SURVIVAL OF RUFFED GROUSE CHICKS IN NORTHERN MICHIGAN

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Abstract: Knowledge of the survival rates of ruffed grouse (*Bonasa umbellus*) chicks during the predispersal period is necessary for effective population management. We marked 76 ruffed grouse chicks using 2 radiotransmitter attachment procedures to determine the chick survival rate. Chick survival from near hatching (9–14 Jun) to fall dispersal (7 Sep) was 0.285 (SE = 0.098) in 1996 and 0.318 (SE = 0.087) in 1997. These rates were considerably lower than previous survival estimates for ruffed grouse chicks. Suturing transmitters externally was preferred over implanting them. Avian predators were the leading cause of chick mortality. Therefore, managers should consider the densities of avian predators when defining objectives for ruffed grouse recruitment.

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Survival of adults and juveniles from fall to spring plays a key role in population fluctuations of ruffed grouse. The importance of chick survival during summer, however, also has been recognized (Gullion 1970). A better understanding of production and recruitment in ruffed grouse populations has been limited by traditional methods of investigation. For example, the number of juveniles per adult in the fall population is a common recruitment index for ruffed grouse (Dorney and Kabat 1960, Stoll 1980). This ratio, however, may not be sensitive to annual population fluctuations (Stoll 1980), and "without knowledge of spring grouse densities, the fall age ratio may be as much an indicator of annual survival as of production" (Davis and Stoll 1973:139). Furthermore, the relationship between a recruitment index and true juvenile density is unknown because it is difficult to quantify and account for the potential bias toward juveniles in sampling procedures, such as trapping and hunter harvest (Rusch and Keith 1971, Johnson 1994:426).

Direct measures of chick production—necessary for developing predictive models of population dynamics—have been used for analyses of ruffed grouse demography. Porath and Vohs (1972) compared the density of adults at the beginning of the breeding season to the density of adults and chicks on 15 July to measure ruffed grouse production. Counts conducted by flushing broods also have been used to measure the abundance of ruffed grouse chicks (Ammann and Ryel 1963) and to estimate chick survival (Rusch and Keith 1971). Godfrey (1975*a*) and Kubisiak (1978), however, indicated that flush counts underestimate brood size in ruffed grouse, especially early in the brood-rearing period. Brood flush counts likely are biased because the probability of sighting individuals or entire broods changes between surveys because of variability in many factors, including the density of vegetation, the ability of hens to avoid observers, and the age of chicks, which affects how widely a brood ranges from the hen and the likelihood of a chick flushing (Healy et al. 1980). Apparent exchange of chicks between broods with overlapping ranges (brood mixing) and the failure to account for total brood loss also may render brood size estimates based on flush counts unreliable.

We are not aware of any application of advanced census techniques for ruffed grouse chicks that address or avoid the 20-year-old criticisms of traditional age ratio indices and flush counts. Advances in radiotracking technology presented an opportunity to increase our understanding of ruffed grouse brood ecology. Transmitters that allow researchers to monitor the movements and survival of wildlife for several months can be made sufficiently small (1.3 g) to be carried by ruffed grouse chicks during the period between hatching and dispersal of broods in the fall.

We designed this study to mark individual ruffed grouse chicks with radiotransmitters. Our main objective was to estimate the survival of ruffed grouse chicks from near hatching to fall dispersal. Second, we compared 2 transmitter attachment methods and identified sources of ruffed grouse chick mortality.

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STUDY AREA

We conducted our study in the northern portion of the lower peninsula of Michigan, USA. Study sites were located in the Huron National Forest (HNF; 44°32′N latitude, 83°58′W longitude) and Pigeon River Country State Forest (PRCSF; 45°11′N latitude, 84°26′W longitude). Each study site covered approximately 200 km^2.

The HNF site was dominated by stands of aspen (*Populus tremuloides* and *P. grandidentata*). Young (1–10 years old), medium-aged (11–29 years old), and old (≥30 years old) aspen stands constituted approximately 6, 27, and 13% of the HNF site (Gormley 1996:24), had mean woody stem (≥0.9 m tall) densities of 16,030, 11,870, and 4,270 stems/ha, and mean canopy heights of 3.9, 8.1, and 12.7 m, respectively (Gormley 1996:80). Stands of upland hardwoods (e.g., *Acer* spp., *Betula papyrifera, Fagus grandifolia*) constituted 17% of the HNF site, were all >30 years old, and had a mean of 4,530 stems/ha and a mean canopy height of 12.2 m. Stands of oaks (*Quercus* spp.) constituted 15% of the HNF site and had a mean of 6,740 stems/ha and a mean canopy height of 9.3 m. Lowland hardwoods (e.g., *Alnus incana*) covered only 1% of the HNF site (mean stem density = 19,390 stems/ha, mean canopy height = 4.4 m), whereas conifers covered 17% (Gormley 1996:24).

The PRCSF site had similar vegetation due to its proximity to HNF (approx. 100 km), but differences existed in the overstory composition. Young, medium-aged, and old aspen stands constituted approximately 9, 13, and 8% of the PRCSF site (Gormley 1996:24) and had mean stem densities of 12,790, 7,150, and 5,070 stems/ha and mean canopy heights of 2.9, 6.7, and 8.6 m, respectively (Gormley 1996:90). Stands of upland hardwoods constituted 22% of the PRCSF site, had a mean of 3,450 stems/ha, and had a mean canopy height of 10.3 m. Lowland hardwoods covered 6% of the PRCSF site (mean stem density = 22,180 stems/ha, mean canopy height = 6.6 m), whereas pine (e.g., *Pinus resinosa, P. strobus*) stands >30 years old and lowland conifers (e.g., *Thuja occidentalis, Abies balsamea*) covered 17% and 16% of the site, respectively. Oak stands were essentially absent from the PRCSF site (Gormley 1996:24). Ruffed grouse brood habitat at the HNF and PRCSF sites exhibited characteristics similar to those described by others in the northern United States (Bump et al. 1947, Godfrey 1975*b*, Kubisiak 1978, Maxson 1978*a*).

Red-tailed hawk (*Buteo jamaicensis*), broad-winged hawk (*Buteo platypterus*), and Cooper's hawk (*Accipiter cooperii*) were the most frequently seen avian predators on the study sites. Other avian predators likely to prey on ruffed grouse also were present (e.g., northern goshawk [*Accipiter gentilis*] and barred owl [*Strix varia*]). Mammalian predators on the study sites included red fox (*Vulpes vulpes*), coyote (*Canis latrans*), and bobcat (*Felis rufus*).

METHODS

We located nests in the spring of 1996 and 1997 by monitoring hens that had been radiocollared as juveniles (2–4 mo old) or adults (>13 mo old) the previous fall. We used a modified version of the cloverleaf traps described by Dorney and Mattison (1956) to capture hens (see Clark 1996 for details of fall trapping methods). Nesting attempts were monitored through completion. When broods from successful nests were approximately 6 days old, they were approached by following the hen's radio signal, and as many chicks as possible within a brood were collected by hand. Captured chicks were transported (<0.8 km) to a field vehicle. They were weighed, positioned on a hot water bottle, and held by an assistant during transmitter attachment. We used crystal-controlled, 2-stage transmitters that had a 12-week battery and weighed 1.25–1.33 g (model BD-2G, Holohil Systems, Ltd., Carp, Ontario, Canada) to individually mark chicks.

We used 2 different transmitter attachment procedures. In the first procedure, we implanted the transmitter just beneath the skin in the interscapular region. We used the surgical procedures described by Korschgen et al. (1996), except that we did not anesthesize the grouse chicks. We wet the down at the base of the neck with chlorohexidine diacetate solution (Nolvasan Solution, Aveco Co., Fort Dodge, Iowa, USA) and made an 8-mm incision along the dorsal midline using a scalpel. We used a stainless steel tube (0.1 × 8 cm) to thread the transmitter antenna under the skin from the incision to an exit site just above the tail. Then we used the antenna to pull the body of the transmitter into position beneath the skin and completely posterior to the incision. We closed the incision with 2 mattress stitches using absorbable suture material. Implanted transmitters had a mass of 1.25 g and were 16 × 8 × 5 mm in size.

In the second procedure, we attached transmitters externally by sutures to the interscapular

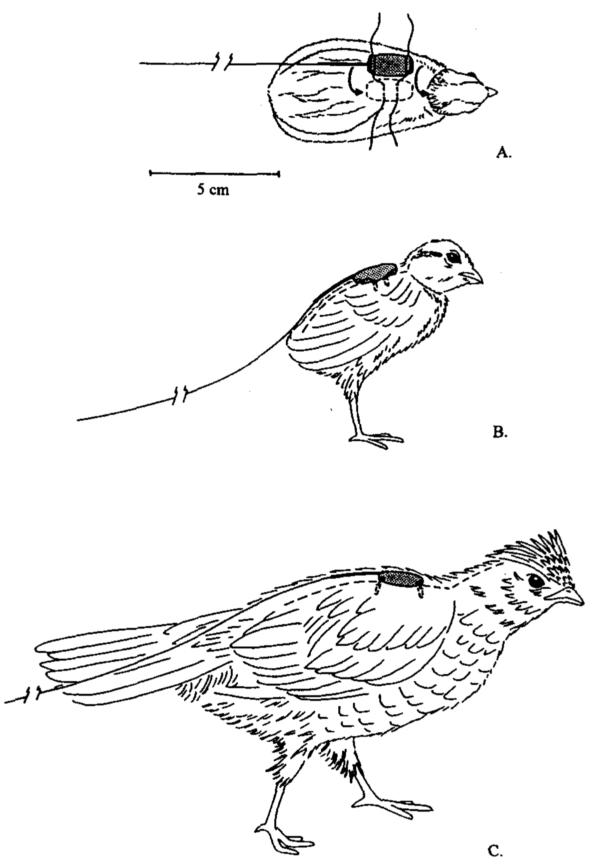

Fig. 1. Schematic drawing of ruffed grouse chicks with externally sutured radiotransmitters. A. Dorsal view of suture material being passed through the tubes and under the skin before the transmitter is flipped over into the proper position (dashed line). B. Lateral view of a 6- to 8-day-old chick with an external transmitter. C. A 10-week-old chick showing that the suture points are allowed to grow apart longitudinally.

region. The transmitters were manufactured with 2 tubes to contain the suture material (Fig. 1). External transmitters had a mass of 1.33 g and were only slightly longer (18 mm) than the implants. Unwaxed dental floss was passed through each tube and then under approximately 5 mm of the chick's skin using a suture needle. The points where the 2 sutures were passed under the skin were half as far apart as the tubes on the transmitter to allow for significant chick growth before the sutures would pull out (Fig. 1). Livestock identification tag cement (Nasco, Fort Atkinson, Wisconsin, USA) was applied to the ventral surface of the transmitter to secure it until the sutures healed. Each suture loop was tied, and the knots were reinforced with glue.

In 1996, each transmitter attachment procedure was used an approximately equal number of times in each brood. In 1997, only the external suture technique was used. Radiomarked chicks were returned to their brood as soon as possible and placed directly with unmarked chicks. Marked chicks were located by triangulation 3–6 times per week. They were approached on foot for visual observation only if they were not with a radiomarked hen or brood mate and were in the same place where they were last located. When we detected a mortality >1 day after the last time the chick was located alive, we assumed that the date of mortality occurred at the midpoint between the 2 events. We used the same method to estimate dates of censoring. Any remains of dead chicks were collected and sent to a forensic laboratory. The results of a necropsy, the condition of the transmitter, and predator signs at the collection site were used to determine the cause of mortality when feasible. A more detailed description of field methods was given by Larson (1998).

Survival probabilities for the radiomarked grouse chicks were calculated using the Kaplan–Meier product limit estimator (Kaplan and Meier 1958) with the staggered entry design (Pollock et al. 1989). Each year, we defined time = 0 as the day the first transmitter was attached. We estimated the survival rate through 7 September because that is when ruffed grouse broods at this latitude begin to break up and chicks become independent juveniles (Godfrey and Marshall 1969). Chicks that died ≤3 days after transmitter attachment and either showed signs of stress (i.e., carcass recovered with no evidence of trauma or malnutrition) or suffered minor accidental trauma during capture and handling were not included in survival or cause-of-mortality analyses. Survival rates were compared between years and between chicks with implanted and external transmitters using the log-rank test (Pollock et al. 1989).

Marked chicks within the same brood may not have been independent, which would violate an assumption of the Kaplan–Meier estimator. Although this would not introduce bias to the survival estimates, it would artificially reduce the variance of the survival rate (Pollock et al. 1989). Therefore, we verified the measures of variance from the Kaplan–Meier procedure for our smallest and largest data sets with standard errors estimated using 100 bootstrap samples (Efron and Tibshirani 1993:45–53, Flint et al. 1995).

RESULTS

During 1996, 13 implants and 13 external transmitters were placed on 26 chicks from 8 broods. Three marked chicks (1 with an implant and 2 with external transmitters) moved to broods with

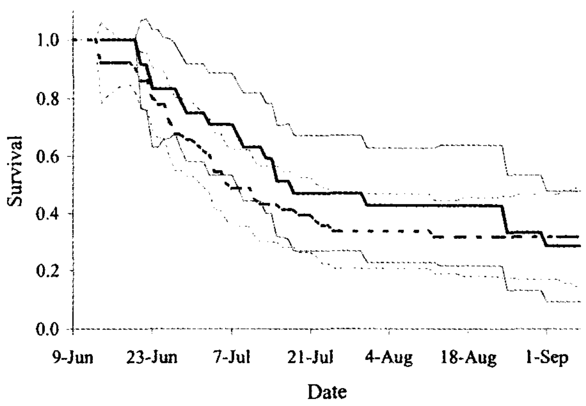

Fig. 2. Survival of ruffed grouse chicks in northern Michigan in 1996 (solid lines) and 1997 (dashed lines). Heavy lines represent the survival rate; lighter lines represent the upper and lower limits of 95% confidence intervals. Survival to 7 September was 0.285 (SE = 0.098, $n = 23$) in 1996 and 0.318 (SE = 0.087, $n = 49$) in 1997.

unmarked hens <2 days after capture. Both before and after the minor brood mixing, there were 1–6 marked chicks per brood. Eleven of the chicks marked in 1996 were at the PRCSF site. During 1997, 50 external transmitters were placed on chicks from 12 broods, with 1–6 marked chicks per brood. Brood mixing was observed when 3 marked chicks left their original broods approximately 37–59 days after capture. All chicks in 1997 were from the HNF site. At the time of capture, chicks were 5–10 days old ($\bar{x} = 6.4$ days, SE = 0.15, $n = 72$) and weighed 16.0–43.0 g ($\bar{x} = 23.1$ g, SE = 0.57, $n = 76$). Although accurate brood counts during capture attempts were impossible, we estimated that brood size was typically near 10, and we rarely captured >0.5 of the chicks from any brood. No chicks died during transmitter attachment, and all marked chicks were successfully returned to and accepted by their broods.

The chick survival rate from 14 June through 7 September 1996 was 0.285 (SE = 0.098, $n = 23$; Fig. 2). At the end of that period, 6 marked chicks were alive, 2 were censored, and 15 were dead. Three marked chicks that died ≤2 days after transmitter attachment were excluded from the sample; 1 with an external transmitter died due to stress, and 2 that experienced torn skin during transmitter attachment (1 with an implant and 1 with an external transmitter) died when there were only 4 other marked chicks at risk. Chicks with external transmitters had a higher survival rate (0.417, SE = 0.142 [SE of 100 bootstrap samples = 0.144], $n = 11$) than those with implants (0.110, SE = 0.104, $n = 12$), but the difference (0.307, SE = 0.176) was not statistically significant (log-rank test, $\chi^2 = 0.75$, $P > 0.3$; Fig. 3). Five of the 6 marked chicks alive on 7 September had external transmitters. One implanted transmitter and 2 external ones remained attached and functional into October.

The chick survival rate from 9 June to 7 September 1997 was 0.318 (SE = 0.087 [SE of 100 bootstrap samples = 0.082], $n = 49$; Fig. 2). At the end of that period, 8 chicks were alive, 9 were censored, and 32 were dead. One chick was excluded because it had a possible leg injury due to handling and died 3 days after capture. Four of the censored chicks were known to be alive on 2 September and likely survived the final 5 days of the study. Although the survival curves for the 2 years are statistically similar (log-rank test, $\chi^2 = 0.02$, $P > 0.8$), the trend toward higher chick mortality early in the summer was more evident in 1997 than in 1996. Only 1 marked chick died after 25 July in 1997.

Five of the 15 mortalities of marked chicks in 1996 were caused by avian predators, 2 were caused by mammalian predators, and none were caused by exposure or disease. Seventeen of the 32 mortalities in 1997 were caused by avian predators, 4 were caused by mammalian predators, and 1 was caused by exposure. No cause of mortality could be determined for 8 chicks in 1996 and 10 chicks in 1997. Often, there were no remains to collect except a transmitter with no distinguishing holes, dents, or scratch marks that may be left by a predator, which also would be consistent

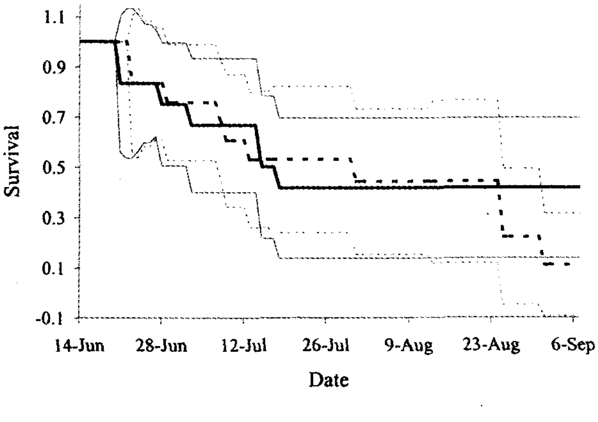

Fig. 3. Comparison of survival of ruffed grouse chicks with implanted radiotransmitters (dashed lines) and externally sutured radiotransmitters (solid lines) in northern Michigan in 1996. Heavy lines represent the survival rate; lighter lines represent the upper and lower limits of 95% confidence intervals. Survival to 7 September was 0.110 (SE = 0.104, $n = 12$) for chicks with implants and 0.417 (SE = 0.142, $n = 11$) for chicks with external transmitters. Note that the origin of the vertical axis is not 0.

with the transmitter simply falling off a surviving chick. When these chicks (1996: $n = 7$, 1997: $n = 6$) were treated as censored rather than dead, the chick survival rate was 0.519 (SE = 0.147) in 1996 and 0.382 (SE = 0.100) in 1997. Five of the 7 potentially sloughed transmitters in 1996 were implants. In cases when the cause of mortality was identified (both years combined), avian predators were more likely to damage the antenna (95%, $n = 22$) but less likely to damage the transmitter (23%, $n = 22$) or leave other remains, such as feathers and bones (23%, $n = 22$), than mammalian predators (33%, 67%, and 67%, respectively; $n = 6$).

DISCUSSION

Our estimates of chick survival during the predispersal period (0.285 and 0.318 in 1996 and 1997, respectively) were lower than those reported in other studies. Dorney and Kabat (1960) estimated the summer survival rate of ruffed grouse chicks to be 0.80 based on mean monthly brood sizes in June, July, and August. Rusch and Keith (1971) calculated a survival estimate of 0.51 for the first 12 weeks by comparing decreasing mean monthly brood sizes to the mean initial brood size at hatching. Bump et al. (1947:315) reported chick survival rates of just under 0.40 from hatching to 31 August, but a description of their methods was not given.

An accurate estimate of chick survival is essential for determining the rate of recruitment into the fall or spring population. Larson (1998:57) reported a production rate of 7.0 hatchlings per hen on the same study sites for the same years as our chick survival study. Multiplying by the mean chick survival rate from this study (0.302) gives an estimate of 2.1 juveniles per spring hen recruited into the fall population. Survival estimates for juvenile females from September to May on the HNF and PRCSF study sites for 3 consecutive years beginning in 1994 had a mean of 0.39 (S. R. Winterstein, unpublished data). Other estimates of survival for juvenile ruffed grouse during the period from fall to spring ranged from approximately 0.13 (Small et al. 1991) to 0.42 and 0.67 (Rusch and Keith 1971). Assuming a sex ratio of 1 among juveniles at the time of fall dispersal, approximately 0.1–0.7 females would be recruited into the spring breeding population for each female in the population the previous spring.

Miniature radiotransmitters previously had not been attached to ruffed grouse chicks. Although transmitters may affect chicks to some degree, we were confident that they probably would not significantly affect survival rates based on the results of the following laboratory studies of transmitter effects on young precocial birds. Bakken et al. (1996) found that neither implanted nor external transmitters (1.5–2 g = 5–5.5% of body mass) had a biologically significant effect on thermoregulation in 1-day-old mallard (*Anas platyrhynchos*) ducklings. Ewing et al. (1994) also reported that 1.2-g transmitters implanted in 1-day-old ring-necked pheasant (*Phasianus colchicus*) chicks that weighed 17.3 g did not significantly affect growth, behavior, or survival. Since we completed our study, Davis et al. (1999) similarly found no difference in survival or body mass gain between wood duck (*Aix sponsa*) ducklings fitted with a 1.6-g transmitter when they were 1 day old (22.9 g) and a control group of unmarked ducklings. Furthermore, because ruffed grouse chicks grow rapidly (Maxson 1978*b*), the transmitter-to-body mass ratio in our study would have been <3% within a week after chicks were captured.

Although both implanted and externally sutured transmitters were retained by some chicks throughout the predispersal period, we preferred the external suturing technique for several reasons. External suturing required less time, equipment, and expertise than the implantation procedure. External attachment also did not require wetting the chicks, and it involved less chance of accidental trauma to them. More importantly, chicks with external transmitters had a higher survival rate. The difference (0.307, 95% CI = [–0.038 to +0.652]) was biologically significant but failed to produce a P-value <0.05 or 0.10 because the standard errors were large. The same argument could be made to invalidate the statistical test for comparing survival estimates between years. The magnitude of the difference in that case (0.033), however, was substantially smaller. Nonetheless, the difference in survival rates between chicks with implants and those with external transmitters suggests that implants may have had a negative impact on survival, implants may have been more likely to fall off than external transmitters, or both. The second reason is likely more important because most of the potentially sloughed transmitters in 1996 were implants (5 of 7). The proportion of potentially sloughed transmitters also was much higher in 1996 (7 of 23) than in 1997 (6 of 49) when implants were not used. This was evident when chicks with a transmitter that may have fallen off were considered censored because the increase in the estimated survival rate was much greater in 1996 (0.285 to 0.519) than in 1997 (0.318 to 0.382).

Mortality of ruffed grouse chicks is highest during the first half of the predispersal period (Fig. 2; Bump et al. 1947:316). Therefore, direct estimates of chick survival should be made from the time of hatching, or, if indirect methods are used, they should include the initial brood size estimated directly from analysis of nesting success. Although our estimate of chick survival began 1 day before the median hatching date (10 Jun; Larson 1998) in 1996, it does not include the mortality of chicks <5 days old. Brood size counts at the time of chick capture could have been compared to known initial brood sizes to account for this. We abandoned this method, however, because counting young chicks was not feasible. Brood size estimates from <2 weeks after hatching should be considered highly unreliable because of the large brood sizes and the extremely brief time the chicks are observable before they hide. Another possible solution to the problem of accurately estimating chick survival early in the predispersal period when mortality is highest is to attach transmitters to chicks closer to the time of hatching. Smaller transmitters than the ones we used are available but currently have a significantly shorter battery life.

It is difficult to determine the specific causes of ruffed grouse chick mortality. Visible signs of a predator at the kill site are not as apparent during the summer as they are at other times of the year, such as when there are tracks or impressions in the snow. Also, the abundance of feathers and other remains from the mortality of mature ruffed grouse that aid in the determination of the cause usually are not present after a chick mortality. Finally, the few chick remains that may be left by a predator are quickly consumed by arthropods and other small scavengers that are most active during summer. It is unlikely, however, that the entire carcass of a chick dying from exposure decomposed completely in the 1–2 days between our chick locations. Despite these problems, we provide evidence that avian predators are the most significant cause of predispersal mortality. Exposure and disease probably cause few chick mortalities. If mammalian predators were responsible for all of the mortalities that were not diagnosed, they would have been the leading cause of mortality in 1996 but not 1997. This, however, is unlikely because undiagnosed mortalities were characterized by a lack of chick remains, occasional damage to the antenna, and an undamaged transmitter, which more closely followed the pattern left by avian predators than mammalian predators.

MANAGEMENT IMPLICATIONS

Accurate estimates of demographic parameters are necessary for understanding and effectively managing populations. We provide the first direct estimate of survival for ruffed grouse chicks. Traditional, indirect methods of estimating ruffed grouse chick survival are based on flush counts, which underestimate brood size to varying degrees throughout the predispersal period and produce positive bias in survival estimates. Our results, which reveal that chick survival is much lower than previously thought, are consistent with that claim. Even when we accounted for the possibility that some chick mortalities were censored when the cause could not be determined (i.e., the transmitter may have fallen off) rather than actual deaths, the survival estimate in 1997 (0.382) was still less than any previously reported chick survival rate for ruffed grouse. The true survival rate may be even lower than we observed because we could not account for mortality during the first 5 days after hatching. Our data also indicated that avian predators were the leading proximate cause of chick mortality. Therefore, managers should consider current and historical densities of avian predators when defining objectives for ruffed grouse recruitment. For instance, if densities of avian predators are higher than in the past, the response of a ruffed grouse population to improvements in brood habitat may be less noticeable than anticipated. In conclusion, more study of cause-specific mortality of ruffed grouse chicks is needed. Investigations into the effects of predation, weather, and food availability on chick survival—especially during the critical first few weeks after hatching—would provide important management information.

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