

2009

Necklace-Type Transmitter Attachment Method for Ruffed Grouse Chicks

Christopher A. Dobony
West Virginia University

Brian W. Smith
West Virginia University

John W. Edwards
West Virginia University

Thomas J. Allen
West Virginia University

Follow this and additional works at: <https://trace.tennessee.edu/nqsp>

Recommended Citation

Dobony, Christopher A.; Smith, Brian W.; Edwards, John W.; and Allen, Thomas J. (2009) "Necklace-Type Transmitter Attachment Method for Ruffed Grouse Chicks," *National Quail Symposium Proceedings*: Vol. 6 , Article 50.

<https://doi.org/10.7290/nqsp06mdb2>

Available at: <https://trace.tennessee.edu/nqsp/vol6/iss1/50>

This article is brought to you freely and openly by Volunteer, Open-access, Library-hosted Journals (VOL Journals), published in partnership with The University of Tennessee (UT) University Libraries. This article has been accepted for inclusion in National Quail Symposium Proceedings by an authorized editor. For more information, please visit <https://trace.tennessee.edu/nqsp>.

Necklace-type Transmitter Attachment Method for Ruffed Grouse Chicks

Christopher A. Dobony¹, Brian W. Smith¹, John W. Edwards^{1,3}, Thomas J. Allen²

¹Division of Forestry and Natural Resources, West Virginia University, Morgantown, WV 26506-6125, USA

²West Virginia Division of Natural Resources, P.O. Box 67, Elkins, West Virginia, 26241, USA

Although methodologies to obtain cause-specific mortality and survival information for adult ruffed grouse (*Bonasa umbellus*) are well documented, procedures for determining similar parameters are lacking for grouse chicks. Mortality among grouse chicks is believed highest during the first few weeks posthatch. During 1999-2002, we equipped ruffed grouse chicks ($n = 97$) from 33 separate broods, ≤ 4 -days-old with radio transmitters to assess the efficacy of transmitters and to examine survival/mortality. Further, we observed that grouse chicks retained transmitters (100%) until recapture or mortality. Handling time was limited because transmitter attachment took only a few minutes per brood. We observed mortality fates for 91% of radio-collared chicks. Therefore, because of the non-intrusive nature, field application, and retention of necklace-style transmitters employed in this study, this method may provide a desirable alternative to assessing survival/mortality among ruffed grouse chicks.

Citation: Dobony CA, Smith BW, Edwards JW, Allen TJ. 2009. Necklace-type transmitter attachment method for ruffed grouse chicks. Pages 480 - 488 in Cederbaum SB, Faircloth BC, Terhune TM, Thompson JJ, Carroll JP, eds. Gamebird 2006: Quail VI and Perdix XII. 31 May - 4 June 2006. Warnell School of Forestry and Natural Resources, Athens, GA, USA.

Key words: *Bonasa umbellus*, necklace-type collar transmitter, ruffed grouse chicks, West Virginia

Introduction

Mortality in ruffed grouse (*Bonasa umbellus*) is thought to be highest during the first few weeks of life (Rusch et al. 1984, Bergerud 1988), but factors influencing chick survival are not well documented. Survival and cause-specific mortality are important components in population management. Grouse chick mortality/survival estimates are often derived from flush counts. Estimating chick numbers via flush counts in <2 -week-old broods, however, is highly unreliable (Larson et al. 2001). Although survival estimates and mortality causes of adult ruffed grouse can be readily obtained via radio telemetry (Godfrey 1975, Maxson 1977, 1978, Small et al. 1991), transmitter size and attachment methods have limited examination of these parameters for young ruffed grouse chicks.

Several methods of transmitter attachment have been used to study young gallinaceous birds including glue-on (Bowman et al. 2002, Spears et al. 2002), subcutaneous anchor (Mauser and Jarvis 1991), and

elastic harnesses (Peoples et al. 1995, Hubbard et al. 1998) on domestic and wild turkey (*Meleagris gallopavo*) poults, and interscapular implants on ring-necked pheasant (*Phasianus colchicus*) chicks (Ewing et al. 1994, Riley et al. 1998) and turkey poults (Korschgen et al. 1996, Hubbard et al. 1999, Bowman et al. 2002). Only a few telemetry studies of ruffed grouse chicks have been conducted. Larson (1998) and Larson et al. (2001) attached transmitters via interscapular implants or external suture technique to 6-day-old (mean 6.4 days, range 5-10 days) ruffed grouse chicks in Michigan. Similarly, Burkepile et al. (2002) used a suture technique to attach transmitters to 1-day-old sage grouse (*Centrocercus urophasianus*) in Idaho. Because of the diminutive size and mass of ruffed grouse chicks relative to sage grouse, the potential effects of transmitter mass (i.e., $>5\%$ transmitter to body mass ratio) and the intrusive nature and stress of the procedure on the animal are important considerations.

Subcutaneous interscapular implants are intrusive and require a sterile environment to reduce in-

³Correspondence: jedwards@wvu.edu

fection rate (Korschgen et al. 1996). Hubbard et al. (1998) found them to affect growth in wild turkey, although the long-term effects are unknown (Hubbard et al. 1998); however, no effect on wing growth was reported in domestic turkeys (Bowman et al. 2002). Wild turkey poults with interscapular implants and mallard (*Anas platyrhynchos*) ducklings with subcutaneous anchors exhibited short-term (2-4 hour) loss of balance and difficulty in walking (Mauser and Jarvis 1991, Bowman et al. 2002). Glue-on attachment of transmitters has been used successfully for turkey poults with no apparent effect on growth or survival, although retention time may be limiting (<29 d) for some applications (Bowman et al. 2002, Spears et al. 2002). Necrosis at the site of attachment has been found when using cyanoacrylate glue to retain transmitters (Burkepile et al. 2002).

As part of a ruffed grouse population ecology study, we wanted to examine survival and mortality of chicks from hatch to age 5 weeks. We were particularly interested in the period from 0-2 weeks posthatch. Because it has been suggested that ruffed grouse chicks exhibit high mortality rates during the first few weeks posthatch (Rusch et al. 1984), it is important to monitor chicks as early as possible while also minimizing capture- and transmitter-related stress (Caccamise and Hedin 1985, Dobony 2000). To minimize our influence on mortality, we selected an attachment method that was non-intrusive, could be attached in the field, and did not require extended periods of recovery or involve excessive handling time. Although successful in other studies (Bowman et al. 2002, Spears et al. 2002), our preliminary experience with glue-on transmitters was unacceptable. We chose to not use the external suture method described by Larson et al. (2001) because of its intrusive nature and our desire to monitor chicks <6 days old. We report on the development of a necklace-type transmitter for use on young ruffed grouse chicks. Our objective was to examine the efficacy of this method on ≤ 4 -day-old chicks and its usefulness in assessing mortality through age 5 weeks.

Study Area

From 1999-2002, we conducted research on ruffed grouse on the MeadWestvaco Ecosystem Research Forest (MWERF) located in Randolph County, West Virginia, and situated in the Allegheny Mountain physiographic province (Fenneman 1938). In 1999, we also used grouse chicks from the MeadWestvaco Dutch Run Tract (DRT) located in Greenbrier County, West Virginia, classified as part of the Ridge and Valley physiographic province (Fenneman 1938).

The 3,413 ha MWERF was established by Westvaco Corporation in 1994 to study industrial forestry impacts on ecosystems and their processes. MeadWestvaco managed the MWERF for forest products, and its oldest forests were second-growth stands established after harvests at the turn of the 20th century (Tilghman 1989, Clarkston 1993). MeadWestvaco managed stands on 40-80 year rotations depending on site characteristics and quality. Harvest methods included diameter-limit to remove valuable sawtimber as well as clearcut and deferment harvests (i.e., shelterwood harvest or clearcut with reserves) for stand regeneration. Elevations ranged from 740-1200 m and topography was rugged, with plateau-like ridgetops atop steep slopes and narrow valleys (Fenneman 1938, Ford and Rodrigue 2001). The MWERF was characterized by a cool, moist climate with average annual precipitation exceeding 198 cm (<http://www.nndc.noaa.gov>). Forest cover primarily was Allegheny hardwood-northern hardwood, mixed mesophytic or cove hardwood associations typical to the Allegheny Mountain physiographic province (Eyre 1980).

MeadWestvaco managed the 2,036 ha DRT strictly for fiber production by clearcutting on an even-aged rotation length of 40-70 years. DRT had a lower site index and received less annual precipitation (107cm; <http://www.nndc.noaa.gov>) than the MWERF. Elevations ranged from 520-1100 m and topography was extremely steep and rugged with ephemeral seeps and streams throughout. Forest cover was primarily oak-hickory associations

(94%) typical of the Ridge and Valley physiographic province (Eyre 1980).

Methods

Trapping and Monitoring Females

We trapped adult ruffed grouse in fall 1998 and spring 1999 using modified lily-pad traps (Gullion 1965). Once captured, we weighed, aged and sexed (Kalla and Dimmick 1995), and tagged each bird with an aluminum leg band (#12 butt-end tags, National Band and Tag, Newport, KY). We also equipped each female with a necklace-type radio transmitter (Advanced Telemetry Systems, Isanti, MN; multiple models were used through the course of the study). Transmitters weighed 10-11 g, had a 2-year battery life, and were equipped with a motion-sensitive mortality sensor.

After release, we monitored radio-marked females twice weekly using a 2-element Yagi antennae and portable receiver (Wildlife Materials, Carbondale, IL, and Advanced Telemetry Systems, Isanti, MN). Beginning 1 March, we monitored females 3 times weekly to accurately determine nest initiation. We obtained azimuths from permanently located global positioning system telemetry stations and grouse locations [mean bearing error and linear error: 7 and 76 m, respectively (Whitaker 2003)] were determined through triangulation (Mech 1983). As the nesting and breeding seasons progressed, we used triangulation and homing techniques to find nest sites (Mech 1983). After locating nests, we obtained at least 2 egg counts by either flushing females from their nests or counting eggs while nests were unattended; one count occurred during egg laying (if found in time) and one during incubation. We used this information to predict hatch dates (i.e., by backdating to when the last egg was laid) and to determine maximum number of potential chicks per brood.

Capturing and Radio-marking Chicks

We randomly selected broods to equip with radio transmitters. We located broods within 24-48 hours posthatch by homing the female's telemetry

signal (Mech 1983). We approached females' locations (<20 m) as quickly as possible to discourage them from hiding chicks and leading us away from broods. We tried not to flush females until we were close enough to easily locate and capture the brood. Once females had flushed, we immediately stopped to avoid trampling unseen chicks and each person captured any chicks that came towards them. We assumed that the potential number of chicks available for capture to be the number of hatched eggs present in the nest. We often located unseen chicks by contact calls they made to females. We captured as many brood members as possible, as quickly as possible, and then carefully moved a short distance away to process the brood (i.e., weigh, affix transmitter) into an area where we were confident no chicks were present. We placed those chicks we captured into a soft fabric bag until fully processed. Handling time for each brood did not exceed 15 minutes post-capture. All chicks (radioed and non-radioed) were released at the capture site after which we immediately vacated the area to allow females to gather broods. All broods were captured between 1000 and 1400 hours and we postponed brood captures if poor weather conditions threatened.

In 1999, we captured chicks 2-3 days posthatch, weighed each individual, and randomly selected chicks from each brood to receive transmitters. Necklace-type transmitters (model MD-2CT; Holohil Systems Ltd., Ontario, Canada) weighed 0.98 g (approximately 7-8% of the body weight at time of attachment) and had a 5-week battery life (Figure 1). We used necklaces made of polyethylene tubing used in arterial surgery (Intramedic Clay Adams Brand, Sparks, MD) that initially had 26 mm circumference loops, but we later increased loop-size to 32 mm (Dobony 2000). We placed monofilament fishing line (2.7-kg test) inside the tubing and knotted it to secure the necklace; we further secured knots with glue formulated especially for monofilament (Anglin' Glue, Clemence Inc., Alpharetta, GA). Numbers of radio-marked chicks per brood ranged from 1-5 depending on numbers of chicks we captured per brood and overall brood size. We



Figure 1: Ruffed grouse chick with necklace-type transmitter attachment method implemented on the MeadWestvaco Ecosystem Research Forest in Randolph County, West Virginia and the MeadWestvaco Dutch Run Tract in Greenbrier County, West Virginia in 1999-2002.

censored chicks that died during the first 24 hours post-release.

In 2000-2002, we slightly modified our transmitter procedures. Upon capture at 2-4 days posthatch, we attached modified necklace-type transmitters (model BD-2A) that weighed 0.54 g, had a 3-week battery life, and had necklaces 42 mm in circumference. The transmitters were configured in the same style as model MD-2CT and attached similarly. Changing transmitter models allowed us to stay within the 5% transmitter to body mass ratio during the first week.

Monitoring Females and Broods

We monitored female grouse and their broods ≥ 1 time per day, typically <2 hours after sunrise and <2 hours before sunset each day. We determined brood locations via triangulation of females' telemetry signals. We then approached the female (usually to within 150 m) and took azimuths on each chick. For chicks not in close proximity to the female, we attempted to retrieve lost chick(s), transmitter(s), or

both. We examined all remains for cause of death and performed necropsies if the immediate cause of death could not be determined.

In 2000 and 2001 we conducted 3- and 5-week brood flush counts of all radio-collared females, which included both broods with transmitted chicks and broods in which no chicks were marked. We estimated brood sizes by locating females via telemetry and flushing broods to make an ocular estimate of chick numbers. We considered this a minimum estimate of brood size. We performed no statistical comparison of means, however, because collared and uncollared broods received different levels of disturbance. We captured collared broods at least twice (i.e., to affix initially, replace at 2 weeks posthatch, or remove collars) depending on survival, whereas uncollared broods were never captured. Therefore, we only provide mean ($\pm SE$) number of chicks per brood at 3- and 5-week flush counts and not statistical comparison of means.

Recapturing Chicks

In 1999, we recaptured radio-collared chicks at 2 weeks posthatch and replaced each collar with one that had a necklace circumference of 52 mm or increased the circumference on the existing collar to allow for growth. We recaptured chicks at 5 weeks posthatch to remove collars. Because chicks retained necklace-type transmitters, we were able to find them via their telemetry signal. If flushed, chicks usually flew only short distances and hid. Once hidden, grouse chicks tend not to move and we easily captured them by hand. When capturing older chicks, we again took care to avoid trampling unmarked chicks. After replacing collars, we returned chicks to where we had flushed them initially and immediately left the area.

In 2000-2002, we again recaptured radio-collared chicks at 2 weeks posthatch and replaced 3-week transmitters with model MD-2CT transmitters (0.98 g, 5-week battery life) that had 52 mm necklaces. This allowed us to reliably track chicks for the 5-week period and accommodate for rapid growth in ruffed grouse chicks. All handling procedures were approved and conducted under West Virginia University's Animal Care and Use Committee protocol 01-0405.

Results

In 1999, we captured 55 chicks from 10 broods (6 at MWERF, 4 at DRT) within 72 hours posthatch. We equipped 35 of the 55 chicks (20 at MWERF, 15 at DRT) with modified necklace-type transmitters. Chicks weighed 12.9 ± 0.2 g (mean $\pm$ SE, $n = 35$; range = 11.4-15.7 g) upon initial capture. From 2000-2002, we captured 86 chicks from 23 broods within 96 hours posthatch on the MWERF. We equipped 62 of 86 chicks with necklace-type transmitters. Chicks selected to receive radio transmitters weighed 14.8 ± 0.3 g (mean $\pm$ SE, $n = 62$; range = 11.2-21.2 g) upon initial capture. We released all chicks within 15 minutes of each capture.

All chicks marked during 1999-2002 retained their transmitters throughout the 5-week posthatch sampling period or until death. We were able to

determine fates of 88 of 97 (91%) of radio-collared chicks. All chicks ($n = 22$) surviving 9-14 days were successfully recaptured to adjust necklace circumferences or replace transmitters. Of these, five reached 35 days posthatch and were recaptured to remove their transmitters. Transmitter-related mortality decreased from 38% (11 of 29 known mortalities) during our initial field season in 1999 to 8% (3 of 40 known mortalities) during 2000-2002. Ocular brood size estimates between collared and uncollared broods were similar within 3- and 5-week flush counts in 2000 and 2001 (Table 1). However, we performed no statistical comparison of means because collared and uncollared broods received different levels of disturbance (e.g., uncollared broods were never captured whereas collared broods were captured twice).

Discussion

Our objective was to develop a transmitter attachment method for ruffed grouse chicks that (1) was non-intrusive, (2) could be completed in the field, (3) did not require an extended period of recovery or involve excessive handling time, and (4) would be retained by the animal throughout the focal period (i.e., 0-5 weeks). Our goal in meeting these criteria was an attachment method that minimized anthropogenic influence while enabling assessment of cause-specific mortality.

Dobony (2000) first used our method in 1999 but found that the necklace circumference required refinement. Rapid growth of ruffed grouse chicks made it difficult to predict what circumference to initially make the necklace in 1999, as well as what circumference was needed at 2 weeks posthatch. The necklace had to be snug enough to prevent chicks from getting their beaks or feet caught, but also had to allow for passage of food items. Dobony (2000) reported that several chicks died in 1999 after ingesting terrestrial snails, which were too large and rigid to pass below the necklace. This resulted in the 38% transmitter-related mortality rate we report for 1999. Enlargement of the necklace circumference used for 0-2-week-old chicks from 34 to 42 mm remedied this

Table 1: Mean ($\pm$ SE) number of ruffed grouse chicks observed at 3- and 5-week flush counts of radio-collared broods and broods that did not receive radio collars on the MeadWestvaco Research Forest, West Virginia, 2000-2001. Number of broods is in parentheses.

		Year	
		2000	2001
<i>3-week estimates</i>			
Collared broods	(6) 1.67 ± 0.56	(8) 3.10 ± 0.55	
Uncollared broods	(3) 1.67 ± 1.20	(4) 2.00 ± 1.08	
<i>5-week estimates</i>			
Collared broods	(5) 1.60 ± 0.67	(6) 2.00 ± 0.55	
Uncollared broods	(3) 1.00 ± 0.58	(9) 1.30 ± 0.47	

problem and contributed to the substantial decrease in transmitter-related deaths recorded during 2000-2002.

Transmitters we placed on ≥ 3 -day-old chicks were approximately 7-8% of their body mass in 1999, while in 2000-2002 the transmitters were $< 5\%$. Typically the transmitter to body mass ratio rule-of-thumb has been $< 5\%$. This is often associated with birds that have the stress of flight (Caccamise and Hedin 1985, Brigham 1989). However, ruffed grouse chicks do not fly until 4-5 days old, and then may fly only short distances. They are physically unable to fly longer distances until their flight feathers have developed. By this time, rapid growth has quickly decreased the transmitter to body mass ratio (Speake et al. 1985). Mauser and Jarvis (1991), Mauser et al. (1994), and Davis et al. (1999) found no effect on survival in ducklings when using transmitters weighing 5-7% of body mass. Speake et al. (1985) placed transmitters on turkey poults that weighed approximately 6% of the body mass and found no impact on survival. To further alleviate any concerns of transmitter mass on survival, we used smaller 0.54 g radio transmitters for the first 2 weeks posthatch in 2000-2002 and replaced them with 0.98 g transmitters for the remaining 3 weeks.

Our brood flush count estimates for 2000-2001

provide limited support that transmitters had minimum influence on chick survival through 5-weeks posthatch. We found 3- and 5-week flush counts appeared similar between collared and uncollared broods. Collared broods at 3- and 5-week flush counts had more chicks per brood on average than did uncollared broods, despite a greater level of disturbance (note: simple comparison only; no statistical comparison of means performed). Such low brood counts - although indicative of higher rates of mortality than commonly reported in other parts of the range - are similar to those found in the central Appalachian region (Haulton 1999, Devers 2006, Smith 2006). Flush counts have been criticized for producing biased estimates of chick numbers (Godfrey 1975). However, presence of such bias in our estimates would not negate support for minimum transmitter influence because our 3- and 5-week flush count protocol was consistent between collared and noncollared broods.

Our 100% transmitter retention until recapture or death provided mortality fates for 91% of radio-collared chicks. Because the transmitter was firmly attached around the chick's neck, predators had to either expend more effort to remove the transmitter (thus leaving teeth marks, beak impressions, bent antennas), or consume the transmitter with the chick

(thus allowing the transmitter to show up in scat or pellets). In 3 instances, we located transmittered chicks that were taken to nest sites and fed to nestling hawks. Only chicks whose transmitter apparently failed or was destroyed could not be assigned a fate.

A possible concern with our necklace-type transmitter is the necessity to recapture chicks at approximately 2-weeks posthatch to replace transmitters, and then again at 5-weeks to remove transmitters. Failure to remove the transmitter would result in the death of the chick. We were successful in capturing all candidate chicks at 2- (9-14 days) and 5-weeks posthatch. When flushed, chicks usually flew only short distances (even up to 5 weeks of age) and hid. Once hidden, chicks tended not to move and were easily captured by hand without harm and replacement of the smaller transmitters typically took 10-15 minutes per brood.

Although radio telemetry is the most reliable method for determining timing and extent of mortality and survival (Korschgen et al. 1996), it is important to ensure that transmitters and attachment methods have minimal effect. Our method allowed us to attach transmitters in the field, minimized our handling time, and did not involve subcutaneous implantation, removal of feathers to apply adhesive, or suturing of any kind. Moreover, our necklace-type transmitter allowed us to begin monitoring 2-4 days earlier in the first week posthatch than methods previously described. Because of its use on younger chicks, non-intrusive nature, field application, and retention time, our necklace-type transmitter may provide a desirable alternative to assessing mortality/survival among ruffed grouse chicks.

Acknowledgments

Our study was conducted as part of the Appalachian Cooperative Grouse Research Project and was supported in part by West Virginia Division of Natural Resources (Pittman-Robertson Federal Aid in Wildlife Restoration Project W-48-R) and the Division of Forestry and Natural Resources, West Virginia University. We thank the Richard King Mel-

lon Foundation and The Ruffed Grouse Society for additional funding and MeadWestvaco Corporation for logistical support. We thank the following individuals for their support: M. Banker, B. Chandler, D. Dessecker, M. Ford, P. Keyser, R. Kirkpatrick, T. Lail, J. Organ, M. Seamster, D. Samuel, T. Sharpe, R. Tucker, J. Vose, and M. Watson. Additionally, we thank N. Herbert, J. Johnson, M. Kollaros, C. Langdon, D. Leput, T. Olexa, R. Smith, and S. Sutton for assistance with fieldwork.

References

- Bergerud, A. T. 1988. Mating systems in grouse. Pages 439-472 in A. T. Bergerud and M. W. Gratson, editors. Adaptive strategies and population ecology of northern grouse. University of Minnesota Press, Minneapolis, MN, USA.
- Bowman, J., M. C. Wallace, W. B. Ballard, J. H. Brunjes, IV, M. S. Miller, and J. M. Hellman. 2002. Evaluation of two techniques for attaching radio transmitters to turkey poults. *Journal of Field Ornithology* 73:276-280.
- Brigham, R. M. 1989. Effects of radio transmitters on the foraging behavior of barn swallows. *Wilson Bulletin* 101:505-506.
- Burkepile, N. A., J. W. Connelly, D. W. Stanley, and K. P. Reese. 2002. Attachment of radiotransmitters to one-day-old sage grouse chicks. *Wildlife Society Bulletin* 30:93-96.
- Caccamise, D. F., and R. S. Hedin. 1985. An aerodynamic basis for selecting transmitter loads in birds. *Wilson Bulletin* 97:306-318.
- Clarkston, R. B. 1993. Destruction of the upland forests by lumbering and fire. Pages 35-46 in S. L. Stephenson, editor. Upland forests of West Virginia. McClain Printing Co., Parsons, WV, USA.
- Davis, J. B., D. L. Miller, R. M. Kaminski, and M. P. Vrtiska. 1999. Evaluation of a radio transmitter for wood duck ducklings. *Journal of Field Ornithology* 70:107-113.
- Devers, P. K. 2006. Population ecology of and the effects of hunting on ruffed grouse (*Bonasa umbellus*) in the southern and central Appalachians. Ph.D. thesis, Virginia Polytechnic Institute and State University, Blacksburg, VA, USA.
- Dobony, C. A. 2000. Factors influencing ruffed grouse productivity and chick survival in West Virginia. Ph.D. thesis, West Virginia University, Morgantown, WV, USA.

- Ewing, D., W. Clark, and Pvochs. 1994. Evaluation of implanted radio transmitters in pheasant chicks. *Journal of the Iowa Academy of Science* 101:86–90.
- Eyre, F. H. 1980. Forest cover types of the United States and Canada. Society of American Foresters, Washington D. C., USA.
- Fenneman, N. M. 1938. Physiography of eastern United States. McGraw-Hill, New York, NY, USA.
- Ford, W. M., and J. L. Rodrigue. 2001. Soricid abundance in partial overstory harvests and riparian areas in an industrial forest landscape of the central Appalachians. *Forest Ecology and Management* 152:159–168.
- Godfrey, G. A. 1975. Underestimation experienced in determining ruffed grouse brood size. *Journal of Wildlife Management* 39:191–193.
- Gullion, G. W. 1965. Improvements in methods for trapping and marking ruffed grouse. *Journal of Wildlife Management* 29:109–116.
- Haulton, G. S. 1999. Ruffed grouse natality, chick survival, and brood micro-habitat selection in the southern Appalachians. Ph.D. thesis, Virginia Polytechnic Institute and State University, Blacksburg, VA, USA.
- Hubbard, M. W., D. L. Garner, and E. E. Klaas. 1999. Wild turkey poult survival in southcentral Iowa. *Journal of Wildlife Management* 63:199–203.
- Hubbard, M. W., L. L. C. Tsao, E. E. Klaas, M. Kaiser, and D. H. Jackson. 1998. Evaluation of transmitter attachment techniques on growth of wild turkey poults. *Journal of Wildlife Management* 62:1574–1578.
- Kalla, P. I., and R. W. Dimmick. 1995. Reliability of established aging and sexing methods in ruffed grouse. *Proceedings of the Annual Conference of Southeastern Fish and Wildlife Agencies* 49:580–593.
- Korschgen, C. E., K. P. Kenow, W. L. Green, M. D. Samuel, and L. Sileo. 1996. Technique for implanting radio transmitters subcutaneously in day-old ducklings. *Journal of Field Ornithology* 67:392–397.
- Larson, M. A. 1998. Nesting success and chick survival of ruffed grouse (*Bonasa umbellus*) in northern Michigan. Ph.D. thesis, Michigan State University, East Lansing, Michigan.
- Larson, M. A., M. E. Clark, and S. R. Winterstein. 2001. Survival of ruffed grouse chicks in northern Michigan. *Journal of Wildlife Management* 65:880–886.
- Mauser, D. M., and R. L. Jarvis. 1991. Attaching radio transmitters to 1-day old mallard ducklings. *Journal of Wildlife Management* 55:488–471.
- Mauser, D. M., R. L. Jarvis, and D. S. Gilmer. 1994. Survival of radio-marked mallard ducklings in northeastern California. *Journal of Wildlife Management* 58:82–87.
- Maxson, S. J. 1977. Activity patterns of female ruffed grouse during the breeding season. *Wilson Bulletin* 89:439–454.
- Maxson, S. J. 1978. Spring home range and habitat use by female ruffed grouse. *Journal of Wildlife Management* 42:61–71.
- Mech, L. D. 1983. Handbook of animal radio-tracking. University of Minnesota Press, Minneapolis, MN, USA.
- Peoples, J. C., D. C. Sisson, and D. C. Guynn, Jr. 1995. Mortality of wild turkey in coastal plain pine forests. *Proceedings of the Annual Conference of Southeastern Fish and Wildlife Agencies* 49:448–453.
- Riley, T. Z., W. R. Clarke, D. E. Ewing, and P. A. Vohs. 1998. Survival of ring-necked pheasant chicks during brood rearing. *Journal of Wildlife Management* 62:36–44.
- Rusch, D. H., S. Destefano, and R. J. Small. 1984. Seasonal harvest and mortality of ruffed grouse in Wisconsin. Pages 137–150 in W. L. Robinson, editor. *Ruffed grouse management: State of the art in the early 1980's*. The North Central Section of the Wildlife Society and The Ruffed Grouse Society.
- Small, R. J., J. C. Holzworth, and D. H. Rusch. 1991. Predation and hunting mortality of ruffed grouse in central Wisconsin. *Journal of Wildlife Management* 55:512–520.
- Smith, B. W. 2006. Nesting ecology, chick survival, and juvenile dispersal of ruffed grouse (*Bonasa umbellus*) in the Appalachians Mountains. Ph.D. thesis, West Virginia University, Morgantown, WV, USA.
- Speake, D. W., R. Metzler, and J. McGlincy. 1985. Mortality of wild turkey poults in northern Alabama. *Journal of Wildlife Management* 49:472–474.

Ruffed Grouse Necklace Transmitters

- Spears, B. L., W. B. Ballard, M. C. Wallace, R. S. Phillips, D. H. Holdstock, J. H. Brunjes, R. Applegate, P. S. Gipson, M. S. Miller, and T. Barnett. 2002. Retention times of miniature radiotransmitters glued to wild turkey poults. *Wildlife Society Bulletin* 30:861–867.
- Tilghman, N. G. 1989. Impacts of white-tailed deer on forest regeneration in northwestern Pennsylvania. *Journal of Wildlife Management* 53:524–532.
- Whitaker, D. M. 2003. Ruffed grouse (*Bonasa umbellus*) habitat ecology in the central and southern Appalachians. Ph.D. thesis, Virginia Polytechnic Institute and State University, Blacksburg, VA, USA.