et al. 1947, Larsen and Lahey 1958, Ritcey and Edwards 1963, Neave and Wright 1969) however, these investigations relate primarily to brood success. Here, I examined relationships between temperature and predation for adult grouse. Mean low monthly temperature was one of 3 environmental variables significantly related to grouse mortality across all sites and years. Further, relationships with avian predation and adult predation also suggest that low temperature may be an important factor. Increased energetic demands brought on by low temperatures have been associated with low body temperature in grouse (Thompson 1987). It has also been suggested that the lack of aspen (*Populus tremuloides*), other high quality winter forage (Norman and Kirkpatrick 1984) and minimal snow accumulations in southern climates result in longer periods of feeding for southern ruffed grouse (Thompson 1987, Servello and Kirkpatrick 1987, Hewitt 1994). Periods of low temperatures exacerbate the need for grouse to feed continually in order to maintain core body temperatures (Thompson 1987). High winds also have been suggested to stress wintering grouse (Thompson 1987) and were related to mortality in my results. Counts of migratory raptors have been associated with wind and cloud cover (Titus and Mosher 1982) but it is unclear how these relate to grouse mortality.

Although abundance of white-tailed deer were positively related to grouse predation rates, it is unclear how such trends relate. DeCalesta (1994) observed declines in songbird abundance and species richness in the presence of increasing deer densities. This result was presumably due to herbivory by deer, however it is unclear whether similar patterns exist for ruffed grouse. The plot of deer sightings per hour and predation rates on grouse by study site showed no correlation. The same could be stated for the abundance of wild turkey. Abundance of turkey were positively related to predation rates on ruffed grouse however, direct competition between turkey and grouse is doubtful and relationships between the 2 factors may be an artifact of seasonal patterns among 2 galliforms with similar life histories.

The results from these analyses represent relationships between measured variables. Establishing causation is not possible without an experimental approach; however, observed patterns may provide evidence for phenomenon that have been suggested previously but remained unsupported by empirical evidence. Although this analysis was based on a relatively coarse dataset, the spatial and temporal consistency of data collected allowed testing of important parameters. The lack of major differences between annual mortality trends for this study indicates that predation on ruffed grouse is relatively constant among years analyzed. Assuming that my results are representative of population trends, southern grouse are not subject to variations in predator mortality as in northern regions and therefore, do not show predator-driven population cycles. Predation on grouse in the Appalachian region appears to be influenced by seasonal factors. Migration of raptors and breeding activity of grouse may be important areas of further research to understand predation patterns. The influx of juvenile grouse, decline in autumn leaf cover and the success of resident predators in a variety of snow conditions would be further areas of interest for hypothesis testing.



## **CONCLUSIONS AND MANAGEMENT/FUTURE RESEARCH**

### **Major findings**

The objectives of this study were to determine the timing of predation on ruffed grouse, create indices of predator and buffer species abundance, quantify weather, temperature and plant phenology, and relate the indices to depredation patterns on ruffed grouse.

- 1) My results indicated that overall predation rates in the Appalachians (~80%) are comparable with elsewhere in grouse range.
- 2) Estimates of overall cause-specific mortality are dominated by avian depredation on grouse (~50%) followed by mammalian depredations (35%) events. These estimates are also concurrent with reports elsewhere in grouse range.
- 3) Patterns of predation are consistent between years suggesting a lack of cyclic population declines in association with predator invasions.
- 4) Predation occurs most commonly in the early fall and late winter/early spring. Predation in spring is related to increased visibility of grouse in the pre-breeding period and high depredation in fall is associated with higher numbers of juvenile grouse in the population.
- 5) Deciduous leaf canopy was negatively related to depredation rates for male grouse, all grouse during the month of March and grouse in the Alleghany Plateau region.
- 6) Depredation on grouse tended to increase during the months of January and February in association with heavy, crusted snow accumulation.
- 7) Buffer species abundance (consisting of rabbits and squirrels) was negatively related to depredation rates overall but positively related to predation rates in February and avian predation rates on ruffed grouse.

- 8) The abundance of avian predators was positively related to predation rates on ruffed grouse in the Alleghany Plateau region, but negatively in the Northern region.
- 9) Comparisons between 6 predator-specific indices and predation rates on grouse showed that only monthly owl abundance and monthly Cooper's hawk abundance were positively correlated with predation rates on grouse.
- 10) Depredation rates on ruffed grouse were not correlated with indices of white-tailed deer or wild turkey.

### **Management Implications / Future Research**

- 1) Access to areas of grouse management should be restricted during pre-breeding period (March and early April) where poaching of ruffed grouse is a concern. Higher proportions of the population are visible at this time, and are at risk of depredation.
- 2) The relationships between white-tailed deer and wild turkey abundance should be explored further. Perceptions that herbivory by deer and direct competition between ruffed grouse and wild turkey are detrimental to grouse numbers, deserves objective review. Current literature does not specifically address these issues as they pertain to ruffed grouse ecology.
- 3) Correlation between predation rates on ruffed grouse and indices of raptor abundance require closer examination to elucidate relationships. Research on nesting ecology, foraging behavior and dietary composition of Cooper's hawks and owls specifically, may reveal the nature of the correlation between sightings of these raptors and predation rates on grouse.
- 4) The relationship between increased predation on grouse in the presence of less deciduous tree canopy may stress the importance of controlling insects that defoliate Appalachian forests. Gypsy moth activity (*Lymantria dispar*) has been observed to alter grouse movements (P.

Devers, personal communication) and, this may also have implications for ruffed grouse survival. The issue deserves further attention.

- 5) Improved indices of prey abundance should be attempted via standardized sampling in order to validate the use of ancillary observations as an index and/or to create more precise indices of their abundance.
- 6) The role of particular weather variables, such as rain volume, was not consistently measured at study sites and thus its importance to adult grouse is not understood. Further analysis of all weather variables may benefit from analyzing data in shorter time intervals as well.

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Table 2.1. Appalachian Cooperative Grouse Research Project study sites and physiographic regions sampled in this investigation between 1997-2000.

Study site	Location	Ownership	Dates Sampled
<i>Alleghany Plateau Region</i>			
KY1	Carter Co., KY	Kentucky Dept. of Fish & Wildlife	2/1/97-12/31/00
		Resources	
MD1	Garrett Co., MD	Maryland Dept. of Nat. Resources	2/1/97-12/31/00
WV1	Randolph Co., WV	Westvaco Corporation	2/1/97-12/31/00
<i>Northern Region</i>			
PA1	Clearfield Co., PA	State of Pennsylvania Forest	9/17/1998-12/31/00
RI1	Kent Co., RI	Rhode Island Div. of Fish and	5/9/1999-12/31/00
		Wildlife	
<i>Ridge and Valley Region</i>			
NC1	Macon Co., NC	U. S. Forest Service	8/18/1999-12/31/00
VA1	Augusta Co., VA	U. S. Forest Service	9/16/1997-12/31/00
VA2	Botetourt Co., VA	Westvaco Corporation	2/1/97-12/31/00
VA3	Smyth Co., VA	VA Dept. of Game & Inland	2/1/97-12/31/00
		Fisheries	
WV2	Greenbrier Co., WV	Westvaco Corporation	2/1/97-12/31/00



Table 2.2. Animal, weather and temperature variables used in logistic regression collected on 10 Appalachian Cooperative

Grouse Research Project study sites between 21 February 1997 and 31 December 2000. Variables were selected by reducing the original data set using Principle Components Analysis (PCA).

Variable	Code	Definition
>75% overcast sky	CLOUD100	Proportion of monthly cloud cover observations with 75-100% cloud cover
Precipitation as rain	PRECIPrain	Proportion of total monthly precipitation observations reporting rainfall
Precipitation as snow	PRECIPsnow	Proportion of total monthly precipitation observations reporting snowfall
Grouse seen per hour	GROUSE_HR	Number of ruffed grouse observations per hour reported by month
% of deciduous canopy cover	LEAFCOVER	Percent of monthly deciduous canopy cover present
Avian predators seen per hour	AVIANPRED_HR	Number of avian predator observations per hour reported by month
Mammal predators seen per hour	MAMMPRED_HR	Number of mammal predator observations per hour by month
Rabbits and squirrels seen per hour	RABBSQUIRREL_HR	Number of rabbit and squirrel observations per hour by month
Mean low temperature	TEMPlow	Mean monthly low from daily low temperatures recorded each month
Wind speeds >20.9 km/hr	WIND13MPH	Proportion of total monthly wind speed with >20.9km/hr wind speeds

Table 2.3. Number of radio collared grouse used in study to determine the relationship of predation and environmental variables among 10 ACGRP study sites between 1997-2000.

Area	Male	Female	Total	Juvenile	Adult	Total
NORTHERN <sup>a</sup>	67	110	177	108	39	147
ALLEGHANY PLATEAU <sup>b</sup>	268	186	454	266	188	454
RIDGE AND VALLEY <sup>c</sup>	383	299	682	363	316	679
KY1	66	38	104	56	48	104
MD1	96	70	166	112	54	166
NC1	57	62	119	62	55	117
PA1	45	101	146	92	24	116
RI1	22	9	31	16	15	31
VA1	53	39	92	60	32	92
VA2	79	56	135	57	78	135
VA3	88	69	157	77	79	156
WV1	106	78	187	98	86	187
WV2	106	73	179	107	72	179
Total	718	595	1313 <sup>d</sup>	737	543	1280 <sup>d</sup>

<sup>a</sup> Includes PA1 and RI1

<sup>b</sup> Includes KY1, MD1 and WV1

<sup>c</sup> Includes NC1, VA1, VA2, VA3, and WV2

<sup>d</sup> Deviation from true total  $n$  due to instances where sex or age could not be determined for individual grouse. In total, 1,331 grouse were included in this study.

Table 2.4. Summary of Animal and Weather Observation data for all Appalachian Cooperative Grouse Research Project study sites. Data include time and distance sums and counts of important species and period of collection 1997-2000.

Study Area	Hours reported	Kilometers driven	Number of observations					Period of data collection
			Predators <sup>a</sup>	Deer	Turkey	Grouse	Alternate Prey <sup>b</sup>	
KY1	4,298	39,955	478	1,143	1,457	210	300	5/13/97-12/31/00
MD1	3,690	13,557	98	1,833	581	393	155	3/27/97-12/31/00
NC1	2,717	27,380	158	129	226	930	54	1/17/00-12/31/00
PA1	2,650	27,465	121	3,543	2,073	388	356	1/30/99-12/31/00
RI1	342	3,580	20	9	9	3	5	1/7/00-12/31/00
VA1	4,001	16,218	72	778	508	650	277	9/12/97-12/31/00
VA2	5,012	37,123	105	2,431	1,606	941	408	4/5/97-12/31/00
VA3	7,659	64,893	402	2,135	659	1,365	593	3/15/97-12/31/00
WV1	6,374	57,422	288	7,006	1,702	1,145	121	2/21/97-12/31/00
WV2	7,362	57,961	283	1,096	622	544	109	3/3/97-12/31/00
Total	44,105	345,553	2,025	20,103	9,443	6,569	2,378	

<sup>a</sup> includes avian and mammalian predators

<sup>b</sup> includes rabbit (*Sylvilagus spp.*), squirrel (*Sciurus spp.*) and woodchuck (*Marmota monax*)

Table 2.5. Mean monthly temperatures (°C) for 10 ACGRP study sites and physiographic regions 1997-2000.

Month	KY1	MD1	NC1	PA1	RI1	VA1	VA2	VA3	WV1	WV2	Alleghany Plateau	Northern region	Ridge and Valley	All
January	2.6	-2.2	1.3	-4.7	-	1.2	1.6	0.9	-2.1	-0.4	-0.5	-4.7	0.9	-0.2
February	5.7	0.2	3.4	-1.1	2.5	3.1	3.8	2.0	0.4	2.2	2.1	0.7	2.9	2.2
March	7.9	1.7	5.0	4.7	5.9	3.8	5.1	2.9	2.4	4.1	4.0	5.3	4.2	4.4
April	14.6	8.9	8.8	7.5	7.7	11.7	14.4	10.9	8.5	9.9	10.7	7.6	11.2	10.3
May	19.7	13.4	11.8	15.1	14.3	16.0	18.6	15.7	13.8	15.0	15.6	14.7	15.4	15.4
June	23.0	17.0	14.0	18.4	18.8	19.0	20.1	17.6	17.2	18.3	19.1	18.6	17.8	18.4
July	24.7	19.2	15.4	17.1	21.3	20.8	21.7	18.7	19.1	20.1	21.0	19.2	19.3	19.8
August	23.0	17.9	15.0	17.2	-	20.2	20.8	17.8	17.8	19.1	19.6	17.2	18.6	18.8
September	19.6	14.8	13.8	15.0	-	16.9	17.4	15.3	15.2	16.5	16.5	15.0	16.0	16.1
October	13.9	10.5	11.5	9.2	-	11.9	13.0	10.6	10.0	10.9	11.5	9.1	11.6	11.3
November	7.0	3.5	8.5	3.7	-	4.6	5.4	-1.7	3.8	4.9	4.8	3.7	4.3	4.4
December	2.3	-1.8	6.6	-4.5	-	2.2	-1.2	3.1	-1.6	0.0	-0.4	-4.5	2.1	0.6

Table 2.6. Cause-specific (% of total mortalities) predation on ruffed grouse on the Appalachian Cooperative Grouse Research Project, summarized across region and site 1996-2000.

Area	Avian % ( <i>n</i> )	Mammal % ( <i>n</i> )	Unknown % ( <i>n</i> )	Total ( <i>n</i> )
NORTHERN	59.5 (47)	22.8 (18)	17.7 (14)	79
ALLEGHANY PLATEAU	52.1 (101)	28.9 (56)	19.1 (37)	194
RIDGE AND VALLEY	47.2 (143)	41.9 (127)	10.9 (33)	303
KY1	59.6 (28)	19.1 (9)	21.3 (10)	47
MD1	44.8 (30)	38.8(26)	16.4 (11)	67
NC1	29.5 (13)	65.9 (29)	4.5 (2)	44
PA1	53.7 (36)	25.4 (17)	20.9 (14)	67
RI1	91.7 (11)	8.3 (1)	0 (0)	12
VA1	74.3 (26)	20.0 (7)	5.7 (2)	35
VA2	50.0 (29)	41.4 (24)	8.6 (5)	58
VA3	35.7 (30)	40.5 (34)	23.8 (20)	84
WV1	53.8 (43)	26.3 (21)	20.0 (16)	80
WV2	57.9 (45)	40.2 (33)	4.9 (4)	82
Total	50.5 (291)	34.9 (201)	14.6 (84)	576

Table 2.7. Stepwise logistic regression results for predicting the probability of ruffed grouse predation in the Appalachians as a function of weather, animal and temperature variables.

Models are presented by region and pooled across regions. Variables are detailed in Table 2.

Region	Variable	<i>n</i>	$\beta$	SE ( $\beta$ )	Wald $\chi^2$	<i>P</i>	Percent Concordance
All	Intercept	302	-3.01	0.123	600.51	< 0.001	53.5%
	PRECIPrain		1.19	0.60	3.94	0.047	
	RABBSQUIRREL_HR		-1.72	0.82	4.44	0.035	
	TEMPlow		-0.02	0.007	5.66	0.017	
Northern	Intercept	22	-2.11	0.222	90.19	< 0.001	48.0%
	WIND13MPH		-4.12	2.03	4.09	0.043	
Alleghany Plateau	Intercept	131	-2.94	0.335	76.93	< 0.001	56.4%
	WIND13MPH		1.96	0.941	4.33	0.038	
	PRECIPrain		1.74	0.901	3.68	0.055	
	LEAFCOVER		-0.56	0.186	9.17	0.003	
	AVIANPRED_HR		2.06	0.908	5.17	0.023	
Ridge and Valley	Intercept	149	-3.79	0.268	219.85	< 0.001	57.5%
	CLOUD100		1.57	0.497	10.03	0.002	
	PRECIPrain		2.31	0.900	6.61	0.010	

Table 2.7. continued

Region	Variable	$n$	$\beta$	SE ( $\beta$ )	Wald $\chi^2$	$P$	Percent Concordance
	AVIANPRED_HR		-2.64	1.473	3.21	0.073	
	RABBSQUIRREL_HR		1.09	0.314	12.05	0.001	

Table 2.8. Stepwise logistic regression results for predicting the probability of predation on ruffed grouse in the Appalachians by month as a function of weather, animal and temperature variables. Variables are detailed in Table 2. Only those months that resulted in model selection are presented.

Month	Variable	<i>n</i>	$\beta$	SE ( $\beta$ )	Wald $\chi^2$	<i>P</i>	Percent Concordance
January	Intercept	19	-2.20	0.255	74.82	< 0.001	60.7%
	TEMPlow		0.17	0.065	7.00	0.008	
February	Intercept	20	-3.65	0.459	3.21	< 0.001	43.1%
	RABBSQUIRREL_HR		0.57	0.317	3.26	0.071	
March	Intercept	19	0.44	1.483	0.08	0.769	77.0%
	CLOUD100		-10.99	4.688	5.50	0.019	
	PRECIPsnow		12.76	6.954	3.37	0.066	
	LEAFCOVER		-7.86	2.690	8.54	0.004	
	MAMMPRED_HR		18.76	11.13	2.84	0.092	
	TEMPlow		0.52	0.21	6.28	0.012	
April	Intercept	21	-1.38	0.379	13.40	<0.001	51.9%
	PRECIPrain		-3.90	1.945	4.02	0.045	
May	Intercept	25	-1.88	0.391	23.19	< 0.001	51.9%
	AVIANPRED_HR		-7.67	4.657	2.71	0.099	
June	Intercept	29	-4.58	0.426	115.52	< 0.001	50.2%
	AVIANPRED_HR		5.16	2.259	5.22	0.022	



Table 2.8. continued

Month	Variable	<i>n</i>	$\beta$	SE ( $\beta$ )	Wald $\chi^2$	<i>P</i>	Percent Concordance
July	Intercept	29	-5.12	0.703	53.11	< 0.001	63.1%
	AVIANPRED_HR		10.80	5.096	4.48	0.034	
October	Intercept	30	-4.02	0.463	75.25	< 0.001	57.2%
	CLOUD100		4.51	1.675	7.27	0.007	
December	Intercept	27	-3.68	0.329	124.88	< 0.001	54.9%
	PRECIPrain		2.90	1.328	4.78	0.029	
	AVIANPRED_HR		4.65	2.756	2.85	0.092	

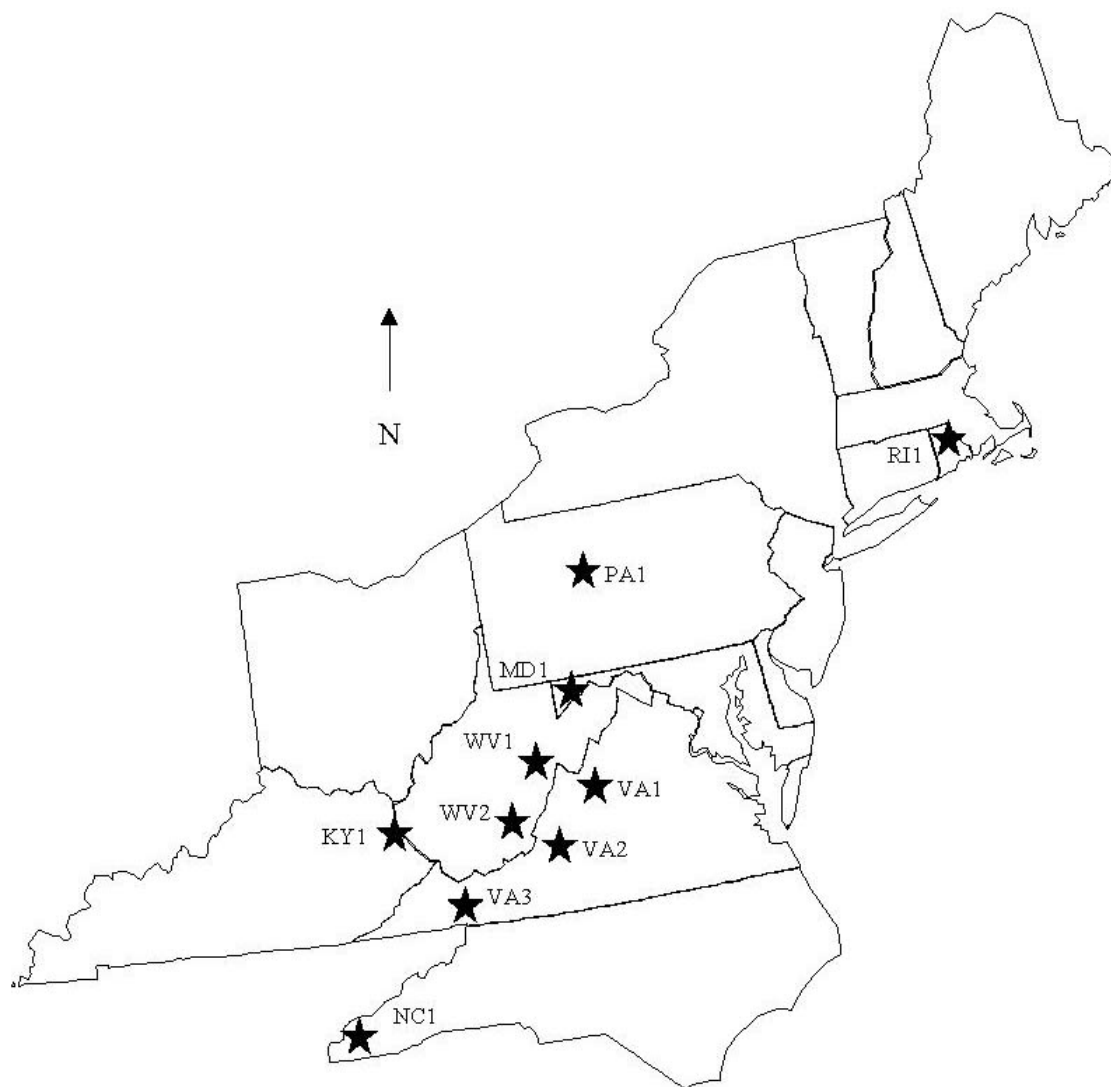
Table 2.9. Stepwise logistic regression results for predicting the probability of cause-specific predation on ruffed grouse in the Appalachians as a function of weather, animal and temperature variables. Variables are detailed in Table 2.

Predator Type	Variable	<i>n</i>	$\beta$	SE ( $\beta$ )	Wald $\chi^2$	<i>P</i>	Percent Concordance
Avian	Intercept	302	-3.59	0.093	1502.98	< 0.001	51.3%
	RABBSQUIRREL_HR		0.17	0.101	2.79	0.095	
	TEMPlow		-0.03	0.009	10.20	0.001	
Mammal	Intercept	302	-4.76	0.233	417.68	< 0.001	50.6%
	WIND13MPH		1.81	1.081	2.80	0.094	
	PRECIPrain		2.70	0.999	7.30	0.007	
Unknown	Intercept	302	-4.79	0.142	1140.63	< 0.001	43.5%
	TEMPlow		-0.03	0.017	3.92	0.048	

Table 2.10. Stepwise logistic regression results for predicting the probability of sex and age-specific predation on ruffed grouse in the Appalachians as a function of weather, animal and temperature variables. Variables are detailed in Table 2.

Grouping	Variable	<i>n</i>	$\beta$	SE ( $\beta$ )	Wald $\chi^2$	<i>P</i>	Percent
Level							Concordance
Male	Intercept	302	-3.15	0.178	312.78	< 0.001	53.7%
	PRECIPrain		1.54	0.841	3.367	0.067	
	LEAFCOVER		-0.42	0.164	6.60	0.010	
Female	Intercept	300	-2.89	0.075	1481.65	< 0.001	-
Juvenile	Intercept	231	-2.94	0.201	213.03	< 0.001	50.8%
	PRECIPrain		1.73	1.005	2.97	0.085	
Adult	Intercept	302	-3.01	0.075	1605.45	< 0.001	51.8%
	TEMPlow		-0.02	0.008	8.97	0.003	

Figure 2.1. Locations of Appalachian Cooperative Grouse Research Project study sites used in this investigation between 1997 and 2000.



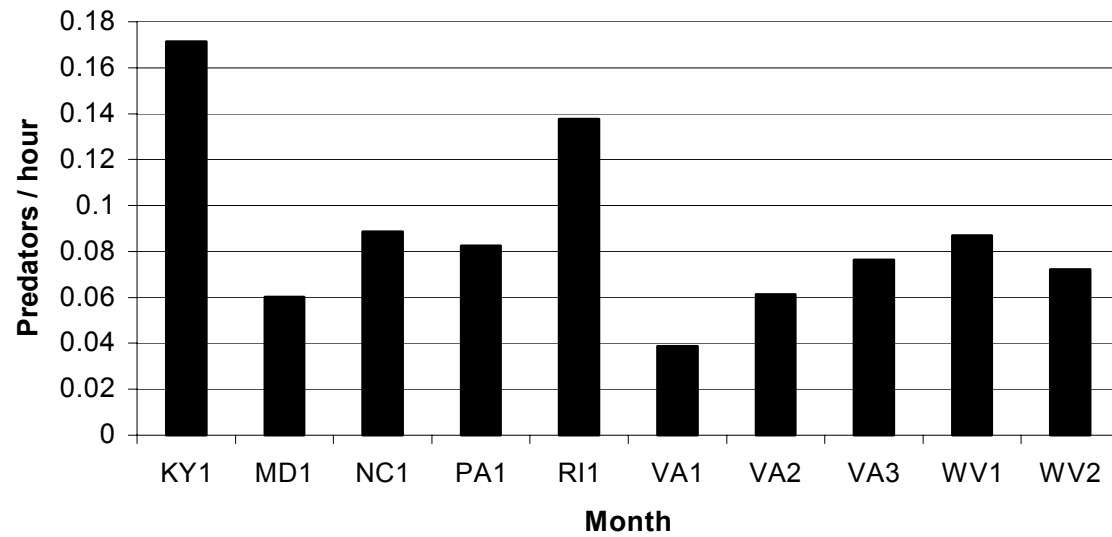


Figure 2.2. Mean number of hawks and owls/hour pooled across years, as observed in the Appalachians by site between 1997 and 2000.

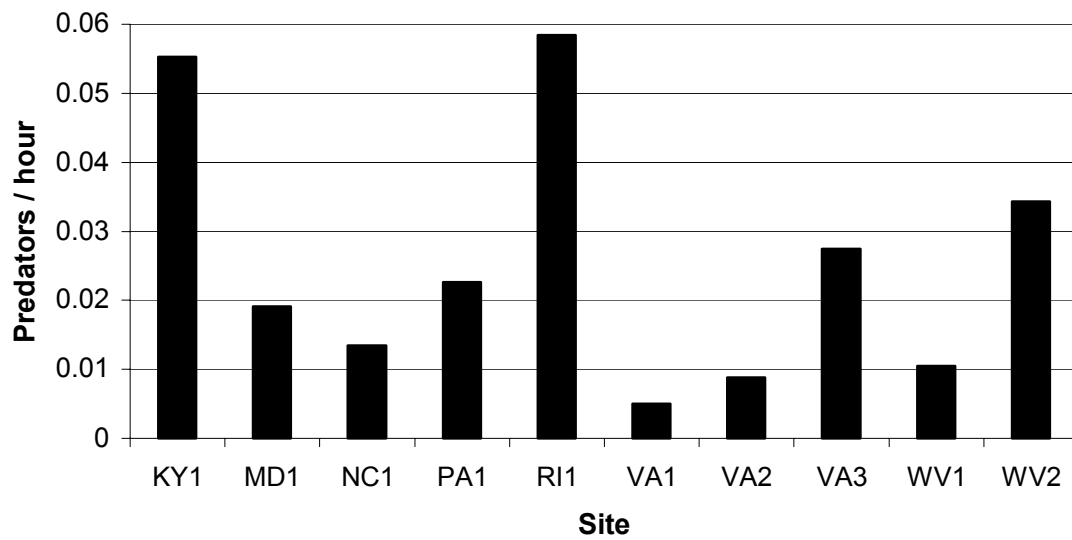


Figure 2.3. Mean number of mammalian predators seen/hour in the Appalachians pooled across years, as observed by site between 1997 and 2000.

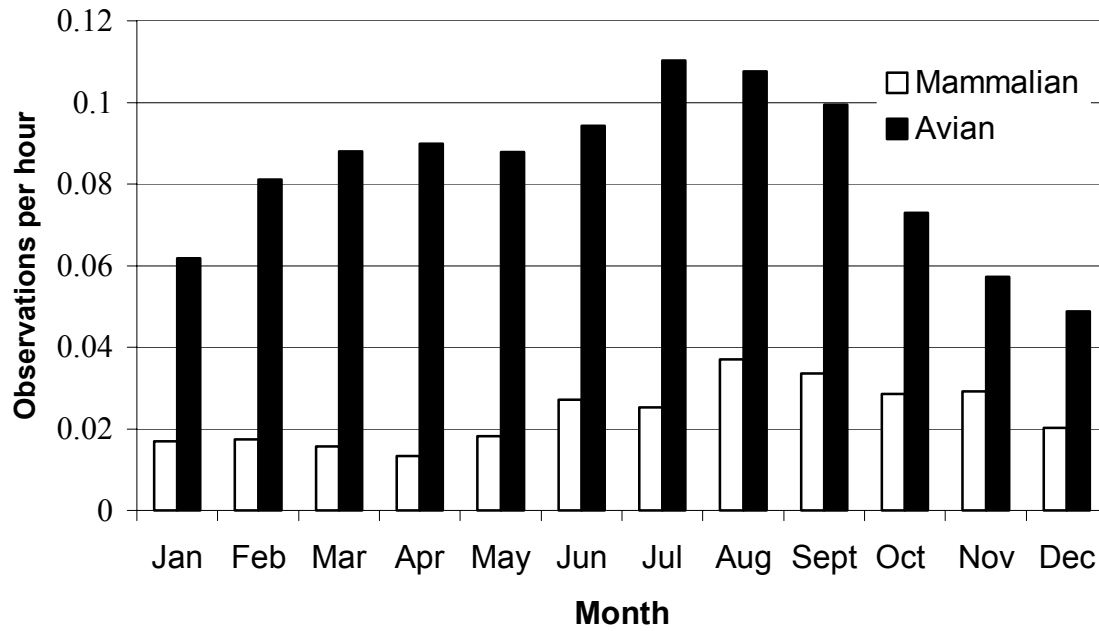


Figure 2.4. Summary of monthly observations for total mammalian and avian predators/hour in the Appalachians, by month, pooled across study sites between 1997 and 2000.

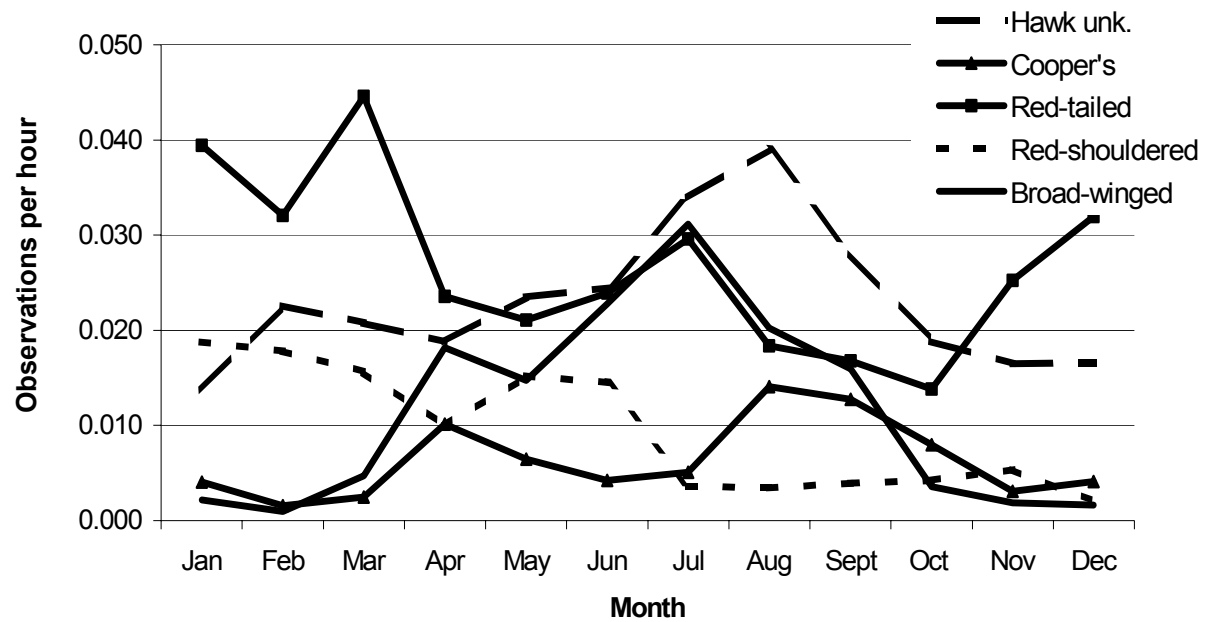


Figure 2.5. Monthly summary of important avian predator species across ACGRP sites between 1997-2000. Values represent the average across all study sites and years.



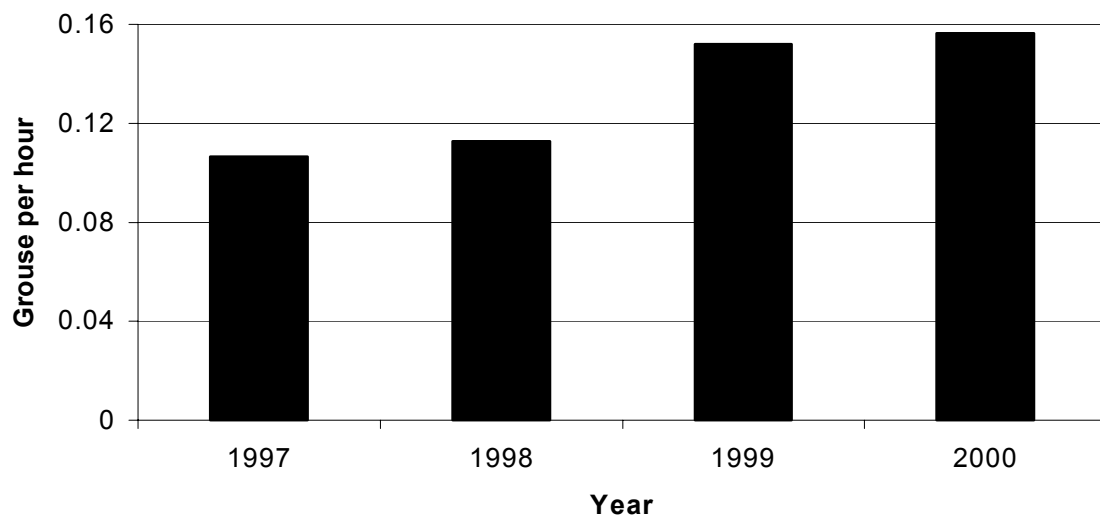


Figure 2.6. Mean number of ruffed grouse seen per hour by year in the Appalachians between 1997 and 2000.

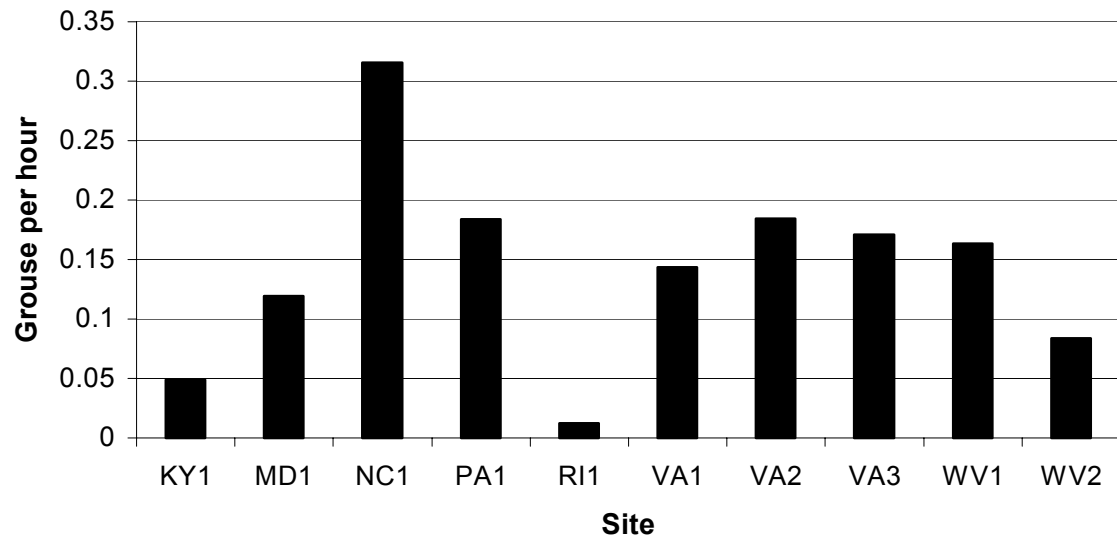


Figure 2.7. Mean number of ruffed grouse seen per hour by site in the Appalachians between 1997 and 2000.

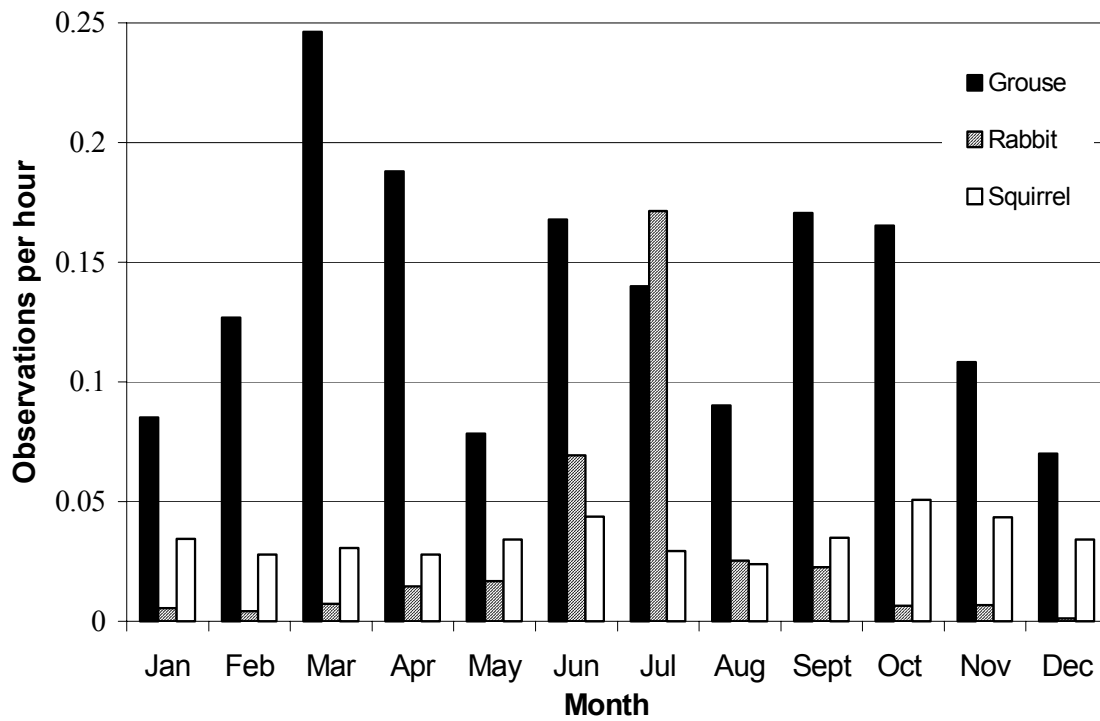


Figure 2.8. Summary of monthly observations for prey species per hour, by month, across ACGRP sites between 1997-2000. Values are averaged across all study sites and all years.

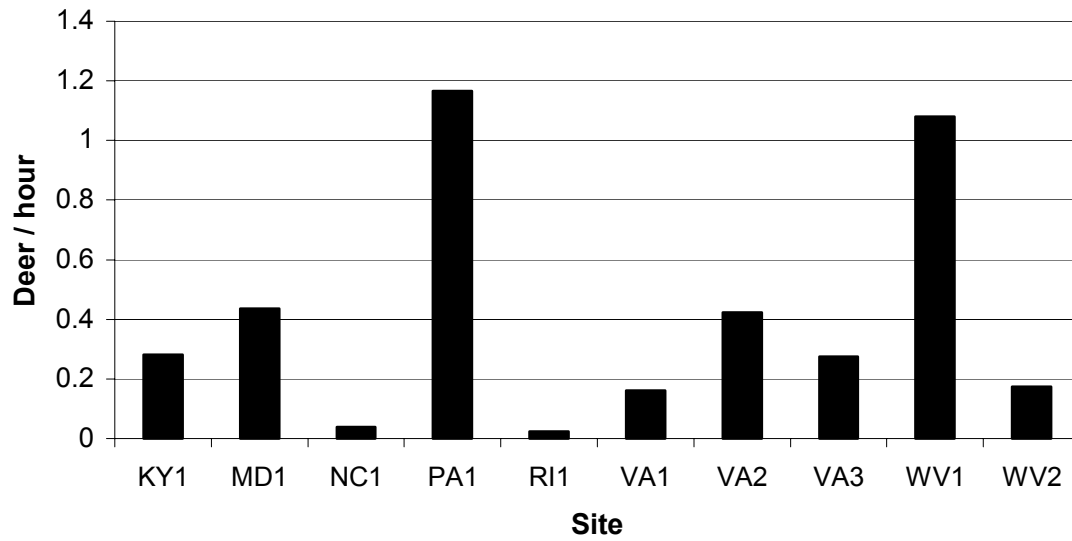


Figure 2.9. Summary for monthly observations of white-tailed deer observed per hour by site in the Appalachians between 1997 and 2000.

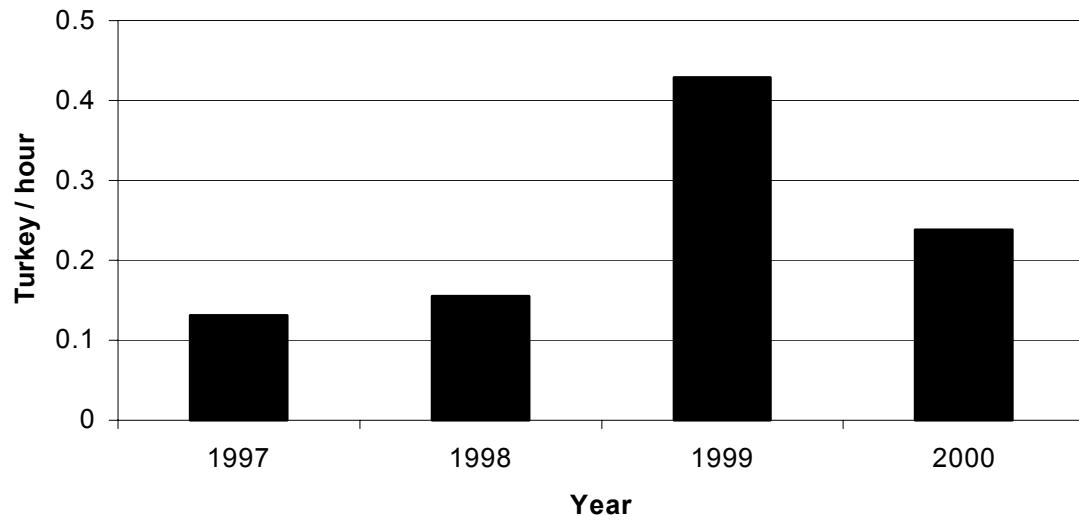


Figure 2.10. Summary for monthly observations of wild turkey observed/hour by year in the Appalachians between 1997 and 2000.

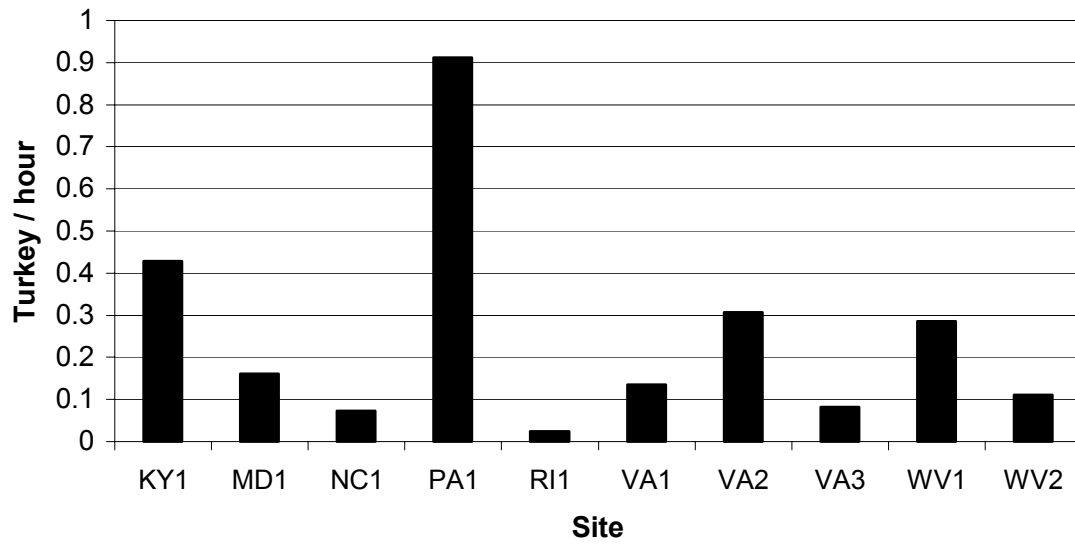


Figure 2.11. Summary for monthly observations of wild turkey observed per hour by site in the Appalachians between 1997 and 2000.

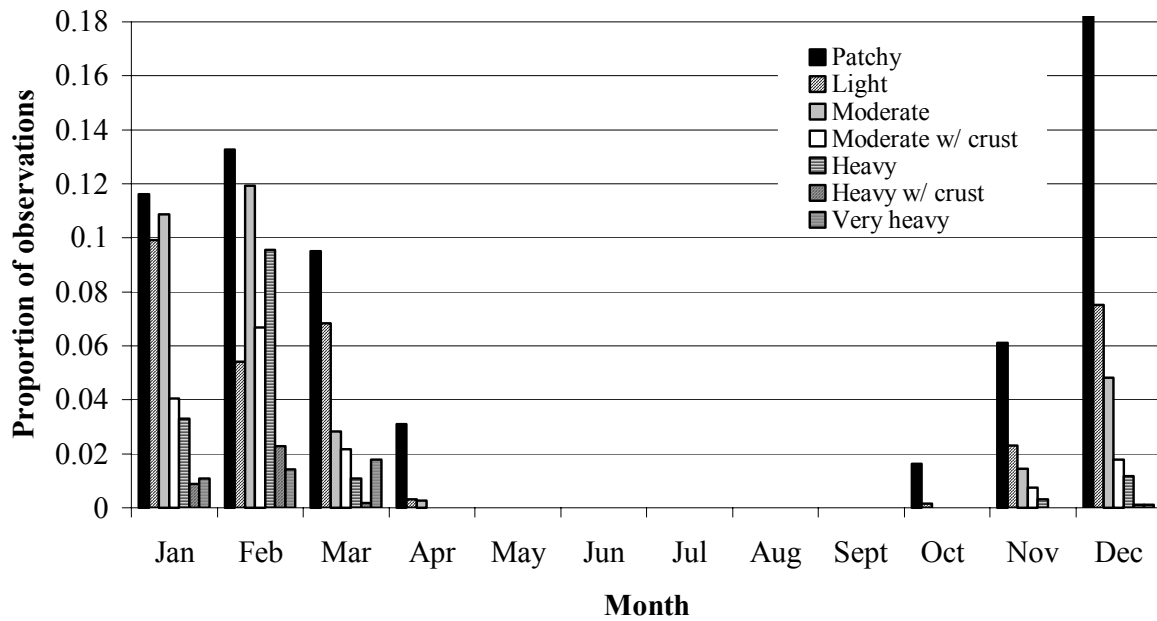


Figure 2.12. Proportion (of total) observations for snow conditions, by month, across ACGRP sites between 1997-2000. Values represent the average across all study sites and all years.

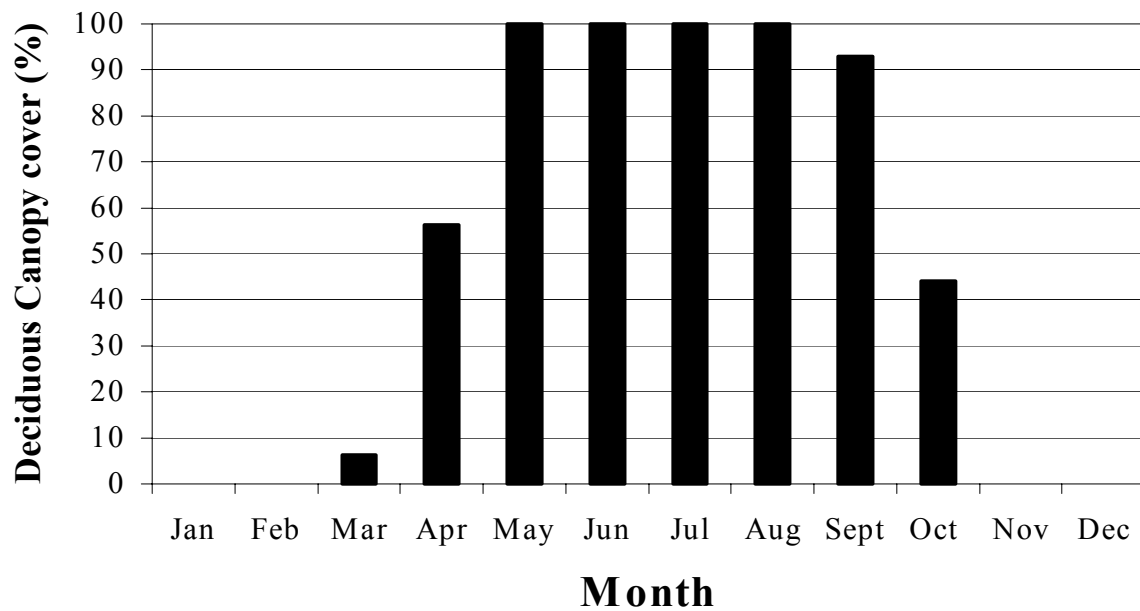


Figure 2.13. Monthly deciduous leaf cover expressed as a percentage of complete canopy between 1997-2000. Amount of foliage was estimated from a leaf-fall survey in autumn 2000 and annual green-up records.



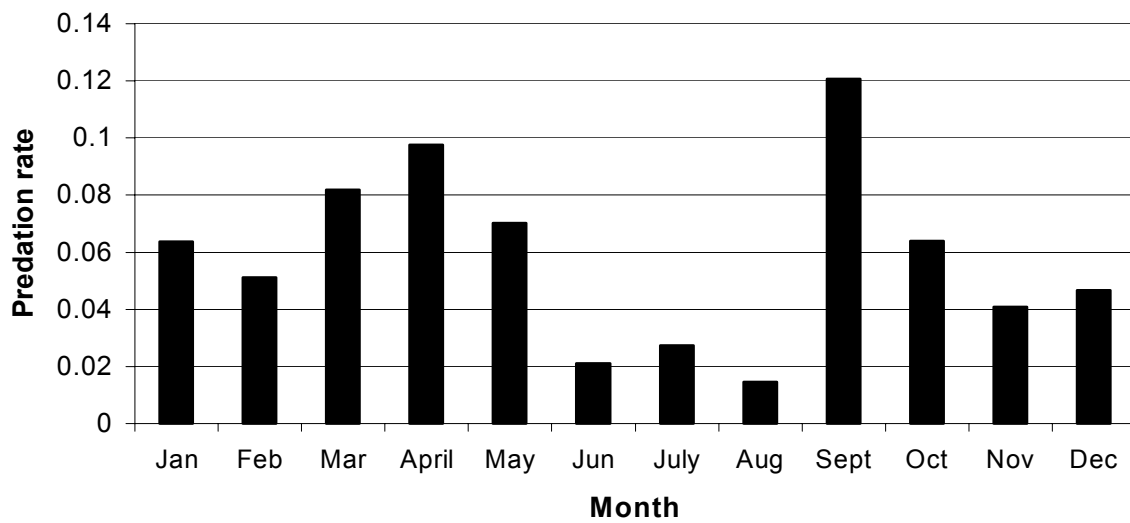


Figure 2.14. Average monthly predation rate on ruffed grouse pooled across all sites and years by month in the Appalachians between 1997 and 2000.

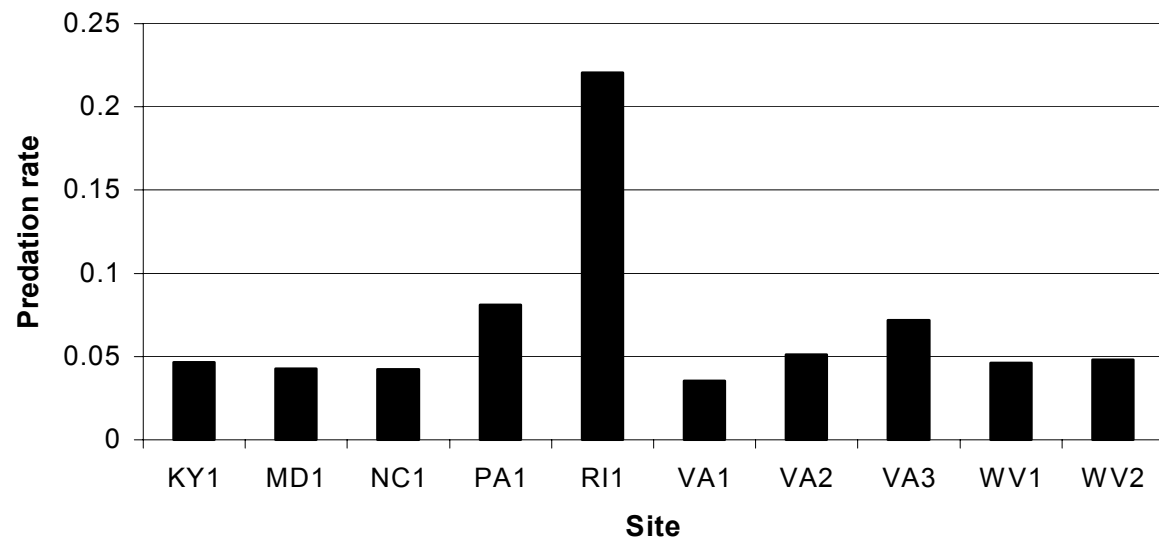


Figure 2.15. Average monthly predation rate on ruffed grouse pooled across all years by site in the Appalachians between 1997 and 2000.

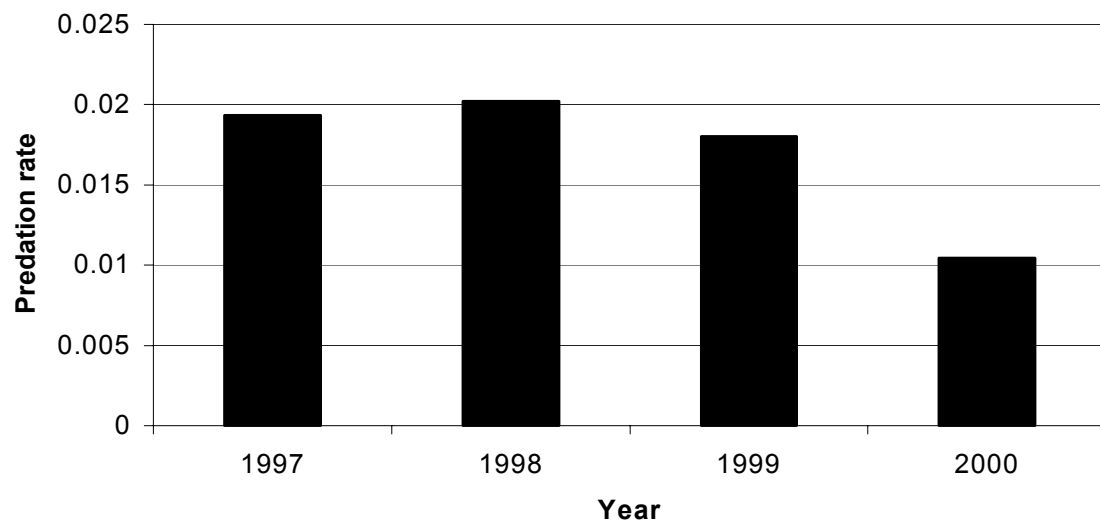


Figure 2.16. Average monthly mammal predation rate on ruffed grouse pooled across all sites and years by year in the Appalachians between 1997 and 2000.

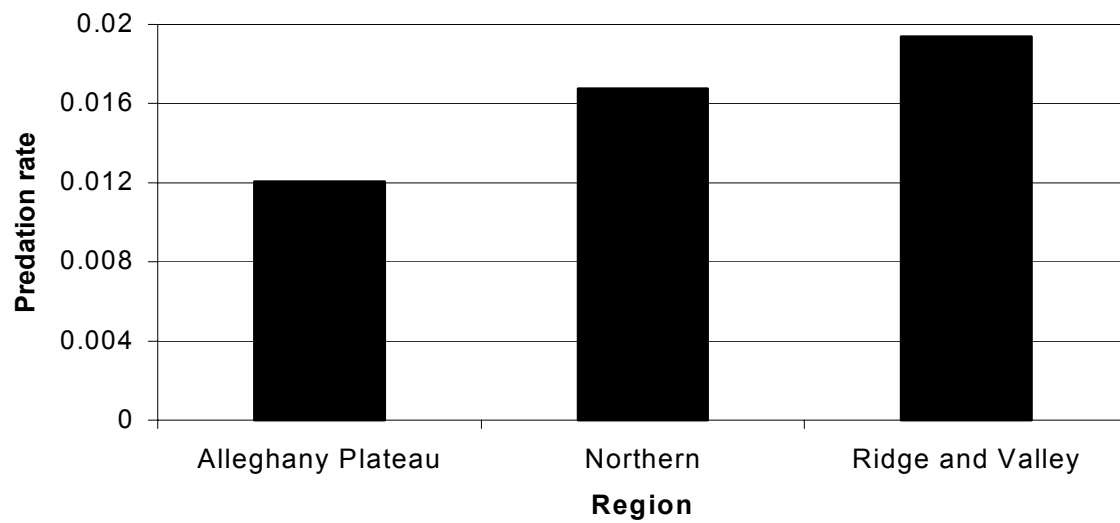


Figure 2.17. Average monthly mammal predation rate on ruffed grouse pooled across all sites and years by region in the Appalachians between 1997 and 2000.

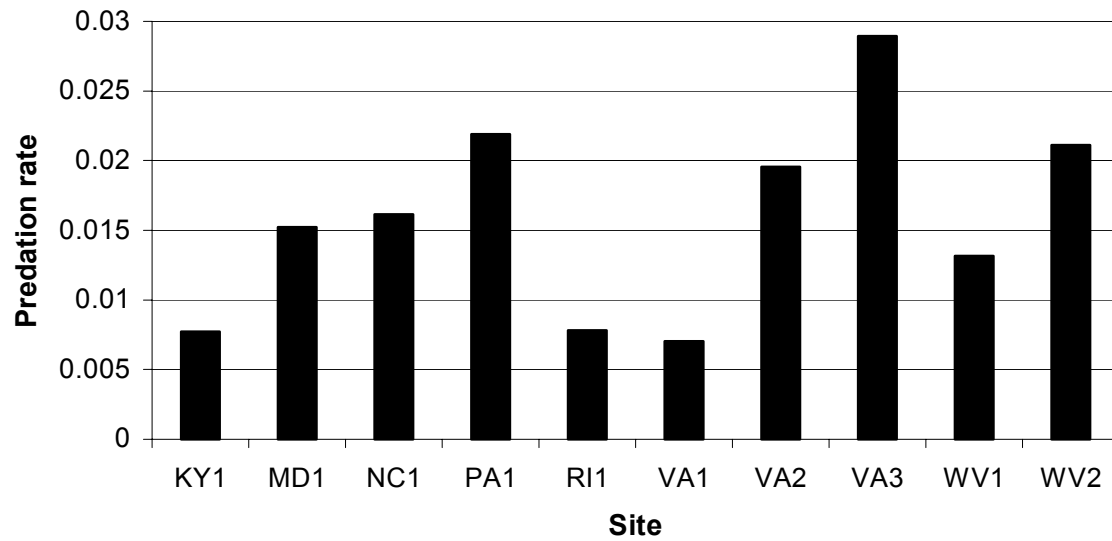


Figure 2.18. Average monthly mammal predation rate on ruffed grouse pooled across all years by site in the Appalachians between 1997 and 2000.

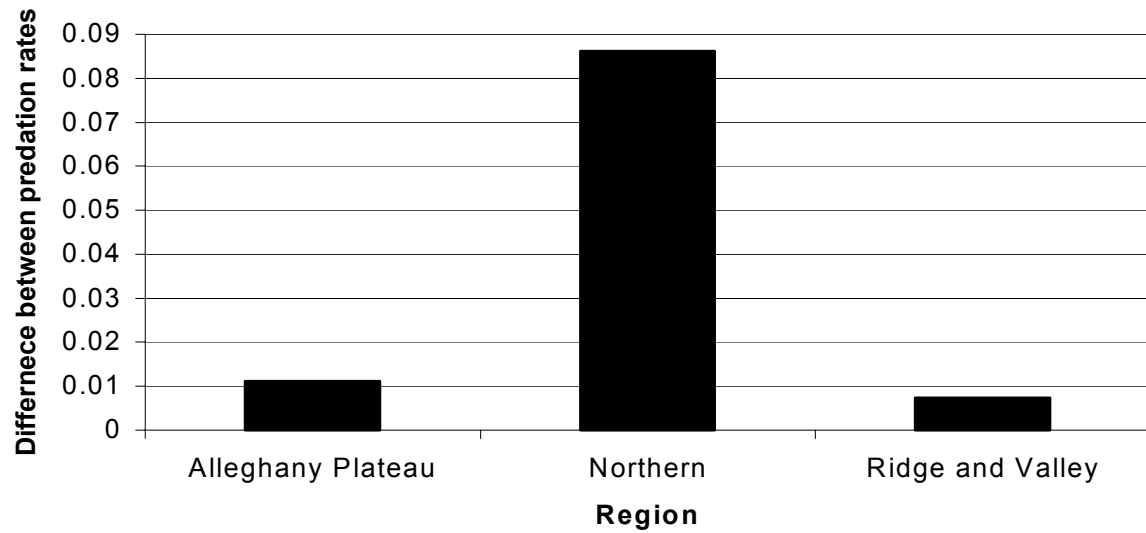


Figure 2.19. Difference between avian and mammal predation rates by region (avian predation rate – mammal predation rate) in the Appalachians between 1997 and 2000.

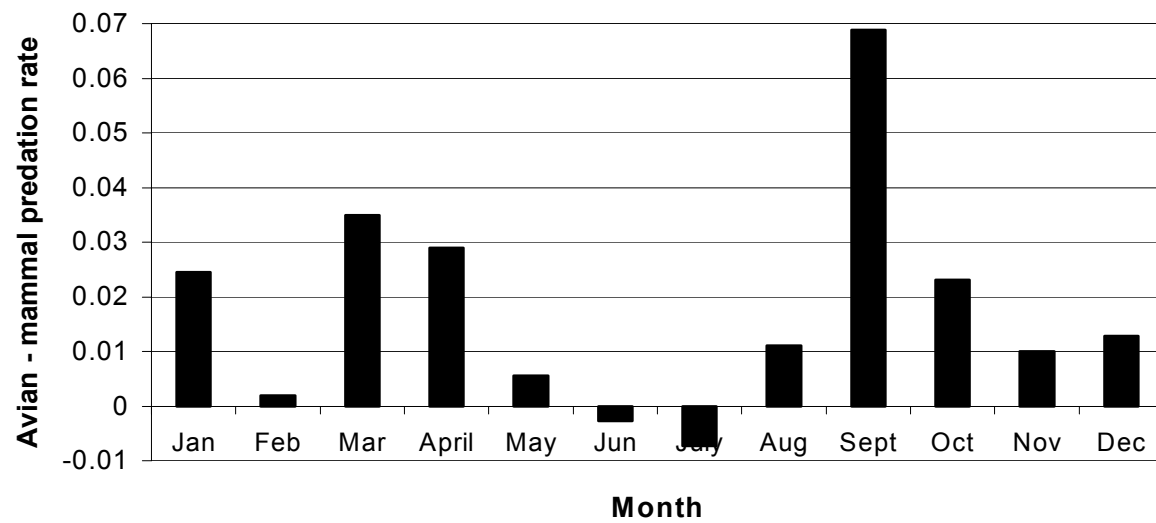


Figure 2.20. Difference between avian and mammal predation rates by month (avian predation rate – mammal predation rate) in the Appalachians between 1997 and 2000.

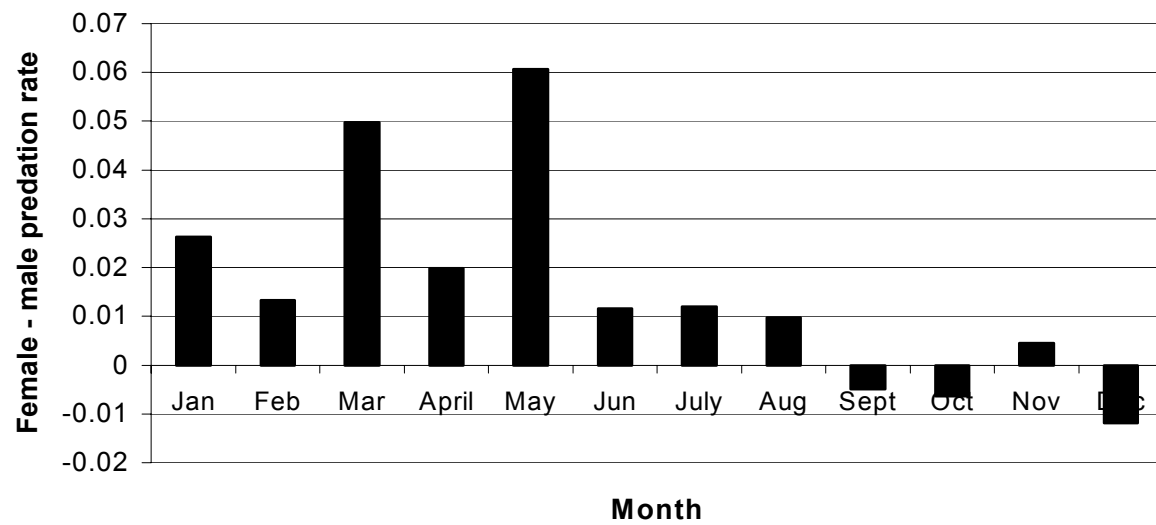


Figure 2.21. Difference between male and female predation rates by month (female predation rate – male predation rate) in the Appalachians between 1997 and 2000.



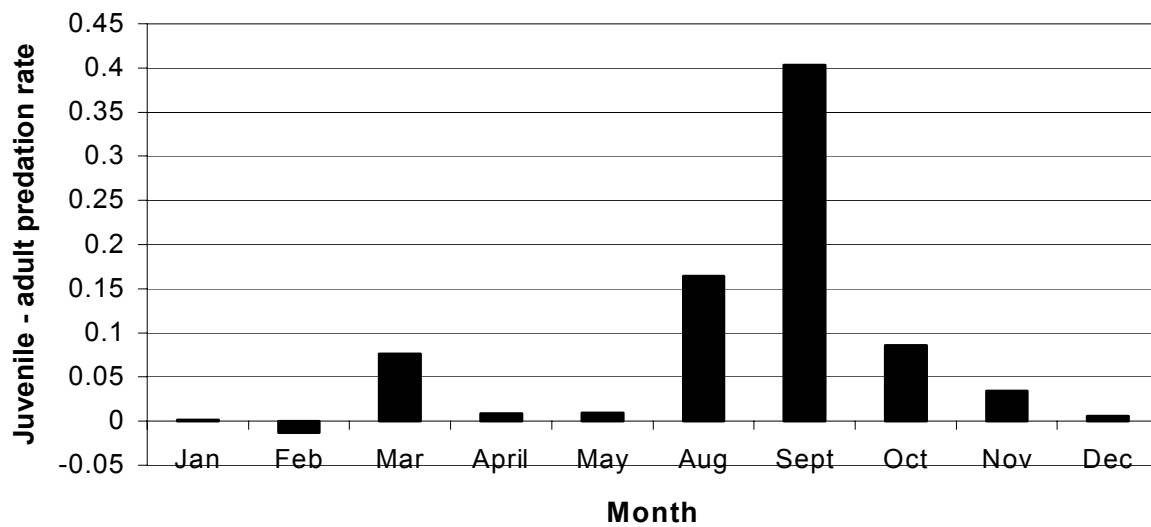


Figure 2.22. Difference between juvenile and adult predation rates by month (juvenile predation rate – adult predation rate) in the Appalachians between 1997 and 2000. June and July were eliminated due to the absence of radio-collared juveniles in Jun and July.

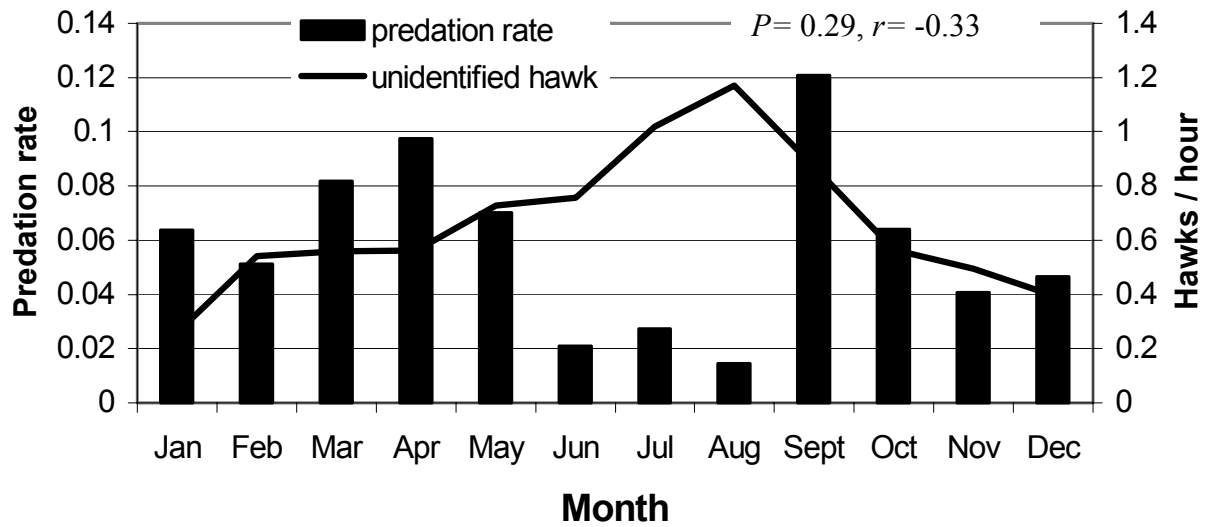


Figure 2.23. Monthly predation rate on ruffed grouse and frequency of unidentified hawks observed by month pooled across sites and years in the Appalachians between 1997 and 2000.

The  $P$  value and  $r$  value for simple correlation are presented with the graph.

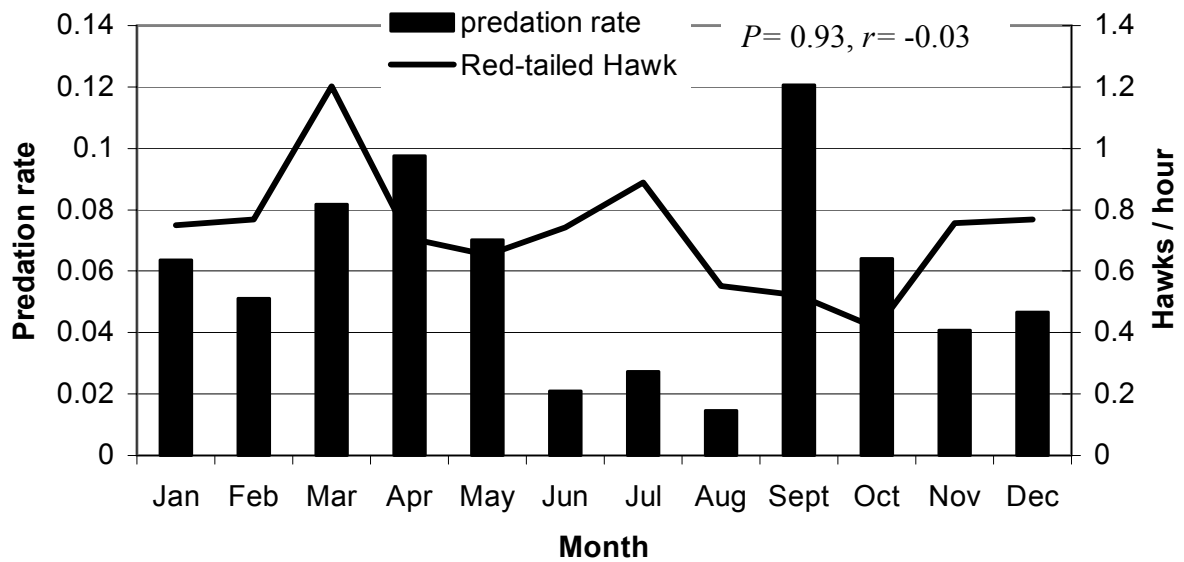


Figure 2.24. Monthly predation rate on ruffed grouse and frequency of red-tailed hawks observed by month pooled across sites and years in the Appalachians between 1997 and 2000. The  $P$  value and  $r$  value for simple correlation are presented with the graph.

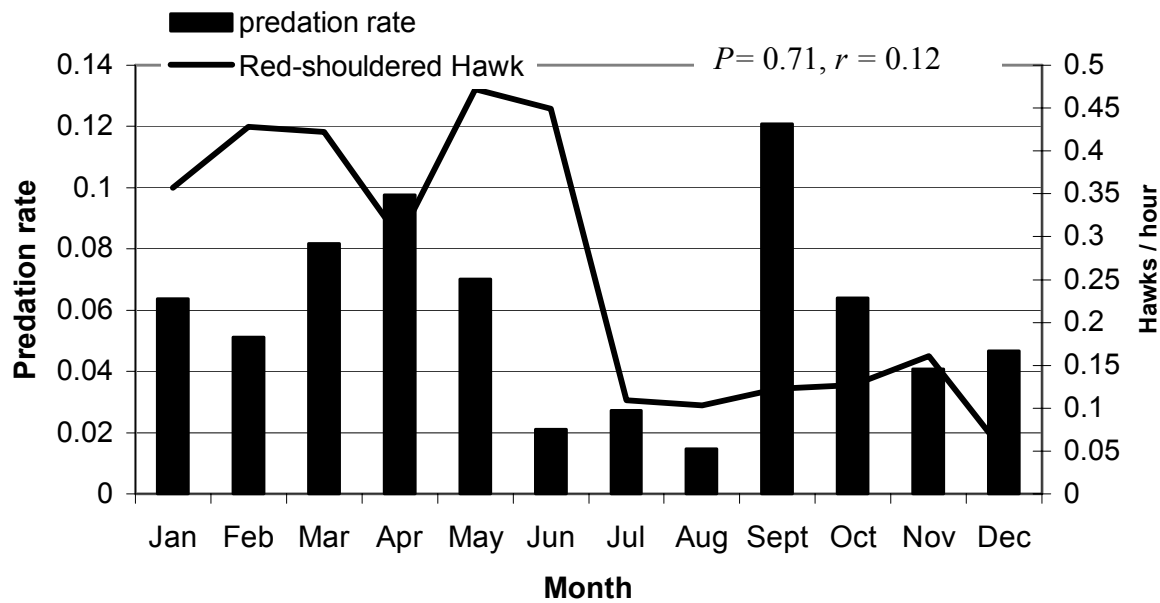


Figure 2.25. Monthly predation rate on ruffed grouse and frequency of red-shouldered hawks observed by month pooled across sites and years in the Appalachians between 1997 and 2000. The  $P$  value and  $r$  value for simple correlation are presented with the graph.

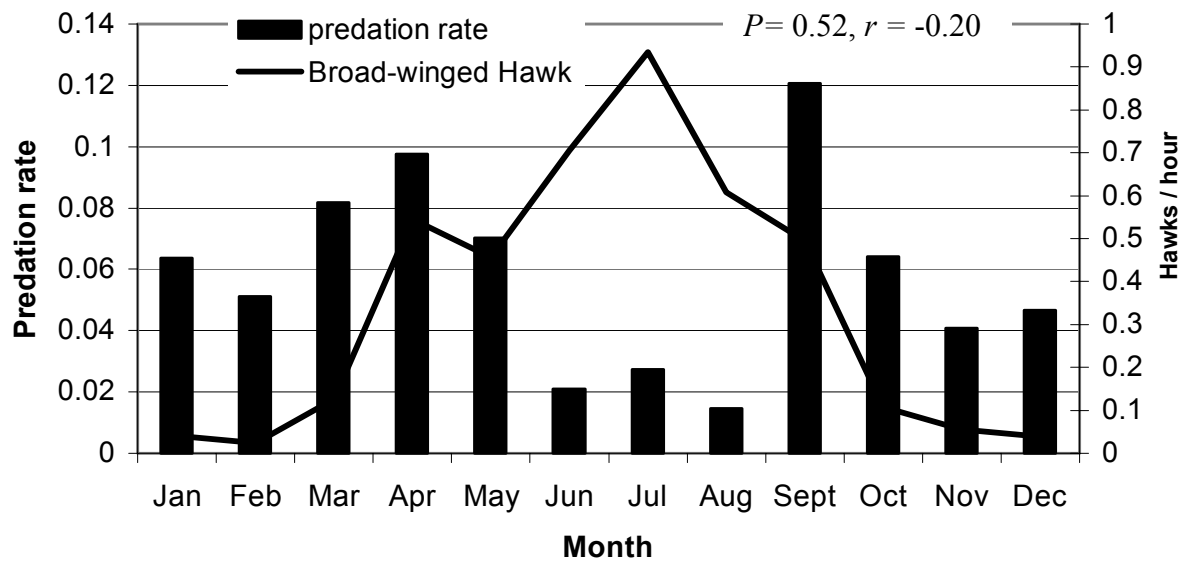


Figure 2.26. Monthly predation rate on ruffed grouse and frequency of broad-winged hawks observed by month pooled across sites and years in the Appalachians between 1997 and 2000. The  $P$  value and  $r$  value for simple correlation are presented with the graph.

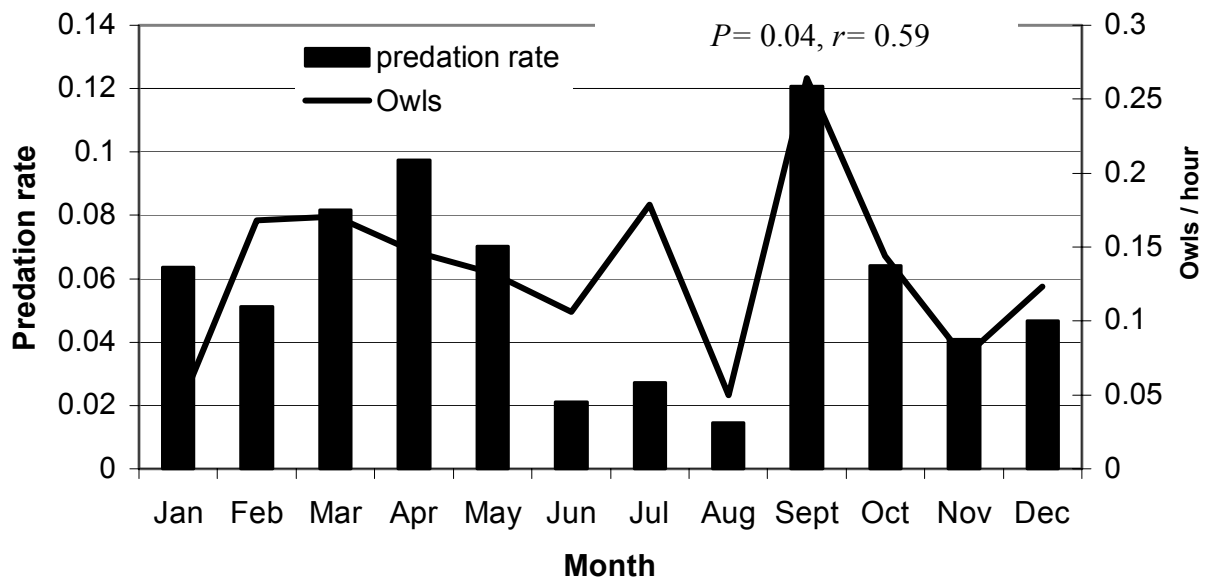


Figure 2.27. Monthly predation rate on ruffed grouse and frequency of great horned and barred owls observed by month pooled across sites and years in the Appalachians between 1997 and 2000. The  $P$  value and  $r$  value for simple correlation are presented with the graph.

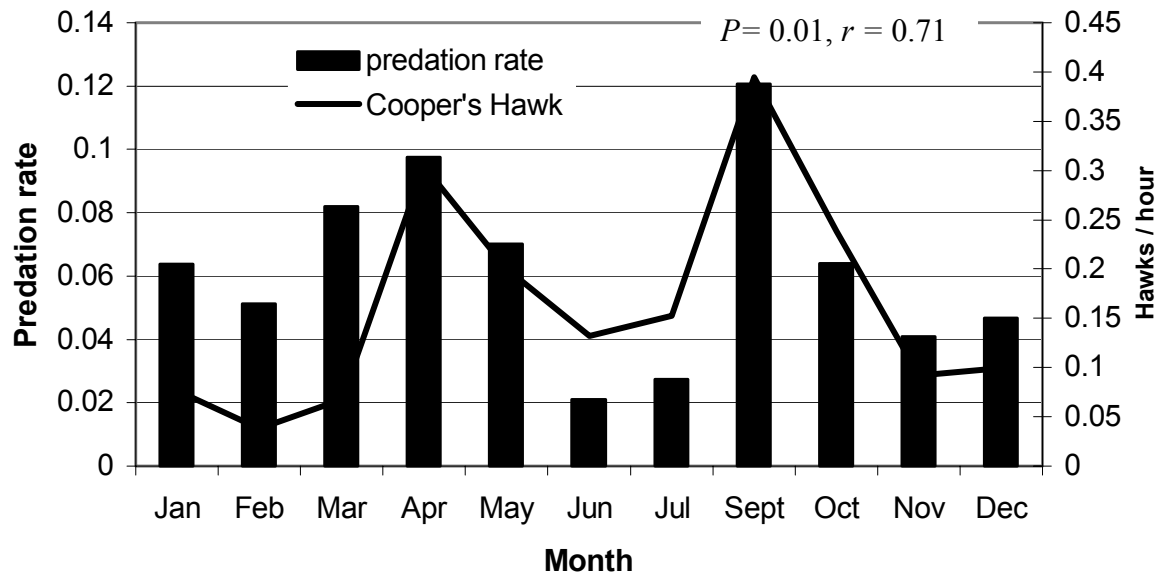


Figure 2.28. Monthly predation rate on ruffed grouse and frequency of Cooper's hawks observed by month pooled across sites and years in the Appalachians between 1997 and 2000 with August removed. The  $P$  value and  $r$  value for simple correlation are presented with the graph.

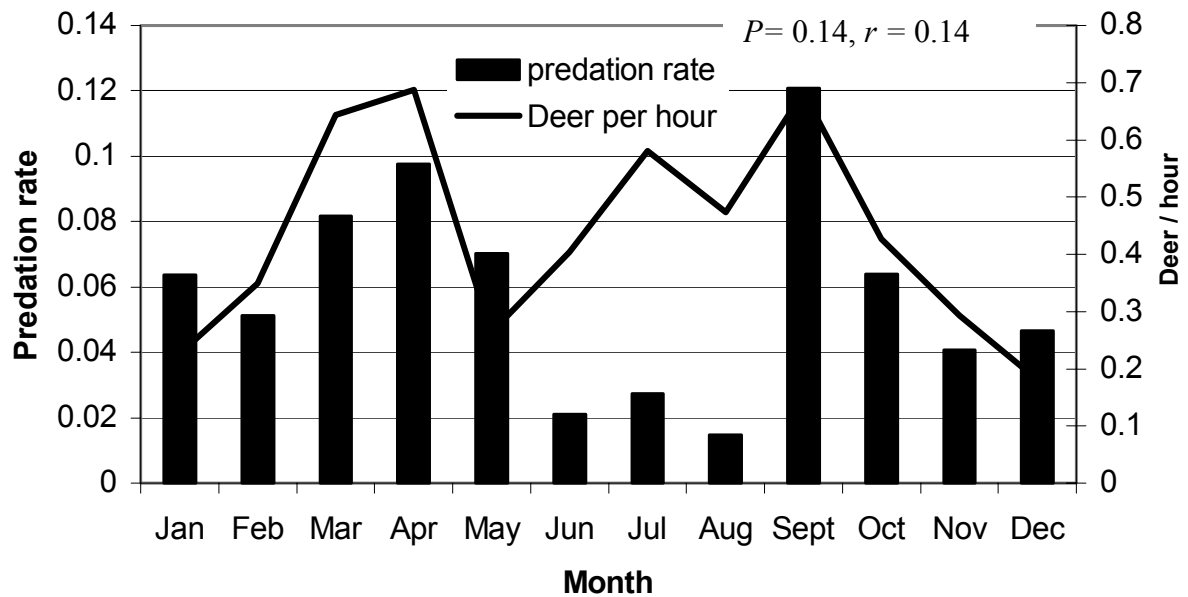


Figure 2.29. Monthly predation rate on ruffed grouse and frequency of white-tailed deer observed by month pooled across sites and years in the Appalachians between 1997 and 2000. The  $P$  value and  $r$  value for simple correlation are presented with the graph.



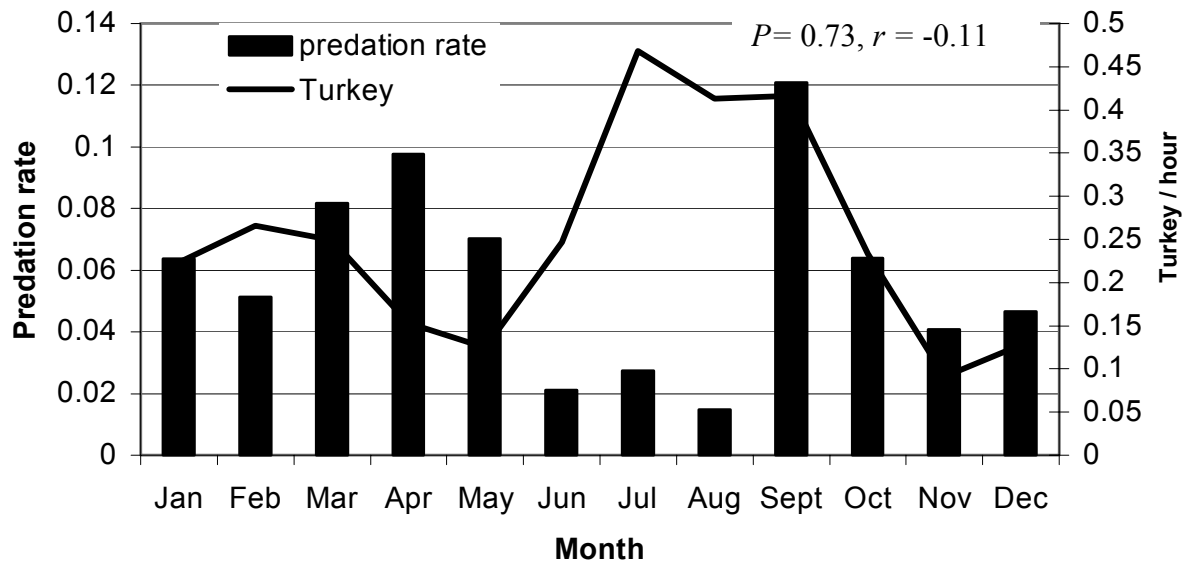


Figure 2.30. Monthly predation rate on ruffed grouse and frequency of wild turkey observed by month pooled across sites and years in the Appalachians between 1997 and 2000. The  $P$  value and  $r$  value for simple correlation are presented with the graph.

## **APPENDICES**

## Appendix A. Animal and weather observation field data form.

## State/Study Area Number: \_\_\_\_\_/

[illegible]

## Appendix B. Telemetry, animal and weather observation codes.

### Telemetry and Observation Report Codes

Confidence Codes	
1	Visual Sighting
2	Confidence high, bird close, angles (30-120°)
3	confident, but less than ideal, conditions, terrain causes bounce, or bird moving rapidly
4	Not very confident, not very good readings, angles ok, but bird is far away (poor signal strength), terrain rough, tough to pinpoint.
5	No confidence in readings, conditions poor (time, terrain, distance, angles, broad signal, bounce), recommend readings not be used in home range analysis

Signal Strength	
1	Weak
3	Good
5	Very Strong

Modulation	
C	Constant
V	Varying
M	Mortality Mode

Cloud	
1	Clear
2	<25% Overcast
3	25-50% Overcast
4	51-75% Overcast
5	>75% Overcast

Wind	
1	No (<3mph), Smoke drift none to slight
2	Low (4-7mph) felt on face, leaves rustle
3	Moderate (8-12mph) Leaves & twigs in motion
4	High (>13mph) raises dust, branches moving

Precipitation	
1	None
2	Fog, mist
3	Light rain
4	Heavy rain
5	Snow

Snow/Ice	
1	None
2	Patchy
3	Light, 1-3"
	Light, to mod. 1-4"
5	Light, or moderate 1-4" and crusted
6	Heavy > 4" or Mod. w/ crust
7	Heavy 4" w/crust or 9-18"
8	Very Heavy 19-24"
9	Heavy > 24"

Predator Species	
1	Golden Eagle
2	Bald Eagle
3	Hawk (unknown)
4	Cooper's Hwk.
5	Goshawk
6	Red-tailed. Hwk.
7	Red-shoulder Hwk.
8	Broad-wing Hwk
9	Owl (unknown)
10	Barred Owl
11	G.H. Owl
26	Sharp-shinned Hwk
12	Red Fox
13	Grey Fox
14	Coyote
15	Domestic Dog
16	Bobcat
17	Raccoon
18	Mink
19	Weasel
20	Road Hunter
21	Fisher
22	Opossum
23	Skunk
24	House Cat
25	Unknown Mammal

Other Species	
1	Rabbit
3	Squirrel
4	Groundhog
5	Bear
26	Bobwhite Quail
27	Woodcock
28	Black Rat Snake
29	Rattlesnake
30	Copperhead
31	Elk

**Appendix C.** Deciduous leaf fall chronology field data form.**Leaf Fall Evaluation Form**

State/Study Area Number: \_\_\_\_/\_\_\_\_ Year 2000

Investigator(s): \_\_\_\_\_

Study will be conducted in the fall of 2000 beginning on **October 20<sup>th</sup>** and end **December 20<sup>th</sup>**. Status of deciduous forest canopy will be visually estimated by research staff during normal field activity.

Visually estimate the % (to nearest 10%) of deciduous leaf canopy present on tree crowns in each of the 3 elevation ranges (as compared to normal, full summer foliage). Conduct survey on the day  $\pm$  2 days specified for each of the 7 dated columns. If certain elevation or slope variables do not apply to your locality, fill in only those that do. Space for any additional notes or comments is provided below. Note: those sites affected by gypsy moth defoliation should indicate (in the comment section) timing and proportion of the study area affected. Completed forms should be sent to: George Bumann, 149 Cheatham Hall, Dept. of Fisheries & Wildlife, Virginia Tech., Blacksburg, VA 24061-0321.

	<b>Oct. 20</b>	<b>Nov. 1</b>	<b>Nov. 10</b>	<b>Nov. 20</b>	<b>Dec. 1</b>	<b>Dec. 10</b>
	%Canopy	% Canopy	% Canopy	% Canopy	% Canopy	% Canopy
	N slope / S slope	N slope / S slope	N slope / S slope	N slope / S slope	N slope / S slope	N slope / S slope
Low Elevation	/	/	/	/	/	/
Mid Elevation	/	/	/	/	/	/
High Elevation	/	/	/	/	/	/

Comments: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

**Appendix D.** Green-up field data form.

## Green-up Data Form

Study Site: \_\_\_\_\_

This form is to be used to record information to help determine plant phenology on the study areas each spring. Divide each study area into low, medium, and high elevation categories. Select a telemetry station, or road segment, in each elevation category that will serve as the reference location for monitoring plant phenology. Indicate the approximate elevation at the location selected for monitoring in the table below. We assume that monitoring of plant growth at these locations will take place during normal daily activities such as monitoring birds. If the observations are noted within the nearest 3-4 days of when the event occurs at each elevation, the data should be adequate to illustrate trends in green-up. For each location, record the earliest date at which the following events occur, along with the code for the event:

S - sprout - the time at which you first see and can identify the plant breaking above ground. Use for herbaceous species.

L - leaf-out - The time when you first notice leaves breaking from leaf-buds on woody plants

F - flowering - The time when you first see flowers of the specified plant. Herbaceous & woody.

You would enter an observation as: L - 3/26 for the first leaves breaking from buds on March 26

Species	Low	Med.	High
Herbaceous:			
Bloodroot			
Trout Lily			
Skunk			
Colt's Foot			
May Apple			
Shrubs:			
Spicebush			
Serviceberry			
Dogwood			
Redbud			
Trees:			
Tulip Poplar			
Red Maple			

Note: Record data only for those species occurring on your area. Draw a line through those that do not occur on your sites.

**Appendix E. Guide to Diagnosing Ruffed Grouse Mortality-a review of predator related  
sign and activity for understanding the fate of ruffed grouse and their eggs**

**compiled by  
George B. Bumann  
149 Cheatham Hall, Virginia Tech.  
Blacksburg, VA 24061-0321  
gbumann@vt.edu**

To assist ACGRP (Appalachian Cooperative Grouse Research Project) cooperators in accurately diagnosing causes of grouse death, several sources of information have been compiled here to assist researchers when recovering carcasses and investigating instances of nest depredation. This summary is intended to complement and/or enhance the knowledge of current ACGRP personnel, and serve as a guide for new field researchers. This summary is by no means a comprehensive view of mortality diagnosis but it will serve as a basic outline by which to understand basic patterns and in turn, assist one in understanding the limitless variations that can occur.

Suggested use of this guide: This guide is divided into 5 sections to give field researchers a well-rounded view of predator diagnosis. It will benefit new staff most to review all of these sections prior to the onset of field work with an emphasis on A. Field Procedures for Carcass Recovery. Once experience is gained in the field, latter sections B. Species Accounts, C. Personal accounts of ACGRP investigators, and D. Scavenging and Marks to Transmitters may be of greater value. Section E. (Tables for the Identification of Predator Species) provides supplemental information that may pertain to isolated instances of grouse death.

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## A. FIELD PROCEEDURES FOR CARCASS RECOVERY

### **Approaching the Scene**

The following compilation assumes that the researcher has narrowed the transmitter signal down to a very localized area and is nearing the point of collar/carcass recovery. This may be best accomplished by removing the antenna from the cable and subsequently removing the cable from the telemetry receiver (generally when within 30 feet of transmitter for the latter). Removing the cable limits your directional ability so turning the frequency 0.004-0.005 Mhz, or higher than the actual frequency ie. turning frequency 150.482 to 150.486 or 150.487 while leaving the antenna and cable attached, will permit directional location of the transmitter.

1. Move Slowly. Once you have reached the general vicinity of the radio collar proceed cautiously and be on the lookout for signs of bird remains and/or disturbance. Do not rush in to recover the collar without viewing the local surroundings first. Evidence can and may be hidden under leaves, snow, on the underside of vegetation or over your head.

2. STOP! Once the first sign of grouse remains come into view, take no further steps into the mortality area. Take a few minutes to stop and rest as you scan the area for additional remains. Treat this as a crime scene and avoid any further disturbance. There is likely to be critical evidence at, or underneath your feet. If you must move in order to view the area, scrutinize each patch of earth before you place your foot down.

### **Initial Assessment**

3. Attempt to recreate the 'crime' by finding the entrance and exit routes of the predator- both Avian and mammalian.

What to look for:

#### Avian

potential flight paths through trees and vegetation ie. corridors free of vegetation and other obstructions

point of impact with grouse denoted by flattened vegetation or disturbed duff layer and/or blood

spread of feathers from plucking/feeding activity (taking into account the prevailing winds of each day following the kill to backtrack events eg. a north wind on the day of the kill will spread feathers to the south of the kill site-successive days of west wind will push those feathers to the east accordingly. also note that moisture has an adhesive quality when feathers contact such surfaces and they will tend to stay closer to the point of origin)

look for feathers or remains adhering to tree limbs, brush or other surfaces above ground level- i.e. taking into account plucking/butchering of grouse from an elevated surface

#### Mammalian

lines of travel though undergrowth or in relation to certain landmarks eg. areas where animals are funneled by rocks, logs, vegetation etc. hair may be stuck to these surfaces where the predator brushes against them.



upturned leaves in an otherwise 'organized' duff layer- though this can be very subtle or non-existent after rain or wind

hair (sometimes only a single 1 or 2) on briar thorns, tree bark, twigs or rocks -save these for species level identification

small bits of mud or water that may have rubbed off of a predators pelage or foot pads (may be found in areas with water crossings or standing water)- if splashes of water or mud can be found, individual splashes may often be teardrop shaped with the point of the drop indicating the direction of travel. similar sign can provide clues to the time of passage and potentially, grouse death.

bent grass or other vegetation can indicate direction of movement ie. grasses will tend to be bent in the direction of travel (look at other stems in the area to assess whether this is animal induced, or an artifact of wind or precipitation)

study the gate or track pattern of tracks if individual prints are not clear; this can help identify the animal and/or reveal the direction of travel (see Rezendes)

## Gathering Information

### Gross anatomy of a mortality site

Based upon the distribution of remains across the area, try to determine how the bird was processed. If the remains are not in one or two neat piles, attempt to recreate the chain of events leading up to death/consumption. Note: in many instances, carcasses that were initially processed in a very small area are fed upon, scavenged and redistributed *ex post facto*. A helpful technique for covering an area in search of evidence as suggested by Harry Spiker of Maryland DNR, is to mark the radio collar or main kill site then walk in a widening series of concentric circles around that point. Bits of flesh, feathers and predator-related sign that would probably be missed otherwise, may be located in this way.

Remains in small, concentrated piles- look for:

disarticulated joints and broken bones, particularly the neck, wings and legs for clues to butchering technique of the predator (see B. Species accounts)

remains may be stuffed or pulled into a confined space in conjunction with few broken bones is often diagnostic of the weasel family- holes used by weasels and mink can be of varying sizes. (see sections B. and E.)

raptors will at times, pull their prey under brush or low cover in order to consume them but remains will be lying flat and not packed into cavities or depressions as with the mustelids

Remains spread over moderate to large area:

see if you can tell what part of the grouse was processed first, second.... and where- identify areas where the neck and head, wings, breast, tail etc. were eaten based on their respective feather tracts; this may help identify the type of predator and presence of scavenging at the site

look for signs of struggle by the predator while dispatching or transporting the carcass- hairs, feathers, tracks, scats among other clues may be visible along this route

get on your hands and knees to view the surroundings from the level of a predator/scavenger- this will often reveal travel routes and sign not detectable from standing height

Fine scale anatomy of the mortality site.

Fractured bones- specifically the larger bones such as the keel (of the sternum), synsacrum, femur, humerus, and neck vertebrae can indicate the amount of force imparted on the bird- high degrees of bone fracture in these bones generally indicate a large mammalian predator although great horned owls and red-tailed hawks are capable of breaking these bones, though highly shattered or splintered bones results from chewing by larger mammals

In instances where the skin or broad, flat bones are penetrated by the K9's of a mammal predator, the distance between the punctures can be diagnostic though be aware of multiple bites to a particular area (see Table of Inter K9 measurements for predators in Section E)

the degree of raggedness where the feathers were sheared off by a mammalian predator can indicate the size of the predator involved. smaller mammals with equally small teeth eg. weasels will make a messy job of chewing through a feather calamus (though they generally avoid chewing through the wing and tail feathers) while a fox or coyote may shear it relatively cleanly, in 1 bite

hairs, however difficult to locate, can be exceedingly valuable evidence for the identification of mammalian predators (see Adoian and Kolenosky 1969 or Spiers 1974) scale and banding patterns observed with the naked eye or with a microscope can result in very clear identification of species present at the kill site \*\* (For microscope preparation of mammal hairs apply a thin coat of clear fingernail polish to a microscope slide; allow this to dry for a few minutes (depends on humidity and temp) until it is firm but no longer tacky. Place the hair of interest onto the fingernail polish then, using another glass microscope slide, sandwich the hair between the 2 slides, imbedding it into the hardening nail polish layer with one firm compression – multiple compressions may obscure or smear the hair's impression. Remove the upper slide and pull the hair from the nail polish layer with the aid of a pin or tweezers. The result will be a nail polish cast of the hair revealing its scale patterns readable under a compound microscope. Adjusting the light source and intensity may be necessary for viewing subtle features of hair morphology. Keep samples of 'known' hair samples as reference.

blood, when present can be a useful clue to the chronology of predator/scavenger actions- blood's viscosity increases as the carcass cools. when tissue appears bruised and contains hemorrhaged blood vessels, the action likely occurred close to the time of death ie. resulting from a predator and not a scavenger; tissue damaged after this cool-down period will be free of clotted blood

the presence of skin on the feather quills may signify their removal after the carcass has cooled off; feathers plucked while the bird is warm will have a clean calamus; be aware that groups of feathers will remain attached to flesh when it is the flesh that is removed, this is not the same as individual feathers being removed and having flesh dislodge with them

rigor mortis is another time/temperature dependant indicator of chronology; like white-tailed deer (Gill and O'Meara 1965) there are certain portions of the grouse that will stiffen before others; the legs and wings are the first to stiffen with rigor (within just a few hours at most) whereas the neck, as in other vertebrates will remain supple for a bit longer- pulling and flexing these parts of the body can give the researcher an indication of time of death (on relatively fresh kills) though this method is highly dependant on temperature and air flow

### **Diagnosis of Mortality**

When making your final diagnosis of cause of death, it is most advantageous to take the gestalt approach. Weigh all the evidence at hand to make the best determination as possible.

Take nothing for face value. Certain situations may present evidence that is blatantly visible and could result in hasty conclusions. Continually step back from the evidence at hand in order to view the entire scene. This will ensure that you do not become overly focused on certain details and miss the overall picture. An additional technique championed by Mike Fies of the Virginia Dept. of Game, is the collection of all material evidence at the mortality site. I would recommend placing all non-perishable evidence (including every single feather found) in marked (with bird ID#) and dated paper lunch bags for later analysis (perishable portions of carcass should be stored in a freezer as soon as possible). If the remains are in several piles, it is recommended that each separate pile be placed in its own bag so that potential conflicting evidence will not be confused; the subtle differences in predator versus scavenger activity may be present here. Not only will collecting remains force investigators to spend a bit more time at the mortality site, but will also allow them to view and handle all the evidence, in addition to revealing hidden or inconspicuous clues. Collection and analysis of material from 'known' sources of mortality is also encouraged since this will lead to more accurate diagnoses in the future. Later study of the evidence with the aid of a hand lens, or better yet, a binocular, dissecting microscope can reveal important mortality sign. Filing collections of grouse remains can be an invaluable resource not only for reference, but educating new field staff.

Two keys are included here to assist field personnel when determining cause of death or source of nest depredation. These 2 keys are designed only to direct the observer's investigation and not intended for final assessment. Use the keys to focus your search and then proceed to species level evaluation (using information provided in Sections B. and C.).

Adult Mortality Diagnosis Key

1. Base of feather quills chewed in half, bite marks on transmitter and harness, bones marred and chewed.....Mammalian Go to 2
1. Feather quills not chewed but kinked along shaft, gouge marks or creases on transmitter or harness, bones not chewed.....Avian Go to 4
2. Larger bones not broken, tooth marks on bones small.....See Mink and Weasel
2. Larger bones chewed and broken, tooth marks large.....Go to 3
3. Bird appears to be killed in a wanton manner, mortality site very messy, portions of carcass appear wasted.....See Domestic Dog
3. Carcass is thoroughly fed upon, bones heavily chewed, majority of flesh is missing, remains possibly buried or covered.....See Coyote, Fox, Bobcat, House Cat, Raccoon, Skunk and Opossum
4. Large bones broken.....See Red tailed Hawk and Great horned Owl
4. Not as above.....See Sharp shinned, Cooper's and Broad winged Hawk

Nest Depredation Key

1. Nest disturbed or structure obliterated entirely.....Go to 2
1. Nest not disturbed beyond missing eggs.....Go to 4
2. Egg shells crushed and mixed into nest material.....See Skunk
2. Egg shells show bite marks and are removed from the nest bowl.....Go to 3
3. Egg shells show fine tooth marks.....See Mink and Weasel
3. Egg shells show coarse bite marks.....See Raccoon, Foxes  
Bobcat, Domestic Dog, Skunk and Opossum
4. Eggs shells missing with only small shell fragments remaining.....See Crow  
and Raven
4. Eggs missing with no sign of shells remaining.....See Snakes, Foxes  
Raccoon, Weasel and Crow

## **B. SPECIES ACCOUNTS**

### **Adult Predation - Mammal**

General comments on mammalian predation Darrow (1938) and Dumke and Pils (1973) respectively: "Mammals typically bite into a large portion of the feathers including the contours which are plucked from the bird. Furthermore, the point at which they are severed is usually well toward the base of the shaft. Avian predators seldom sever the feathers, particularly the contours."

"Dressing of the carcass ie. removal of feathers prior to consumption was not observed in any cases of mammalian predation but has been attribute occasionally to mustelids."

### **Mink (*Mustela vison*) and Long-tailed Weasel (*Mustela frenata*)**

Account by Darrow on ruffed grouse in New York.

The weasels and mink drag their prey under or into some kind of shelter such as a stone pile or overhanging bank. An interesting fact about these later species is that after consuming the head and neck, which they do first, they usually sever one wing and then proceed to eat the flesh and wing bones away from he feathers. This leaves the wing feathers together as a unit with the shaft ends clipped but the line of clipping is quite irregular in contrast to the situation with respect to foxes. Another habit of these species is to leave the portion of each mandible forming the bill itself after consuming the balance of the skull."

Account by Dumke and Pils (1973) on mink kill of pheasant in Wisconsin.

"Hen 217 was alive prior to the blizzard of December 11 which dropped 16 inches of snow on the study area. Numerous feathers, intestinal waste, one leg band and the transmitter were found in the ditchbank den on December 16. The den was located in a spoil band adjacent to a large block of shrub carr. The entrance measured 3-4 inches and the tunnel to the cavity containing the remains was 24 inches long and dropped 18 inches below ground level. Two tunnels extended further down from the cavity. Likely, portions of the carcass were carried further into the den complex, but excavation did not extend beyond the first cavity. Mink was implicated based on the size of the den, since no tracks or other remains could be found.

The partially consumed carcass (of cock 243) was found in a picked corn field among foxtail an quack grass. The head, neck, heart and liver were missing along with 80% of the breast. Very little flesh was removed from the wings and the legs were completely intact. A trail of blood and feathers showed the bird was killed in the nearby roosting site and pulled under a canopy of foxtail and quack grass were feeding took place. Mink tracks were present at the kill and feeding sites."

### **Domestic Dog (*Canis familiaris*)**

"The dog kills wantonly many times letting victims lie; heavy tooth marks distinguish from fox (Fitzwater 1985)."

Evidence of play behavior in conjunction with heavy bite marks to the victim (with little attempt at feeding or dismemberment) is often diagnostic of this group, especially at times when natural food sources are low.

### **Coyote (*Canis latrans*)**

There are no documented accounts of coyotes killing ruffed grouse in the current literature although dietary studies indicate coyote consume grouse in small numbers (R. E. Chambers unpub. data). Sign from this species is most likely similar to foxes and may be separable from that of fox unless scat or hairs are found. Report of an inferred coyote predation by Chris Crosson on the ACGRP is included later in the Section C. Personnel Accounts of ACGRP Personnel under the Mammalian Predator-caused Mortality portion of this document.

### **Foxes (*Vulpes vulpes* and *Urocyon cinereoargenteus*)**

Account by Einarsen (1956) on ring-necked pheasant in Oregon

"Foxes have an especial interest in birds as food. They are most aggressive in taking nesting birds at denning time and the chances of finding bird remains will be greater in the accumulated litter adjacent to the den or in the den mouth. When feeding upon such large birds as the pheasant, there is considerable waste, telltale in character. It will be noticed by close observation that the toes of sizeable birds will be drawn out of natural position. In eating, muscles and tendons of the bird will be nibbled carefully by the fox for all meat particles. The tendons, which control the toes, are pulled as feeding progresses. If rigor mortis in their victim has set in, tendons will not return to their normal expanded position. A bird killed and left after the predator has fed will often have its toes cramped. As foxes nibble at leg remains, it is commonly found that the toes are bent out of natural position and so remain in many recoveries. Other mammalian predators like the cat may feed in a similar way but usually they are found in different terrain and other signs will be apparent to the watchful worker. Foxes often defile uneaten remains and the odor is likewise an identifying sign (some times likened to that of skunk).

Since the bulk of the food on a bird is on the breast and legs, these are the parts that will be attacked by the fox most readily. It is characteristic of the species when food is relatively abundant to leave the appendages scattered about. Even the head may be found uneaten. Thus, when a bird is picked up, it is almost always possible to locate most of it with the exception of the meatier portions. Foxes gnaw greedily on bird bones when food is not plentiful. Although you may find that the red-tailed hawk shears off cartilage and thin bones in a comparable manner, there will be no tooth marks also, but the evidence they leave is at variance with the signs left by foxes."

Account by Dumke and Pils (1973) on pheasant in Wisconsin.

"The carcass was found buried under 4 inches of snow in the center of a plowed field. Most of the flesh was consumed from the breast; the head and right leg were missing. Tooth marks were evident on the harness and antenna cover. Fox tracks were present at the cache site. Apparently the fox proceeded directly to the burial site from the field border and returned by the same route." In 9 of 16 instances foxes cached the carcasses and scat was found close by.

Account by Darrow (1938) on ruffed grouse from New York.

"Foxes usually bury parts of their kills for later use. They typically shear off considerable groups of feathers as units, the quill feathers in this case being most diagnostic."

### **Bobcat (*Lynx rufus*)**

Account by Darrow (1938) on ruffed grouse in New York.

"The bobcat consumes the bird almost entirely except for a quantity of clipped feathers usually including the primaries bitten off as a unit."

### **House Cat (*Felis catus*)**

Account by Einarsen (1956) from Oregon

"Most cats, and especially those of feral habits, avoid the big open fields in the daylight and confine themselves to covered and marginal areas. A cat kill is more easily determined in the open area than in any other type of habitat. The messy type of feeding common to the cat is not hampered (in open spaces) and a bird as large as a pheasant may be strewn over several hundred square feet of space as the cat worries away at the carcass. There is little preference for special parts. When the bird or mammal is reduced to a remnant, teeth marks can be seen in almost every bone exposed. These may be gnawed on successive days until hardly anything remains but a few sinews or large bones. In extreme hunger, cats, when feeding on large birds like a pheasant, they will leave only the feet, and perhaps a small remainder of the head with bill attached. They do not attempt to pluck the bird but swallow meat and feathers alike and attack the meaty portions first, taking an unbelievable quantity. "

### **Raccoon (*Procyon lotor*)**

Account by Anon (1936)

The heads of adult birds are usually bitten off and left some distance from the body. The breast and crop may be torn and chewed, the entrails are sometimes eaten, and there may be bits of flesh near water.

Account by Darrow (1938) on ruffed grouse in New York.

"The raccoon unlike the foxes does not as a rule carry different portions of the remains to different places. Usually the wings are left attached to the main skeleton while the legs are severed as well as the body of the birds being largely eaten. Also the raccoon does not regularly devour the head."

Account by Dumke and Pils (1973) on pheasant in Wisconsin.

"The hen's remains were found scattered in and around a decaying willow tree. The right wing remained attached to a portion of the sternum and the humerus of the left wing. All bones were stripped of flesh, and chewing was evident on the keel of the sternum, the scapula and the humerus of the left wing. This portion of the carcass, with fresh raccoon scat, was found in the crotch of a willow tree 7 feet above the ground. The left leg stripped of flesh, was located near the transmitter on the ground below the tree. The transmitter harness and antenna were intact with no tooth marks evident anywhere on the package. Nearby at another feeding site, was a portion of the left wing and numerous breast feathers. Yet at another site was the part of the pelvic girdle. The willow tree was located on the edge of a 10-acre woodlot at the intersection of 2 drainage ditches. Dens were found under the tree and along the ditchbank."

### **Striped Skunk (*Mephitis mephitis*)**

Account by Darrow (1938) on ruffed grouse in New York.

"The skunk has been the least uniform in its methods of any of the species studied, its chief characteristics being a general chewing of the bird, resulting in many broken bones which

are often left attached to each other and to the main skeleton. Large feathers are often clipped at both ends.

### **Virginia Opossum (*Didelphis virginiana*)**

Accounts of poultry depredation by Burkholder (1955)

Most noted predation by the opossum is on birds and their eggs. Chickens killed by opossum are mauled considerably. Opossum usually commence feeding on poultry at the anal opening. Young poultry or game-birds are entirely consumed with only a few wet feathers remaining.

Account by Darrow (1938) on ruffed grouse in New York.

"The opossum seems to habitually eat the bird, feathers and all."

### **Adult Predation - Avian**

General mechanics of avian predation by Einarsen (1956) and Darrow (1938) respectively:

"The talons of hawks and owls are especially lethal. With the successful stoop, the victim quickly becomes inert within the raptor's grasp. In examining bird kills, it is only by the closest external scrutiny that the place of the talon's entry can be found. This point is usually at the juncture of the spinal column and brain and just below the crown of the head. Deep wounds in the chest cavity, sometimes striking the heart area, are often disclosed by autopsies."

"The avian predators seldom sever the feathers, particularly the contours. When such evidence is found, it almost invariably applies to the main wing or tail feathers and the shaft has usually been pulled in 2 well towards its outer end. A characteristic of the avian group not applicable to mammals is the presence of parallel creases on the shaft and vane of the plucked feather. Another point is whether or not the larger bones have been broken. Except for the great horned owl the avian predators very seldom break the humerus, coracoid, femur or tibia... A character which will usually separate the work of the hawks as a group is the presence of a portion of the skull especially if it included the eye socket with the eye picked out"

### **Red-tailed Hawk (*Buteo jamaicensis*)**

Account based on the findings of Einarsen (1956) in Oregon

"When the hawk has made his kill, he rarely travels far with his victim but may alight on a low-limbed ash or oak tree or select as fencepost near at hand. Often, when the kill is made in a open fields or stubble, the redtail will begin rending while standing on the carcass, and throw skin and feathers long distances as he snaps his head to remove them from his beak. This litter may be scattered over several hundred square feet around the feeding spot. Finally, he exposes the meat, which is torn out in great chunks, and with it come bits of tendon and bone. This is all gulped down.

The sternum is rarely left intact by a redtail. It can be found only as a remnant on most skeletons. The bird may be disjointed also, and scattered over a wider area. It is not unusual for a hawk to return to the kill again and again, and as long as the meat is fresh it may salvage even the remnants of the skin left on the feathers.

Unlike the turkey vulture (*Cathartes aura*), often found in the same ranges, they are not normally carrion eaters. It has been our observations here that their interest in dead animals is



restricted to their own kills, which must be fresh enough to be free from taint or decomposition though they may have lain for several days in cool fall or winter weather."

Account by Dumke and Pils (1973) of pheasant in Wisconsin.

"... a major portion of the breast, neck and right leg flesh was consumed. Streaks of whitewash were noted radiating from the carcass after both visits by the hawk. A major portion of this pheasant had been devoured in about an hour."

### **Great Horned Owl (*Bubo virginianus*)**

Account based on the findings of Einarsen (1956) as they apply to ring necked pheasant in Oregon

"Heavy birds or animals are usually eaten on the ground although 1 pair of horned owls took adult mallard ducks which weighed about 3 pounds- equal to their own weight- carrying them nearly a mile to their nest and young. The neck meat of birds is the favorite morsel for the horned owl. This conclusion is drawn from the fact that almost invariably an owl flushed from a recent kill will have begun to feed on the neck before attacking the remainder of the carcass.

This is not true with mammals. Here preference is shown for the meaty portions on the hindquarters and the viscera. It is usually found that in feeding on birds, the owl cleverly removes the meat from the bones without dismembering the carcass. Do not be misled, however, when coming upon a messy kill. Based on circumstances, these may be signs that point to the horned owl again. The owl feeds with the aid of its feet. The victim is held in the talons in a suitable position and each mouthful is carefully flensed from the bone in a manner of a skilled craftsman. In instances observed during this study when owls killed pheasants, neck meat was found to be first in favor, followed next by breast meat. An owl may return to a kill later and reduce a bird to a mere skeleton, often breaking fairly large bones."

Account by Dumke and Pils (1973) of pheasant in Wisconsin.

"Of the raptors on the study area, only the great horned owl was capable of breaking pheasant femoral bone."

"Hen 85 's legs, pelvic girdle and most of the thoracic vertebrae were found completely stripped of flesh, with the transmitter, above 8 inches of snow in willow brush. The tibio-tarsus of the left leg was broken. Feathers were scattered in a 3-foot circle. The transmitter harness and antenna were intact except the antenna wire was kinked in 2 places 5/16 inch apart. The bent antenna could have been caused by the raptor's beak. During this same period a great horned owl pair established a nest less than ¼ mile from the kill site."

Account by Darrow (1938) on the ruffed grouse

"The great horned owl is the only avian predator that habitually breaks larger bones. It normally consumes the anterior portion of a bird first. Also the creases produced on the feather shafts by the beak of this bird may be wider apart than in the case of other species."

Account from Bent (1961) on the content of a G. H. Owl nest

Major Bendire reports a nest that contained "a mouse, a young muskrat, 2 eels, 4 bullheads, a woodcock, 4 ruffed grouse, 1 rabbit and 11 rats. The food taken out of nest weighed almost 18 lbs."

### **Sharp-shinned Hawk (*Accipiter striatus*)**

Account based on the findings of Einarsen (1956) in Oregon

"Songbirds, quail, young poultry, and even adult pheasants fall as victims before this aerial torpedo. In almost every case, the prey is large enough so this lightweight hawk has difficulty in flying off with the victim. The practice, then, is to drag the kill into cover. This bird is a fastidious feeder and will dress its prey more neatly than any other predator. This is not an infallible rule but it common enough to be noteworthy in this range. It begins to pluck its prey quickly and will do a creditable job in a very short time. The dressing plan is very systematic. It may not stop to eat a tidbit or to allay hunger but usually continues on a small bird until they are plucked. Limbs and head then are removed, and the first entry, when feeding begins, is usually in the body wall at one side of the abdomen, where the entrails can be removed more easily. In eating valley quail, the bird may be entirely disemboweled before any other meat is chosen. The sharp-shinned, in a surfeited mood, may, like the horned owl, select the tender neck morsels, leaving each vertebra intact with hardly a shred of flesh remaining. The sharp-shinned and the Cooper's hawk both return to a cold kill until they are satisfied or the skeleton is picked bare. If a bird is hungry, this may be within a few minutes after having been flushed from a kill. The heavy gorging by both the sharp-shinned and the Cooper's hawks results in frequent casts of chalky excrement."

Comments on the feeding behavior of sharp shinned hawks by Bent (1961)

Despite its small size this hawk has been observed tackling prey items much larger than itself. One account reported a sharp shin pursuing a pileated woodpecker in a tree until the observer scared it off. On another occasion this little hawk attacked an adult black-crowned night heron on the wing and successfully knocked it to the ground. It was in turn frightened off by the heron's cry and did not attempt to dispatch or feed upon it.

### **Cooper's Hawk (*Accipiter cooperii*)**

Account based on the findings of Einarsen (1956) in Oregon

"The Cooper's hawk is almost twice as large as the sharp-shinned when the extremes of each species are compared, as one might suppose, the Cooper's can be bolder in its attack, sweeping down on its victim from a perch, resorting less to surprise in hunting. Bohl (1954) reports in a thesis on pheasant survival the following:

"A Cooper's hawk pursued and caught a young cock pheasant in flight and dragged the bird down through a six-foot entanglement of blackberry vines. The last cries of the pheasant were heard as the observer quietly approached the area. From a distance of 20 feet, rocks were thrown to the inside of the vines in an attempt to flush out the hawk within shooting range. The rocks had no effect and the approach was made to within 5 feet of the hawk. At this point, the hawk could be seen through the vines tearing the feathers and flesh from the pheasant's neck. The hawk was shot and found to be a juvenile male Cooper's."

It, too, likes to pluck its bird victims and again the entrails are the tastiest morsels for beginning a meal, although it is not so consistent in this choice as its near relative. Picking birds in a systematic manner is a habit confined primarily to these 2 species. Because of their small size and great expenditure of energy, we would not expect them, perhaps, to follow the practice of owls, and waste space in their smaller stomachs with stray feathers. Plucking is apparently practiced to decrease the waste bulk and facilitate feeding.

This species also often hides its kill in brush piles, tangles, or under overhanging boughs, especially if the victim is of some size. The same advice in searching for remains of victims as is mentioned under the sharp-shinned hawk applies here."

Account from Stoddard (1936) on bobwhite quail

"The hawk had started to work on the upper breast and had cleanly removed the feathers. I picked the remains carefully and found that the sharp claws of the hawk had penetrated the quail's back in several places from the rump forward to the wings."

### **Broad winged Hawk (*Buteo platyperus*)**

Species specific sign of broad winged hawks on bird carcasses is limited in the current literature though their apparent ability to prey on grouse should not be overlooked. ACGRP investigators have noted increased incidences of avian caused death in grouse during influxes of these hawks though no direct observations of broad-wings taking grouse have been made to date. A study by Rusch and Doerr (1972) showed ruffed grouse was the major dietary component of Alberta, Canada broad-winged hawks. Grouse remains represented as high as 42% of the biomass brought to tethered broad-wing chicks in Rochester, Alberta (Rusch and Doerr 1972). Marks by this species most likely match that of Cooper's and Sharp shinned hawks.

Account cited by Bent (1961)

"Mr. Burns (1911) gives the following interesting account of the hunting and feeding habits of this hawk: ...Very small mammals are swallowed whole, and the larger skinned and even the leg bones clean-stripped and left attached to the hide. Birds are plucked of primaries, rectrices and a few breast feathers, flinging them aside with a quick flirt of the bill; after tearing off and devouring the head, the body is ripped open and the intestines eaten, piece by piece, the limbs and body follow."

### **Egg Depredation - Mammal**

Hernandez et al. (1997) initially set out to develop a dichotomous key of the ground-nest predators of west Texas. The range in inter- and especially intra-species variability is great at times, especially when comparing different age classes of the same species. Egg size has been considered very important regarding the amount of evidence left at the nest site (Hernandez et al. 1997, Montevicchi 1976). Smaller eggs tend to be removed with little or no evidence remaining. In situations such as the later, reptiles have been implicated due to lack of remains though this may not be entirely accurate. Keep this variability in mind as you proceed and look to other forms of evidence whenever possible.

### **Striped Skunk (*Mephitis mephitis*)**

Study done by Hernandez et al. (1997) using active infrared cameras on artificial nests.

The 14 eggshells examined could be classified into 3 groups: 1. The egg was bitten on 1 end, leaving the fragment that was approximately 75% complete. The eggshell had a small- to medium-sized hole with the shell crushed inward (9 of 14 eggshells), 2. The eggshell was in the same condition as above, but the bite was not at the very end, but offset to the sided of the egg. There was still 1 large fragment approximately 75% complete (3 of 14 shells), 3. The eggshell was crushed into several small-medium fragments (2 of 14 shells).

Skunks probably cannot easily carry or hold chicken-sized eggs; therefore the eggshells are found near the nest (within 1 m).

Account by Rearden (1954) on natural and artificial waterfowl nests in Maine.

"A skunk typically tears a nest almost entirely apart. Of the 2 nests destroyed by this animal in the present study, both were completely demolished. In each case a layering effect was noted of shells and nest material, as if the animal had eaten an egg, dropped the shells, and pawed nest debris over them before eating another egg. In one instance the animal had actually dug into the dry ground underneath the nest. Eggs were found in both nests destroyed by skunk. In each case they were found mixed with the nest material. Complete chewing of the shells appears commonly but the shell fragments are not separated, that is, the egg is apparently is crushed in the animal's mouth and the contents then sucked or lapped up, thus the membrane and shell fragments more or less cling together in a shapeless mass. This crushing effect is noticeably different from the "chewing" of mink or raccoon."

Skunk hair was found at the site of both nests destroyed by that animal. In each instance long white guard hairs were located well as the shorter underfur fibers. Odor of skunk was detected at both of the nests, which, although faint, was distinct."

Account by Einarsen (1956) from Oregon

"The cat-like tracks of skunks may lead to some confusion, but usually there are characteristic approaches to their depredations. They kill few adult birds at large and their interest in them should be keenest when birds are nesting or have young. Skunks have a keen sense of smell and, obviously, sift the wind for scents directly affecting their welfare.

The skunk usually opens an egg along the long axis. The removed portion of the shell may be scattered or eaten. The manner in which an egg is opened varies, however, with size of the egg and the stage of incubation. Well-developed embryos usually result in messy remains due to blood smears. As a rule, a small opening is first made in the egg and then the skunk begins to lap the liquid contents with its tongue. As the egg contents recede, the skunk will push its nose more deeply into the shell, leaving a crushed margin, the shell still being attached to the egg membrane. Usually, little of the contents are left before the shell is abandoned and another egg is attacked. Rarely do skunks carry away eggs. In most instances, all the eggs in the nest can be accounted for within the original nest depression, or near at hand. When eggs are too large or numerous for immediate consumption, skunks were found to make return visits, a practice often followed in raiding poultry nests.

Account by Darrow (1938) on ruffed grouse in New York.

"The skunk invariably crushes the shells completely and in addition tears apart the structure of the nest mixing the remains with leaf fragments and humus."

### **Mink (*Mustela vison*)**

Account by Rearden (1954) on natural and artificial waterfowl nests in Maine.

"Ordinarily a mink does not molest the structure of the nest." Of 4 nest depredated by mink "...eggshells were found, 2 had rather small holes eaten out of the ends or sides. In the third example, the shell was broken into rather small pieces. In all 3 instances, the edges of the shells were finely chewed... Close inspection of the shell remains frequently will disclose tiny toothmarks on unbroken portions of the shell. Although this is not infrequently noted in instances of egg destruction by other mammals, it appears to be particularly true of mink.

Hairs (of mink) were found at 3 of the 4 nests destroyed by mink."

### **Long-tailed Weasel (*Mustela frenata*)**

Account by Rearden (1954) on natural and artificial waterfowl nests.

"One artificial nest was believed to have been destroyed by a weasel. No shell fragments could be found in or around the nest though a musky odor resembling that of weasel or mink was detected nearby. Three scats were found within 1 foot of the nest and were believed to be those of weasel. If tooth marks (similar to those of mink) are present on the shell remains, these probably could permit separation of the 2 mammals (by measuring the distance between tooth impressions on shell)."

Account by Teer (1964) on predation of blue winged-teal nests by long-tailed weasel in Manitoba.

Three depredated nests were intact; nest materials, canopies, and down were not disarrayed. Only the eggs were affected, and only a small number of the total clutch in each of the 3 nests was broken. Two of 6 eggs in one nest and 1 of 7 in a third clutch were broken, and 3 could not be found despite diligent search. Eggs were broken at the ends, with openings generally about 15-20mm in diameter. Small punctures, often in pairs, were found in the sides or ends of all broken eggs. The liquid contents were present in some of the broken eggs, but the embryos were missing.

A large, male long-tailed weasel was live-trapped in the same area (of nest predation). It was placed in a wire cage and given blue-winged teal eggs and chicken eggs. The weasel did not break the eggs but made small, paired, conical punctures in them. These punctures were identical with those found in broken eggs at the plundered teal nests."

Account by Darrow (1938) on ruffed grouse in New York.

"The weasels operate in a similar manner (as foxes) but often take several eggs to the same place which is normally under some kind of shelter. Shell remains left by a weasel usually show a longitudinal sectioning of the eggs and the edges of the remaining portion are finely chewed in a very characteristic manner. Mink is quite similar to the weasel."

### **Raccoon (*Procyon lotor*)**

Study done by Hernandez et al. (1997) using active infrared cameras on artificial nests.

Raccoon (n=104) in 1 of 3 conditions: 1. The eggshell was in 2 distinct fragments of approximately equal size, the tip and bottom of the egg. Smaller fragments were attached to the main fragments, or scattered about them (55% of eggshells identified), 2. The eggshell was crushed into small, numerous fragments. The top and base of the egg could sometimes distinguished (39% of eggshells), 3. The eggshell was 1 large fragment with a bite on the side of the egg (6% of eggshells).

TrailMaster photographs revealed that raccoons held eggs upright and typically bit into one end of the egg. Most eggshells were found in the vicinity of the nest (within 5 m).

Account by Rearden (1954) on natural and artificial waterfowl nests in Maine.

Nests destroyed by raccoon are often pawed and sometimes extremely so; "that is, the base of the nest had been disturbed, or the nest rim had been pulled out or broken in several places. Seven (out of 16 nests observed) had the rim pulled out only on one side. Three nests had not been disturbed at all, except for the removal of the eggs.

Eggshells were usually found within 30 feet, with most of them being within 6 feet of the nest. Shell remains left by a raccoon are typically half shells, either eaten from the end of the egg, or less frequently, from the side causing a lengthwise splitting or breaking of the egg. The shells are coarsely fractured, and do not have a finely chewed appearance. In some instances the shells are completely broken (in contrast to crushing), with small pieces perhaps the size of a fifty-cent piece left. Small indentations caused by the teeth of the animal are seldom apparent on eggs destroyed by raccoon. Raccoon typically do not consume the eggshell with its contents, rather leave most of it at the spot where the egg is consumed.

Hair of raccoon was found in 19 of the 20 nests destroyed by raccoon, hairs sufficient for identification of that mammal were found. Another habit (among larger mammals at least) that appears to be peculiar to the raccoon is that of carrying the eggs to a prominent rock or boulder near the nest and there eating the eggs. Large boulders at the edge of a stream or lake are particularly favored by the animal for this practice."

Account by Davis (1964) referring to depredation of poultry and game-bird nests.

"One or more eggs may be removed (by raccoon) from poultry or game-bird nests and may be eaten away from the nest. The shells are heavily cracked with the line of fracture being along the long axis of the egg. There is often some disturbance of the nest materials."

Account by Darrow (1938) on ruffed grouse in New York.

"The raccoon usually leaves the major portion of the shell intact, biting into the egg from one end- typically the smaller. With respect to eggs containing advanced embryos the shell is often considerably more broken. In any case, however, the nest itself is little disturbed, if at all."

### **Red Fox (*Vulpes vulpes*) and Gray Fox (*Urocyon cinereoargenteus*)**

Study done by Hernandez et al. (1997) using active infrared cameras on artificial nests.

Of the 5 eggshells found for gray foxes, all shared the following characteristics. The eggshells had a small (<2.5 cm, round opening extending across the middle to lower base of the egg. The eggshell fragment was large and >75% complete. All 5 fragments were found >25 m from the nest. In 1 study (A. Sargeant, Northern Prairie Sci. Cent., unpubl. Data) nest predation by red foxes was observed; the foxes grabbed 1 egg at a time and departed immediately to cache it. The process was repeated until all the eggs were cached. Most (450; 99.8%) of the 454 eggs eaten by red foxes were buried, and only 1 (0.2%) was eaten at the nest. In our limited sample of gray fox observations, we found that their behavior was similar to that of red foxes.

Account by Rearden (1954) on natural and artificial waterfowl nests in Maine.

"In 3 cases of fox predation the nest rim was pulled out only on one side. In 2 cases the nest was badly torn up, the base dug into and the nest from completely destroyed. Ordinarily the fox does not dig up a nest, as much as either the skunk or raccoon; as a rule, the animal appears to paw out on side, presumably to obtain the eggs more easily.

Eggshells were found at only 1 nest destroyed by fox. It appears to be a rather common trait of this animal either to eat the eggs, shell and all, or to carry them well away from the nest (often to young in the den) before consuming them. However the eggshells in the 1 case found, were well broken up and had lost most of the spherical shape. They appeared broken- not crushed- more like damage caused by raccoon than any other of the mammals studied.

Fox hairs were found in each instance of suspected predation by that animal. The underfur (of foxes) is easily caught by twigs and even by herbaceous vegetation, thereby making

it readily found at the site of a destroyed nest. A fox may raid a nest and not take all of the eggs present."

Account by Darrow (1938) on ruffed grouse in New York.

Foxes habitually carry each egg to a point from 1 foot to 75 feet or more from the nest before eating it, each egg usually being taken to a different spot. Also the nest cavity itself is left undisturbed. When the egg shell remains are found, the work of the fox is recognizable by the comparatively coarse fracturing of the egg shell and usually by the appearance of a distinct bite having been taken out of the side. Also shell remains frequently show paired punctures in the remainder of the shell roughly opposite the main break." Bump also noted instances where foxes "filched" eggs from active nests only to leave the remainder of the clutch which was later incubated by the hen and successfully hatched.

### **Gray Fox (*Urocyon cinereoargenteus*)**

Accounts of quail nests Nelson and Handley (1938) from Camp Lee, Virginia

Eight nests (replenished with eggs after first predation) were observed in areas where predator tracks could be seen. Nearly all of the depredated nests were emptied of eggs with "no trace of egg shell at or around nest." In cases where shell remains were found they were few in number and small in size. The remains of one egg were "found about 20 feet from the nest." Nest structure damage was minimal or nonexistent. In a few cases nests were "pawed out on one side or completely pawed out and scattered." One egg from 1 nest "was bitten but left uneaten about 8 inches from the nest."

### **Bobcat (*Lynx rufus*)**

Study done by Hernandez et al. (1997) using active infrared cameras on artificial nests.

Seven eggshells were collected from bobcat incidents and had several characteristics in common. The eggshells had a small (<1.5 cm) narrow opening in the center of the egg. The eggshell fragments were large and >75% complete. Five of the 7 eggshells were only partially eaten (with some contents still present), and 2 were completely eaten. In instance, only 1 egg was partially eaten, leaving 2 eggs intact. All 7 eggshells were left in place in the nest bowl.

Account by Darrow (1938) on ruffed grouse in New York.

"The bobcat crushes the shells (like skunks) but does not disturb the nest."

### **Domestic Dog (*Canis familiaris*)**

Account by Darrow (1938) on ruffed grouse in New York.

The dog consumes the major portion of the eggs leaving only small bits of the shell. Nest disturbance varies widely with breed and individual.

### **Opossum (*Didelphis virginiana*)**

Account by Darrow (1938) on ruffed grouse in New York.

Opossum consumes the major portion of the eggs (as dom. dogs do) leaving only small bits of shell but does not normally disturb the nest itself.

## Egg Depredation- Avian

American Crow (*Corvus brachyrhynchos*) and Common Raven (*Corvus corax*)

Account of American Crow by Rearden (1954) on natural and artificial waterfowl nests in Maine.

"Three of the nests (depredated by crows) were undisturbed insofar as the cavity was concerned. The black duck nest, which in was in thick vegetation, had 1 side of the rim pulled out and scattered for a distance of 3 feet. The 3 remaining artificial nests had the rim lightly pulled out on 1 side in each instance.

Parts of eggshells were found at every nest destroyed by crows. It is seldom that the remains of all eggs can be accounted for at a nest destroyed by this predator. The birds frequently fly to 1 or more perches to eat eggs, and it appears that, as often as not, more than one crow is involved in the raiding of a nest. However, it seems practically impossible for a crow to puncture an eggshell and pick it up without leaving some shell fragments, however small, in the nest. In 2 instances of the 7, small fragments (half the size of a dime) were found in the immediate vicinity of the nest. In the other 5 instances the shells recovered were much larger and retained their spherical character.

Usually the egg retains its spherical shape and has a moderate or large opening, most often on the side. Often there is another small puncture just below and to 1 side of the large opening, caused by the lower mandible of the bird. At times a puncture, with outward projecting fragments, is present opposite the main opening in the shell. At times a crow will almost completely demolish an egg, leaving small, flat, shell fragments, perhaps the size of a quarter. It is likely that the stage of development of the embryo within the egg is a factor in determining the size of the opening." It is believed eggs destroyed by both ravens and crows are similar in appearance and that differentiation of the 2 where their ranges overlap is all but impossible.

Account by Anon (1936)

Crows usually remove the egg from the nest before breaking a hole in it. The raven breaks a hole in the egg up to an inch in diameter. The raven leaves a clean edge along the break, never crushing the egg.

Account based on the findings of Einarsen (1956) from Oregon

"It is fact that the crow prefers to remove eggs from the nest. If feeding itself, it may, in its cautiousness, fly to some post, snag or elevated perch to dine undisturbed while still on the watch for an enemy. If it has young, it takes one egg at a time from an open nest, carries it to its own nest, returning again and again until all are consumed. The crow watches incubating pheasant with persistence. As soon as she withdraws from the nest, another egg is removed. We found crows capable of capturing pheasant chicks several days old and persisting in the practice. Raids on domestic chickens are common.

Eggs of larger birds, such as gulls, ducks, or sage grouse, offer a good clue to raven depredations. Their attack on eggs is vigorous and the egg is usually opened along its long axis. The opening is large, frequently resulting in the complete removal of the upper one-third of the shell, as it lies in the covert. In outline, the opening resembles that made by the skunk except that its edge is clear-cut and never crushed in. The massive strong bill of the raven necessitates a large opening to get at the substance of the egg. There is little liquid remaining in the shell after the meal. The skunk forces its mouth into the shell and crushes in the edges to get the last drop



of albumen or yolk. The raven accomplishes this neatly with its bill after a sufficiently large opening has been made in the shell."

Account by Darrow (1938) on ruffed grouse in New York.

"The important egg eater among birds is the crow, which may leave the shell remains close to the nest or at a short distance from it. The chief characteristic is the presence of a partial or complete punctures in the shell which are in the portion of the shell opposite the main opening and which comprise outward projecting fragments."

Study by Montevecchi (1976) of artificial nests and egg depredation in New Jersey

It was found that medium to small sized eggs (those of ruffed grouse fall roughly between Montevecchi's medium and small size classification) were most commonly pecked, then removed from the nest site rather than feeding upon the eggs at the depredation site. Flight distances of crows with eggs ranged from 1 to 1000 m. Many individual crows (both common and fish) would remove and cache eggs some distance away taking many more than could be consumed in the observed time. Individual crows that associated with groups of 2 or more other individuals were more successful at depredating eggs than individuals in pairs or as singles. Cooperation among individual crows in foraging groups has been noted when foraging eg. perched sentinel(s) signaling to individuals foraging on the ground around nest sites.

### **Egg Depredation - Reptilian**

Black Snake (*Elaphe obsoleta*)

Account by Hardy(1951) on ruffed grouse in Kentucky.

Hardy(1951), in Kentucky, documented this snake consuming ruffed grouse eggs with apparent ease and noted no predator-specific sign the nest bowl following depredation.

Account by Dobony (2000) on ruffed grouse in West Virginia.

Dobony (2000), with the aid of video surveillance cameras, recorded nest depredation of a ruffed grouse nest by a black rat snake in West Virginia and noted that there was no disturbance to the nest other than missing eggs. The removal of eggs occurred over a 2-3 day period with only a few eggs being removed at a time.

## **C. ACCOUNTS OF ACGRP PERSONNEL**

### **Mammalian Predator Mortality**

Account of bobcat kill by Harry Spiker of Maryland DNR

Carcass was recovered on a steep hillside (40-50°) about ¾ of the way up the slope, amidst a sparse boulder field. The grouse remains were located in a patch of hardwood regeneration (largely composed of blackberry and sassafras) amidst a larger, more mature stand of trees. The main body of the bird was buried under leaves that were scratched into a pile over the remains. The innards of he bird were not opened or exposed though the main portion of the breast meat was consumed and the head was gone.

Accounts of fox kills by Harry Spiker of Maryland DNR

Scenario 1. The completely uneaten carcass was found cached next to an 8" maple log in a semi-mature stand of trees during mid-winter. The remains were in a depression though not covered or below the soil surface in a tangle of debris piled on the edge of a clearing by a bulldozer. The fox had apparently bitten the grouse across the back judging by the K-9 marks on either side.

Scenario 2. A second grouse carcass was recovered in the spring on the edge of a field, cached in hole along side a root mound about 50 yds. from a gated logging road. This time the grouse was under the soil surface but again, uncovered. Fox scats were present near the cache site. Both red and gray foxes are present on the MD1 ACGRP study site though grays predominate.

Scenario 3. From the evidence at hand 1 adult male's death appeared as though the bird was killed on the drumming log. A trail of feathers led away from the log to the collar which was underneath a large boulder. Fox tracks and bed impression (outline of fox's body ) were evident in the dust around the travel route and radio. The grouse had been completely consumed.

Scenario 4. The carcass was taken by the fox to a den on private land on the edge of a pasture. The radio itself was recovered at 1 of 3-4 entrances that led underneath a large 2x15x20', horizontal, flat rock. Standing on top of the rock, the skittering of more than 1 fox pup could be heard as they ran about in the den cavity beneath the slab. Ferns in the area surrounding the rock were trampled in several places and the remains of several other prey items were seen scattered about the entranceways.

Account of an opossum killing a trapped grouse given by Scott Fiedhof, Kentucky Dept. of Fish and Wildlife Resources.

While checking traps on evening, technician Jason Russell came upon an opossum inside the trap body. The opossum had consumed the majority of the juvenile male grouse. The only remaining parts were the wings. The wings were still attached to each other by a limited amount of flesh where the keel used to be. The opossum was released from the trap body unharmed.

Account of weasel kill by Harry Spiker of Maryland DNR

The bird's home range had been centered around a logged hilltop. When the grouse was heard on mortality mode, it was recovered downhill in a stand of pole timber with intermixed hemlocks averaging 10" dbh. The radio signal was narrowed down to the base of a tree towards what appeared to be a chipmunk hole (~2" in diameter). Realizing that the signal was coming from the hole, Spiker and his assistant proceeded to extract the entire grouse carcass from the hole. Much of the muscle mass had been consumed including the breast, legs and wings (along the humerus only). Based on the size of the hole and chew marks on the carcass, it was determined to be the work of a weasel.

Account of weasel kill by G. Bumann on Virginia 3 ACGRP study site

After being trapped in the fall of 1999, grouse 1.143 (an adult male) traveled 0.5-0.75 mi. southwest along the mountain top before localizing its movements near a new clearcut of ~1ha. He had been transmitting in the live mode the previous afternoon but was now on mortality. The carcass was located ~30' away from a skid trail in the center of the clearcut in a pile of tops. A pile of feathers ~1.5' in diameter and the transmitter (with 1 bite mark from a set of small teeth) were underneath 1 of the tops. A faint trail of feathers lead downhill 15-20' through the leaves and tops; here the carcass was located. The remains had been pulled, with some apparent force, down into a thick tangle of oak twigs and leaves: only the wings projected out. Upon pulling the carcass out of the stash, one could see that the head was completely missing, ~50% of the flesh

had been removed from the breast, and entirely from the legs and wings. The latter was thoroughly cleaned of muscle including around the base of the primary wing feathers and between the radius and ulna. The wing feathers were completely intact though some of the other larger feathers did show evidence of being chewed. Those feathers that had been chewed appeared splintered and gnawed by a fine set of teeth. Tissue and muscle around the cloaca and even on the dorsal side of the synsacrum was removed, though the viscera were not touched. Further downhill in some sand, the evenly spaced, paired tracks of weasel were evident. It had made several passes through this patch of earth. Coyote tracks were also found but not believed to have been associated with the grouse remains.

1.143 was on the air for 80 days.

Account of an unknown mammal kill by G. B. Bumann and Jason Blevins, Field staff of ACGRP site VA 3 (Clinch Mountain Wildlife Management Area, Saltville, VA)

Hen 1.035 was heard on live transmission mode on July 18th from telemetry station 701. On July 19th she was heard on mortality mode from telemetry station 257. The best azimuths of the 6 taken put her toward the head of Divide Hollow on Short Mountain. The location proved to be relatively close considering the steep terrain. The transmitter itself was recovered in a pile of matted, wet feathers on the downhill side of a large *Rhododendron maximum* thicket (which transitioned into a mature mesic-deciduous hardwood forest) in the area where it became sparse approximately 50m from the bottom of the hollow. Among the plumes were several primary wing feathers (1 from the left side appeared chewed at the base). Seven tail feathers, many semi-plumules and other assorted contour feathers composed the remainder of the pile.

Considering that it had not rained since the night of 17th, we assumed that 1.035 had been killed prior to this event. Most of the feathers were in a pile ~18" in diameter next to a log, of 8" in height on a small level spot along a faint deer trail and nearly under a large *Rhododendron maximum*. The transmitter had no predator related marks to it although the tip (~2.5" from the end) was bent into a "J" shape. It is not clear whether this was predator induced or the result of normal grouse activity. From my hands and lines I found 2 feathers in the uphill direction (~2') from the transmitter recovery site and could also deduce a potential path of travel by the predator/grouse. Following the suspected path 18-20' uphill I recovered 7-8 more feathers on the edge of a more heavily used deer trail. Moving along slowly and continually looking at the lay of the land from ground level, Jason Blevins and I followed the trail of sparse (sometimes only a single 1 or 2 every 8-15') matted feathers up into the ever thickening *Rhododendron* patch. Along side 1 rock, there was a small hole (possible weasel sized cavity) though the lack of sign in and around its mouth led me to believe its location was purely incidental. The trail of feathers (a mix from all parts of the axial portion of the bird) led up hill a distance of ~25-30 yds until it spread out slightly near a *Rhododendron* with low horizontal stems. Though no grouse pellets were found, we believe that this bird was taken from her roost site in the low level

*Rhododendron* then dragged downhill and consumed where the collar was found. Upon following the trail of feathers back down to the collar location, it was apparent that the movement of the predator and carcass was in part, guided by subtle features in the topography including small sticks, logs, low profile rocks, tree roots and small mounds of earth. The arrangement of feathers in relation to the aforementioned features suggested that this predator's movements were influenced by microhabitat features on a very small scale and hence, potentially a smaller predator. No carcass remains were found. I did find 2 more feathers down hill from the collar location but low light conditions and rain prevented any further investigation. Due to the lack of aerial flight paths into the supposed roost site and the tooth impressions on the 1 feather, I concluded that this was a mammalian predation event.

Account of coyote predation event on ACGRP site VA 2 by Chris Crosson.

The grouse of interest moved a considerable distance from its normal area of occupancy and was later found to have been killed by a coyote in an evergreen stand with a modest amount of laurel undergrowth. Remains of the bird consisted of 2 diffuse piles of feathers ~10-15 m apart. Flesh and feathers present at the kill site appeared matted and wet as though moistened with saliva. They (the feathers) had been thoroughly chewed or mouthed by the predator. The understory, primarily the duff layer, was disturbed for an area of 20 yds around the transmitter recovery site. Many of the feathers left behind were obviously chewed through. Pieces of flesh (with groups of feathers attached) and bone fragments were also seen at the site. Two fresh coyote scat were also present only 1.5-2' away from the feather pile containing the transmitter.

Account of bobcat predation event on ACGRP site VA 2 by Chris Crosson.

The radio signal led to an upper ridge covered with an open mature stand of hardwoods. Upon approaching a large hollow log (which an adult human could fit inside of) a dead weasel was discovered (bitten on the back of the neck). Local sign indicated this was a bobcat den, beside which the grouse carcass was recovered. The radio was found in the middle of a very neat, circular pile of feathers; many of which did not show bite marks on the feather shafts. Feathers did not appear very wet or matted as compared to coyote kill previously noted by Crosson.

Account of bobcat predation event on ACGRP site VA 2 by Chris Crosson.

The grouse remains were recovered in a shallow dip beside a log with leaves overtop. It appeared as though a bobcat had cached the carcass (without consuming any of it) and raked ground cover over its kill. A circular area of scratched earth was visible around the remains.

Account of mink kill by G. Bumann on Virginia 3 ACGRP study site

Hen 1.621 had an established home range in Ray Bottoms (a modest flat bottom between 2 mountain ridges) until she was killed in early-December of 1999. J. C. Blevins initially followed the mortality signal of 1.621 to the recovery site but the collar itself was in a den and not recoverable. Approximately a week later, C. S. Swank and myself returned to recover the radio amidst the numerous bottomland tangles. Heavy snows had fallen around the time of the hen's supposed death and 10-14" still remained on the ground. Thick *Rhododendron sp.* thickets and 2 stream crossings made this mink's lair difficult to find. When we reached the den site, we found it neatly situated under the partially undercut root mass of a red maple (*Acer rubrum*) and virtually on the edge of a flowing stream. Hunched over, we maneuvered under the *Rhododendron sp.* limbs in front of the opening to the den. A small trough in the snow with a set of very fresh male mink tracks entered the snow-bordered hole of ~4" in diameter. Before I reached in for the radio, I poked a stick up into the hole. A wild scamper could be heard as the mink fled up further into the root mass cavity. After pulling away much of the snow along the roots I was able to retrieve the collar (with a gloved hand) and found it to be only 12" inside the den. The den itself was found to be relatively spacious. Fully 3.5' wide inside the entrance, its height varied from a few inches to ~1' and was of undetermined depth (perhaps 6-8') and angle upwards toward the back 12-18". Only a few scattered ruff and contour feathers could be found; no sign of the carcass existed. Minimal bite marks were observed on the collar or harness.

Account of weasel kill by Jason Blevins, Field staff of ACGRP site VA 3 (Clinch Mountain Wildlife Management Area, Saltville, VA).

Grouse 1.172 was recovered in mid-November on the spine of Short Mountain, slightly uphill of the clearcut around which its home range was established. The carcass was lying slightly on its left side and was largely unmolested with the exception of there being a bite mark on the back of the bird's neck and some of the right breast being consumed. Very fine tooth marks were evident in the muscle tissue of the consumed area.

Account of weasel kill by Jason Blevins, Field staff of ACGRP site VA 3 (Clinch Mountain Wildlife Management Area, Saltville, VA).

The radio signal led to a forested hillside in Twin Hollows where only a few feathers were seen leading into a small hole. When the log that backed up to the hole was removed, the transmitter was found down inside the cavity only 2" below the ground surface.

### **Avian Predator Mortality**

Account of hawk kill by Harry Spiker of Maryland DNR

A hunter sitting in a relatively mature stand of forest observed a hawk flying through the understory with a large prey item in its talons. The hawk turned out to be a red-tail, which then dropped its booty. The hunter walked over to investigate and discovered it was a radio-collared grouse. The only visible damage to the carcass was the fact that it had been decapitated and the neck flesh stripped away. The radio was hanging on the spinal processes of the neck vertebrae and little more. It was amazing that the radio stayed with the carcass as long as it did for it certainly could have fallen off at any moment.

Account of supposed hawk kill by G. Bumann on Virginia 3 ACGRP study site 5/21/00

Male 0.482 had been missing for ~5 days when I heard his signal on mortality from the telemetry station 200 high on the ridge tops of Twin Hollows. Both J. C. Blevins and myself went after the bird on 2 consecutive days without success. It could also be heard from the gorge, but as soon as one would drop down lower into the hollows around Big Tumbling Creek, the signal would disappear. Not until D. Martin of the Virginia Dept. of Game did an aerial telemetry location did we realize that the bird was on the other side of the management area on the top of Short Mountain. We could drive to within 0.3 mi from the collar on the Short Mountain Road, but could not hear it due to the ridge and hollow that lay between. The transmitter was found on the near side of a steep hollow near the top of the mountain. The actual location of the radio (I did not discover until I stepped on it) was in a small opening 15x30' on the edge of a *Rhododendron sp.* thicket in a mature stand of hardwoods and under 2" of fresh, wet snow. Just like making a snowman, I picked up a gob of snow and began lifting and rolling the blanketed of white off of the mortality site. I discovered 2 major piles of feathers, 1 downhill from the other, about 8' apart. All the feathers that had predator related marks on them were kinked or bent as if plucked by a raptor; none exhibited evidence of chewing.

Account of a Cooper's hawk killing a wood duck by Scott Friedhof, Kentucky Dept. of Fish and Wildlife Resources

One evening in August 1999 I participated in an attempt to capture wood ducks with a rocket net at Kentucky's ACGRP study site, Yatesville Lake WMA. Wood ducks were baited into range of the net with cracked corn for 2 weeks prior to the actual capture attempt. We

observed the bait line from a camouflage blind located about 15-20 feet behind the net. The bait line was located only 20-25 feet from the water's edge. About 30 wood ducks inched their way up to the cracked corn and began feeding. The ducks flushed (as a group) suddenly and before reaching the water, a Cooper's hawk zoomed in from behind our blind and hit an adult male duck out of the middle of the flock. The hawk and duck hit the ground about 4 feet from the water's edge. The hawk had only one set of talons in the duck. The other foot was used for balance as the hawk tried to use its beak to kill the duck. The hawk picked only at the duck's neck. The duck struggled occasionally and managed to drag the hawk into the water. The duck became submerged and almost half of the hawk was submerged as well. Just when I thought the duck had won; the hawk pulled the duck back onto the bank step by step. A few more picks at the neck area and the duck finally did succumb. The hawk plucked feathers from the duck's back and ate the flesh from the back first. At that point, the person responsible for catching the ducks, scared the hawk away with a BB gun. The hawk flew to the other side of the narrow cove and perched. The remaining ducks returned to the bait site again with the hawk in view. About an hour later, the hawk returned to the duck and finished feeding. The remaining portion of the breast was consumed upon return. The hawk flew back in the direction of the attack, right over our blind, upon completion. The hawk never moved the duck after the kill nor did the hawk excrete any whitewash while at the kill site. The duck was not dismembered, but was left intact.

Account of an avian kill by Jason Blevins, Field staff of ACGRP site VA 3 (Clinch Mountain Wildlife Management Area, Saltville, VA)

Bird 1.063, an adult male, was heard on mortality mode by Todd Fearer at approximately 6 am the morning of March 30, 1998 in Twin Hollows. This information was radioed to Jason Blevins who recovered the transmitter shortly after. At the time of recovery by J.C. Blevins, the transmitter was transmitting in the normal (live) mode. The grouse had been completely plucked down to the skin, such that only a few of the 1° wing feathers and some of the tarsal feathers remained. 1.063's head was removed and its neck meat consumed as well as some of the breast meat around the crop and furcula. The radio was lying in a dense feather pile about 5 yds from the carcass.

Account of an avian kill by G. B. Bumann. Field staff of ACGRP site VA 3 (Clinch Mountain Wildlife Management Area. Saltville, VA)

Grouse 0.836 was captured and radio collared on Friday October 20 along Ray Bottoms by J. C. Blevins and subsequently heard on mortality mode on Sunday October 22 (2 days later) by G. B. Bumann and J. L. Golding. The signal led us to the area near where the bird was initially captured. Ultimately, the radio collar was recovered ~20m from the trap body. The bird's remains were spotted underneath the cover of several young eastern hemlocks (*Tsuga canadensis*) and *Rhododendron sp.* All that could be found in the area around the transmitter (consisting of a circle ~12" in diameter) were neck and ruff feathers intermixed with oak (*Quercus spp.*) leaves. One feather still had a piece of flesh attached to the calamus (~5 x 8 x 10mm) which was desiccated around the edges but still pliable at its center. Judging by the ambient conditions, the flesh was probably removed from the bird's body the previous day. Small amounts of blood were also present on the leaf litter around the feathers indicating that the bird was probably dispatched by the predator on this spot using attacks to the head and neck area of the grouse. None of the feathers in this spot gave direct evidence of raptor or mammal activity. Miscellaneous feathers (largely from the ventral side of the bird) were spread in and around an area 10' in diameter beneath the young hemlocks and *Rhododendron*. Some of the feathers were distinctly found along faint paths through the leaves toward the road which was

~20 m away. Several of these faint paths in the leaves (denoted by the most subtle displacement of groups or individual leaves) were centered around the aforementioned circle of feathers though one in particular, led directly away from the supposed kill site. A single belly feather lay in the direction of the inferred direction of travel by the predator/scavenger. Upon following this sign further (sometimes looking several feet ahead for displaced leaves or feathers) I moved out from underneath the hemlock patch and into an open mature forest on a trajectory that was across the gentle slope. Singular feathers and other limited sign led me ~17 m to the base of a large white oak tree (*Quercus alba*). At the downhill side of the tree there was a second pile of feathers that consisted of some belly feathers and a fair number of primary and secondary wing feathers as well as wing coverts (most of which were from the right wing of the grouse).

Three meters below the tree base there was a degraded tree top (~1.5 x 1 x 3 m) which produced a brushy tangle. Amidst this tangle was a splay of whitewash and one ruff feather. I am not certain the whitewash was from the predator of this grouse though this did look like a plausible refuge for a feeding raptor. Further searches of this brushy structure revealed no further evidence of grouse or predator.

My tentative evaluation of the predation event was that 0.836 was attacked in the vicinity of the hemlock/*Rhododendron* patch (perhaps in the direction of the live trap or road. It was then dispatched under the evergreen cover. Some feeding on the grouse may have occurred here though it was probably limited to the neck and upper breast. The carcass was then moved to the site of the large white oak by unknown means (perhaps the predator or a scavenger. Additional feeding occurred on the grouse carcass at the oak. Feeding at the oak site consisted largely of the wing areas, breast and belly regions so far as I could tell. It is possible that another animal came in contact with the dead bird since there were additional feathers (3 or 4) around the back side of the tree and 1 was ~15" off the ground in the crotch of shallowly divergent limb.

Continuing on past the large white oak, I tracked the leaf disturbance further yet along the contour of the slope. Another 20-30 m away I found 1 more grouse feather where the trail turned downward toward the road grade. From the latter evidence, I guessed that the main portion of the carcass, if still intact, was at the very least, 60 m from the site where the radio transmitter was recovered though I never did find it. My guess is that a mammalian scavenger may have encountered the carcass at the oak tree feeding site and carried it away in the direction of where the last feather was found.

Account of an avian kill by Jason Blevins. Field staff of ACGRP site VA 3 (Clinch Mountain Wildlife Management Area, Saltville, VA)

Three main piles of grouse remains were recovered at the scene of this avian predation event in Ray Bottoms. The 1st consisted of neck and ruff feathers and the transmitter, the 2nd was a diffuse scattering of feathers on the ground as well as 10-15' up in a tree, and the 3rd was the actual carcass ~20' away underneath a slightly elevated log. Jason surmised this grouse was killed by the raptor. The head, neck and portions of its breast were consumed on the ground at the site of the ruff feathers and transmitter. The grouse was then taken to an elevated plucking/feeding site in a nearby tree (leaving a broadcast pattern of feathers in the 2nd pile) where more of the neck and remainder of the breast may have been consumed. The predator, or a scavenger deposited the remnants of the carcass under a horizontal log (~8" in diameter) in a space that was ~9" high.

Account of hawk kill by G. Bumann on Virginia 3 ACGRP study site 6/1/00

Jason Blevins heard hen 1.481 on mortality mode at 10am this morning. This was only a few days before here 3-week brood check. Her signal could only be heard from high in Twin

Hollows, which meant she is probably high up on the other side of the management area. After driving around, we followed the signal up the hollow to the north of Divide Hollow. The hollow branched and we went to the left. The signal could be heard very strong now on the cable though we were still several hundred meters away. Nearing the top of Red Rocks Mountain we came to a spot where the signal could be heard all the way around the dial. The trail of feathers was soon found oriented in the downhill direction. All of the evidence pointed to a raptor kill. There were 2 main piles of feathers with a feathered trail of ~9yds long between them. The pile on the uphill side appeared to be the impact site and the downhill 1 a plucking/feeding site. The carcass was not found and was probably carried off by the predator or a scavenger. The mortality site was near the ridge top in a mature sugar maple stand (*Acer saccharum*) on north-west aspect with a reasonable amount of herbaceous vegetation composed primarily of goldenrod (*Salidago spp.*) Solomon's Seals (*Polygonatum spp.*), and ferns. Overall the stand was very open and the herbaceous cover thin and patchy- great brood cover.

At the uphill 'impact' site, the predator appeared to have secured the hen and began processing the left, hind portion of her body. Nine tail feathers from left of center as well as, several rump and undertail coverts, semi-plumes and a few ventral contours were found here. All together the circle of debris was 1m across. Some lighter feathers were stuck to ferns and vegetation 3-5" off the ground. The fight/drag trail leading downhill was primarily semi-plumes with a couple ventral contours and rump feathers. One of the later had a small speck of blood on it. A few matted feathers were found on the convexity on the underside of a 2-3" stick denoting that the hen had in fact been dragged downhill and not up. Just uphill of the second pile of feathers the hen had been dragged underneath a stick that was 9" above the ground.

The lion's share of the feathers and the radio were at this lower site in an area of ~70cm. Nearly all of the primary wing feathers from the left and right sides were present, in addition to their coverts (upper mainly), rectrices from the right side of the tail and many ruff and neck feathers were present. Most of the feathers appeared to have been plucked by the kinks in the quill or the missing distal portion on some of the larger feathers. None had any flesh attached to the calamus.

The transmitter was found in the very center of the circle. The end of the antenna was bent into a "J" shape and there were 2 sub-parallel creases near the bend of the harness tubing. The age of the kill was not certain, though the overall feather remains appeared "matted," in Jason's opinion. No rain or other precipitation had fallen recently, but the ground was somewhat moist which may have accounted for the lack of fluffy feathers. All feathers were collected in 2 bags (for the uphill pile and the trail and the other for the downhill pile). A thorough search of the surrounding area did not reveal any more grouse remains.

### **Unknown or Miscellaneous causes of Death**

Account of window kill and house cat scavenging by Harry Spiker of Maryland DNR

After making an unusually long movement and into an urban area, the bird was detected on mortality mode. The radio signal was narrowed to an abandoned house. Apparently, the grouse flew into the second story window (which appeared to be broken from an outside impact) and fell to the ground amidst some shrubs and ~6" from the foundation. From there it looked as though a house cat found the carcass and began to feed on it. The breast muscle was entirely consumed and the sternum gnawed



Account of a hunter crippled grouse mortality by Jason Blevins, Field staff of A( GRP site VA 3 (Clinch Mountain Wildlife Management Area, Saltville, VA)

Hunters were observed walking the road between telemetry stations 200 and 201 on the day preceding the grouse recovery. The carcass was recovered ~1/4 of the way up the opposing ridge. Apparently it had been wounded, flew down across the hollow (a strait line distance of 0.25-0.3 mi and into an area of modest mountain laurel (*Kalmia latifolia*) undergrowth. The bird was found lying face down with wings outstretched as though it had expired in flight. Upon further investigation Jason found several lead pellets in the breast of the bird.

Account of unknown death by G. Bumann on Virginia 3 ACGRP study site 5/11/00

The last day hen 0.353 was known alive was on May 5<sup>th</sup> when Denny Martin flew over in the plane doing aerial telemetry. She was now on mortality mode on the rugged portion of the mountain on private land. Her signal was finally localized on a steep (~45°) northern slope after coming in from the other side of the mountain. The radio was found ~35 yds uphill from an abandon logging path in a clump of leaves and loose feathers just downhill of a deer trail that followed the contour. Next to the transmitter was a clump of neck and ruff feathers. None of the feathers appeared to be chewed, or plucked for that matter. All feathers were placed in a bag for later inspection. A trail of feathers led uphill from this point for ~50 yds. Feathers from the rump and belly regions were mixed in and under leaves, sticks and dead wood. The amount of disturbance and the fact that many of the feathers were in and under some leaves and structure suggested to us that the carcass was dragged uphill as opposed to down (where most of the material would have been found atop the duff layer). There were no tooth or beak marks on the radio though the last 2" of the antenna was bent at a 30° angle.

5/14/00- lab analysis of 0.353's remains. One hundred and ninety nine feathers were recovered from 0.353's mortality site (excluding the bunch from the ruff region that were stuck together). The vast majority of the feathers were from the belly and rump regions. Most of those were from the belly and consisted of contours and semiplumes (2/3 of all feathers by volume). Only 1 secondary feather from the left side was found. It had a small indentation on the upper side of the quill 7/8" from the end. Three wing coverts were collected: 1 of which was severely bent 1/3 of its length from the distal end and the vane on 1 side appeared damaged or worn. The ruff feathers were certainly broken away from the skin by some mechanical means. The base of the ruff quills are broken, though it is not at all clear whether they were sheered by the action of mastication or vigorous plucking. I will have to consider this an unknown predation event.

Account of harness related death by G. Bumann on Virginia 3 ACGRP study site 5/21/00

I could not hear 1.425, 1.882, or 0.044 from telemetry station 262 (an over look where nearly all collared grouse can be heard from). Upon driving to Twin Hollows I found 1.425 on mortality from telemetry station 205, in the direction of 206 (he was last heard on live transmission mode on 5/19). Driving around toward 206, I recovered 1.425 (an adult male) ~30' from the road surface in a 10-12 year old clearcut (dominated largely by fire cherry (*Prunus pensylvanica*)). His remains were recovered just above the road bank lying face down with his wings outstretched. Closer examination showed that a stick about the diameter of a pencil and 1 m long had worked its way up through the harness and made a single twist strangling the bird. His neck was bruised with a small tear in the skin on the back of his neck had lost a few neck feathers due to the abrasion of the harness. Judging by his position, I ascertained that he was walking uphill when the stick threaded through. Fighting the collar and stick the bird twisted

180° and choked. My guess is that he was not there long though there were 3 margined burying beetles (*Nicrophorus marginatus*) and several bottle flies (Calliphoridae) were present. I believe 1.425 died 1.5-2 days ago judging by the insect activity, mild odor of decay and state of rigor. The bird's wings, legs and neck were all relatively flexible (probably denoting a state shortly beyond rigor mortis) and its eyes were sunk in.

#### D. SCAVENGING AND MARKS TO TRANSMITTERS

Scavenging of grouse carcasses is a likely source of interference when assessing cause of death. Carcass longevity, defined as the time after which the predator stops feeding and a scavenger begins, is seldom greater than one week and is often only minutes or hours (Hewson 1981, Faanes 1987, Pain 1991, Hewson 1995, Travaini et. al 1998). Subsequent feeding on the carcass by animals other than the initial culprit will invariably leave sign contrary to former's identification. Observing the state of rigor, degree of blood and tissue desiccation, condition of body structure and feather quills among other clues (see Fine scale anatomy of kill) may help the observer to recreate a logical chronology of events.

Scavenging studies of other galliform species note that a significant number of carcasses deposited are removed within 3 days by larger mammals (Grondahl 1958, Dumke and Pils 1973). Waterfowl carcasses (n=50) exposed on land persisted an average of 1.5 days while those carcasses concealed by vegetation persisted an average of 3.3 days before being scavenged (Pain 1991). "Carcasses deposited along ditch banks, roadsides and fence lines were the first to be discovered by large scavengers (Dumke and Pils 1973)." The importance of recovering birds quickly can not be overstated.

Marks to the transmitter itself, though sometimes hard to interpret, can provide clues to diagnose grouse death. A hand lens can be very helpful here in reading sign on transmitters and skeletal material. Members of the ACGRP as well as Mike Fies (personal comm.) has noted in his studies of bobwhite (using necklace-style transmitters) that mammalian predators/scavengers will often chew the transmitter, harness and antenna in the process of feeding. This behavior often leaves indentations from the cusps of mammal teeth in the transmitter body and the epoxy backing. Sometimes the indentations can be quite severe, looking as though the transmitter became caught up in the fray only to become the focus of the animal's chewing. Chewing of the softer harness and antenna by mammals also shows cusp marks and the soft plastic coatings often become torn and ragged.

Avian predators will also leave their mark on transmitter units though these marks appear incidental compared to those of mammals. Marring patterns of the transmitter body are less pitted, as with mammals in favor of scratches or gouging. Avian marks to the harness tubing and antenna resemble slices or defined kinks. Pinch marks are commonly apparent and thought to reflect the biting of a raptors sharp beak. Where an isolated bite mark can be seen, the span between pinch marks may be a clue to the size of the predator. A feature of the antenna often attributed to avian predators is "stripping" of the antenna itself. Here it is thought that the wire is grasped in the beak and pulled, under pressure for a portion of its length. The resultant shape of the antenna resembles a corkscrew or spiral pattern. This has been likened to coiling holiday ribbons with a pair of scissors (Fies personal comm.). Mammals almost certainly produce the same coiled or kinked antenna but again, this will probably be associated tooth impression or ragged edges typical of mammals. Many times the transmitter alone will be found with scarcely a mark. Dumke and Pils (1973) noted that it is "common practice for mammalian predators to remove the transmitter (of pheasants) and drop it almost anywhere." Under these circumstances

Bumann

it is likely that the bird was decapitated the radio fell off before any predator specific marks could be deposited. The same could also be said for avian predators.

## E. TABLES FOR IDENTIFICATION OF PREDATOR SPECIES

I. Summary of Minimum Holes Sizes that Mammals Passed Through -adapted from Stullken and Kirkpatrick (1953).

Species	Weight ranges (lbs)	Minimum hole passed**	
		Rectangle	Circle
Virginia Opossum	2.5-4.5	51 x 64	70
Raccoon	9.5-10	76 x 89	89
Long-tailed weasel	100-200*	-	22
Mink	2.1	38 x 51	-
Striped Skunk	2.75-3.75	51 x 64	70
Red Fox	7-10.5	76 x 76	89
Gray Fox	7.75-9	57 x 83	84

\* weasel weight in grams

\*\* hole measurements in (mm x mm - diameter in case of circular holes)

II. Inter- K-9 measurements for select Mammalian Predators (measurements taken from specimens in Museum of Natural History at Virginia Tech, Blacksburg, VA) U= upper jaw measurement, L= lower jaw measurement, all measurements in millimeters

Raccoon ( <i>Procyon lotor</i> )								
		Male n= 3		Female n=1		unk. n=6		overall n= 10
min	U	23	U	17	U	20	U	17
	L	22	L	15	L	18	L	15
mean	U	23	U	17	U	23.4	U	22.6
	L	22	L	15	L	21.8	L	20.7
max	U	23	U	17	U	26	U	26
	L	22		15	L	24	L	24

<b>Long-tail Weasle (<i>Mustela frenata</i>)</b>						
		<b>male n=10</b>		<b>female n=5</b>		<b>overall n= 15</b>
<b>min</b>	<b>U</b>	5.5	<b>U</b>	5.5	<b>U</b>	5.5
	<b>L</b>	5.5	<b>L</b>	4	<b>L</b>	4
<b>mean</b>	<b>U</b>	7.3	<b>U</b>	5.9	<b>U</b>	6.8
	<b>L</b>	6.4	<b>L</b>	5	<b>L</b>	6
<b>max</b>	<b>U</b>	9	<b>U</b>	7	<b>U</b>	9
	<b>L</b>	7	<b>L</b>	6	<b>L</b>	7

<b>Mink (<i>Mustela vison</i>)</b>						
		<b>male n= 8</b>		<b>female n=7</b>		<b>overall n= 15</b>
<b>min</b>	<b>U</b>	10	<b>U</b>	9	<b>U</b>	5.5
	<b>L</b>	8	<b>L</b>	7.5	<b>L</b>	4
<b>mean</b>	<b>U</b>	10.5	<b>U</b>	9.4	<b>U</b>	10
	<b>L</b>	8.8	<b>L</b>	7.7	<b>L</b>	8.3
<b>max</b>	<b>U</b>	11	<b>U</b>	10	<b>U</b>	8.5
	<b>L</b>	9.5	<b>L</b>	8	<b>L</b>	9.5

Skunk ( <i>Mephitis mephitis</i> )							
		male n= 9		female n=5		unk. n=5	overall n= 19
<b>min</b>	U	13	U	12.5	U	14	12.5
	L	12	L	10.5	L	14	10.5
<b>mean</b>	U	14.9	U	13.8	U	15.8	14.8
	L	13.8	L	11.6	L	14	13
<b>max</b>	U	17.5	U	15	U	19	19
	L	16	L	13	L	14	16

Red Fox ( <i>Vulpes vulpes</i> )							
		male n= 6		female n=2		unk. n=7	overall n= 15
<b>min</b>	U	19	U	20	U	18.5	18.5
	L	17.5	L	18	L	16.5	16.5
<b>mean</b>	U	21.3	U	20.5	U	19.4	20.5
	L	18.8	L	18	L	18.2	18.4
<b>max</b>	U	24.5	U	21	U	22	24.5
	L	20	L	18	L	20	20

Gray Fox ( <i>Urocyon cinereoargenteus</i> )								
		male n=6		female n=2		unk. n=1		overall n= 9
min	U	18.5	U	19	U	14.5	U	14.5
	L	15	L	17	L	*	L	15
mean	U	19.5	U	19	U	14.5	U	18.5
	L	17.2	L	17	L	*	L	17.1
max	U	21	U	19	U	14.5	U	21
	L	19	L	17	L	*	L	19

<b>Coyote (<i>Canis latrans</i>)</b>						
		<b>male n= 1</b>		<b>female n=1</b>		<b>overall n= 2</b>
<b>min</b>	U	26	U	*	U	26
	L	25.5	L	28	L	25.5
<b>mean</b>	U	26	U	*	U	26
	L	5.5	L	28	L	26.8
<b>max</b>	U	26	U	*	U	26
	L	25.5	L	28	L	28

<b>Bobcat (<i>Lynx rufus</i>)</b>						
		<b>male n= 3</b>		<b>female n=1</b>		<b>overall n= 10</b>
<b>min</b>	<b>U</b>	20.5	<b>U</b>	19.5	<b>U</b>	19.5
	<b>L</b>	20	<b>L</b>	18.5	<b>L</b>	18.5
<b>mean</b>	<b>U</b>	25.4	<b>U</b>	22.1	<b>U</b>	24
	<b>L</b>	22.7	<b>L</b>	19.7	<b>L</b>	21.7
<b>max</b>	<b>U</b>	27.5	<b>U</b>	23.5	<b>U</b>	27.5
	<b>L</b>	26	<b>L</b>	20.5	<b>L</b>	26



### III. Scat Measurements from Select Mammalian Predators (adapted from Rezendes 1992)

Note: scat diameter is generally the most reliable measurement

Species	measurement
Weasel	1/8" x 1 1/4"
Mink	3/8" - 5/8" x 3"
Skunk	3/4" or more diam.
Raccoon	3/4" - 1" or more diam.
Coyote	3/4" or greater
Red or Gray Fox	3/4" or less
Bobcat	5/8" - 3/4"

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