Colorado Division of Parks and Wildlife
September 2013-September 2014

WILIDLIFE RESEARCH REPORT

State of:	Colorado	: Division of Parks and Wildlife
Cost Center:	3420	: Avian Research
Work Package:	1656	: Columbian Sharp-tailed Grouse Conservation
Task No.:	N/A	: Columbian sharp-tailed grouse chick and juvenile radio transmitter evaluation
Federal Aid Project No.	N/A	

Period Covered: September 1, 2013 – August 31, 2014

Author: A. D. Apa

Personnel: J. Haskins, B. Petch, T Balzer, L Rossi, J Yost, CPW; Brandon Miller, RMBO/NRCS/CPW

All information in this report is preliminary and subject to further evaluation. Information MAY NOT BE PUBLISHED OR QUOTED without permission of the author. Manipulation of these data beyond that contained in this report is discouraged.

ABSTRACT

The Columbian sharp-tailed grouse (CSTG, *Tympanuchus phasianellus columbianus*) is one of six subspecies of sharp-tailed grouse in North America. CSTG currently occupy 10% of their former range due to habitat loss. Since the initiation of the Conservation Reserve Program (CRP), CSTG have increased in distribution and density. Managers desire to improve existing or historically enrolled CRP fields. Research techniques to evaluate the population response of CSTG to habitat treatments (via understanding chick and juvenile demographic parameters) do not exist. Therefore, the objectives of my study are to: 1) evaluate the capture and transmitter attachment technique for day-old CSTG chicks, 2) evaluate the capture and transmitter attachment technique for 30-day-old CSTG chicks, 3) evaluate the capture technique for > 120 day-old CSTG juveniles, and 4) evaluate 2 necklace transmitter attachment designs for female CSTG. My study occurred near Hayden, Routt County, Colorado from April - August 2014. I captured CSTG in the spring using walk-in funnel traps, fit females with 2, 12 g necklace-mounted radio transmitter designs to, monitor survival, and nesting effort. I captured chicks from successful females and radio-marked a sample with 0.65 g backpack style (3.9 g for juveniles) transmitter sutured along the dorsal midline between the wings. I monitored survival and movement daily. I conducted summary statistics and Kaplan-Meier function estimates with staggered entry for female and chick survival. I captured 32 female CSTG and monitored survival and productivity from April through August. I documented a 5-month female survival rate of 0.57 which similar to previous research. Twenty nests exhibited a 47% apparent nest success. Twenty-five chicks and 16 juveniles from seven broods were radio-marked with a mean chick mass was 16.3 g and juvenile mass of 94.3 g. The total average handling time was 31 minutes. Chick survival to 17 days was 0.49 and juvenile survival was 0.66 from 18 -50 days-of-age. The primary cause of female mortality was predation. Survival estimates for chick and juveniles was consistent with previous research in Alberta and South Dakota with sharp-tailed grouse. The techniques evaluated in this pilot study are deemed appropriate for future research in Colorado.

WILDLIFE RESEARCH REPORT

COLUMBIAN SHARP-TAILED GROUSE CHICK AND JUVENILE RADIO TRANSMITTER EVALUATION

ANTHONY D. APA

PROJECT OBJECTIVES

My project goal is to evaluate trapping and transmitter attachment methods on CSTG that have been previously used on GRSG. My study objectives are to:

1. Evaluate the capture and transmitter attachment technique for day-old CSTG chicks.
2. Evaluate the capture and transmitter attachment technique for 30-day-old CSTG chicks.
3. Evaluate the capture technique for > 120 day-old CSTG juveniles.
4. Evaluate 2 necklace transmitter attachment designs for female CSTG.

If the techniques are successfully developed they will be used in a future research project.

INTRODUCTION

The Columbian sharp-tailed grouse (CSTG, *Tympanuchus phasianellus columbianus*) is one of 6 subspecies of sharp-tailed grouse in North America. Current distribution ranges from British Columbia in the northwest to Colorado in the southeast. In-between populations exist in Washington, Idaho, Wyoming, Montana (extirpated), Utah, and Nevada (reintroduced) and Oregon (reintroduced). It currently occupies 10% of its former range across western North America (U.S. Department of the Interior 2000) and habitat loss is cited as the primary reason for its decline (Yocom 1952, Giesen and Braun 1997, McDonald and Reese 1998, Schroeder et al. 2000). Since the establishment of the Conservation Reserve Program (CRP) in 1985, CSTG have increased in distribution and density primarily in Idaho, Utah, and Colorado (U.S. Department of the Interior 2000).

The CSTG (Mountain Sharp-tail) is a game species in Colorado, and is designated as a species of state special concern. Management efforts to increase distribution in un-occupied but historic range of CSTG have occurred via reintroductions into Oregon and Nevada from source populations in Idaho. Additional reintroduction efforts have occurred within Utah and Colorado. Specifically, Colorado Parks and Wildlife has conducted reintroduction efforts within historic range in Dolores and Grand Counties.

Overview of Potential Future Research - Although management efforts continue to expand the range of CSTG, there is interest in improving habitat quality within occupied range. Improving habitat quality could: 1) increase densities and occupancy, 2) improve habitat in vacant and/or low quality CRP in unoccupied to expand distribution and/or, 3) be used as habitat improvements to mitigate impacts related to other habitat loss issues on the landscape (e.g., oil and gas exploration and development).

Although research in Colorado (Boisvert 2002, Collin 2004) suggests that CRP is generally beneficial to CSTG (over other agricultural practices), adjacent higher quality habitats in native or mineland reclamation provide higher quality habitat resulting in more productive CSTG populations. Poor quality CRP, consists of 1-2 grass and < 3 forb species (Boisvert 2002), with the grass species being predominantly sod-forming species (e.g. intermediate wheatgrass (*Thinopyrum intermedium*) and smooth brome (*Bromus inermis*)). These species tend to dominate sites and do not provide high quality CSTG nesting and brood-rearing habitat (Boisvert 2002).

Dasmann (1964:59) stated “To manage wildlife we must first manage the habitat.” Thus habitat management can range from complete protection from disturbance to improving quality so that the wildlife populations can be productive, maintained, and/or optimized to increase its carrying capacity (Dasmann 1964). Although Dasmann (1964) was correct in his statements nearly 50 years ago, the wildlife-habitat relationship is complex and differs widely among species and landscapes. Although our understanding of the wildlife-habitat relationship has improved, knowledge has evolved to define and assess habitat quality as it relates to population growth rates, density, and demographic rates (Van Horne 1983, Knutsen et al 2006, Johnson 2007). This is paramount when attempting to couple habitat quality change with wildlife population demographic changes.

CSTG provide a unique opportunity to evaluate a population response to habitat quality change. CSTG are a highly productive, generalist species (Apa 1998) having centralized breeding locations and limited movements during the breeding season (Boisvert et al. 2005). This behavior allows managers to target habitat improvements in nesting and brood-rearing areas. Since CSTG are breeding and brood-rearing habitat generalists and more productive (when compared to greater sage-grouse [GRSG; *Centrocercus urophasianus*]; Apa 1998), these characteristics can facilitate a relatively rapid response to habitat management. This allows managers and researchers to work cooperatively in attempting to couple landscape level habitat quality improvements in coordination with the demographic and population response of CSTG.

More information is needed to evaluate the demographic and population response of CSTG to breeding and summer/fall habitat improvements through more rigorous estimates of chick and juvenile (> 5 weeks-of-age) survival, dispersal, and recruitment. The field methods to obtain those estimates exist for surrogate species, but not for CSTG. Transmitter attachment and capture methods have been developed to estimate GRSG chick survival from hatch to 50 days (Burkepile et al. 2002, Gregg and Crawford 2009, Dahlgren et al. 2010, Thompson 2012), but only one study investigated approaches to estimate GRSG juvenile survival (> 50 days-of-age for estimates of dispersal and recruitment; Thompson 2012). Additionally, one study (Manzer and Hannon 2007) has developed the field techniques to estimate plains sharp-tailed grouse (*T. p. jamesi*; PSTG) chick survival from hatch to 30 days-of-age, but PSTG are approximately 100 g larger (Sisson 1976) than CSTG (Collins 2004) and are not a perfect surrogate for my proposed field method evaluation.

STUDY AREA

Study Area Specific to Pilot Research

My study was conducted near Hayden, Routt County, Colorado. It is interspersed with native big sagebrush (*Artemisia tridentata spp.*)/grass or mountain shrub communities, dominated by private land that is currently, or was historically, enrolled in the Conservation Reserve Program. Primarily exotic grasses (smooth brome and intermediate wheatgrass) and forbs (alfalfa (*Medicago sativa*) dominate the habitat (Fig. 1). The average annual precipitation in Hayden, Colorado is 43.2 cm. The average minimum and maximum annual temperatures are -2.8^{o} C and 14.4^{o} C, respectively.

METHODS

Methods Specific to Pilot Research

Grouse Capture – I captured CSTG in the spring using walk-in funnel traps (Schroeder and Braun 1991) in the morning on dancing grounds and opened traps ½ hour before sunrise and closed/blocked them at the cessation of trapping each morning. I initiated trapping based upon the timing and peak of female attendance (Giesen 1987).

I fit females with a either a 14.5 g necklace-mounted radio transmitter (Model A4120, Advanced Telemetry Systems, Isanti, MN) or a 15 g necklace mounted radio transmitter (Model RI-2BM4, Holohil Systems, Ltd., Ontario, Canada) both with a 4-hour mortality circuit and approximately a 8.5 month nominal battery life. Each transmitter had its 16 cm antenna bent to lie down between the wings and down the back of the grouse. I classified grouse by gender (Snyder 1935, Henderson et al. 1967) and age (yearling or adult; Ammann 1944), placed them in a cotton bag, and weighed them on an electronic balance. I fit all females with an individually numbered aluminum leg band (size 12) on the tarsus, and released them at the point of capture.

Nest Monitoring and Chick Capture - I monitored movements using triangulation from a ≥ 30 m distance (to minimize disturbance) using hand-held Yagi antenna attached to a receiver, and monitored nesting behavior to identify nest location. Nesting was also confirmed by obtaining a second directional location at a 90^o angle to the first. If a female was observed in the same location for two consecutive days, she was assumed to be incubating. I attempted a visual observation of the female, if vegetation concealment was conducive, 7-10 days post-incubation confirmation and monitored nest fate using telemetry at a ≥ 30 m distance (24-26 day incubation period).

Once monitoring revealed a successful hatch (female movement away from the nest), I captured all chicks in the brood within 12 - 24 hours. I located females < 2 hours after sunrise during brooding and flushed the female. I captured all chicks by hand and confined them in a small heated cooler to assist in maintaining thermoregulation. I weighed (± 0.01 g) all chicks with an electronic scale and a random sample (depending on brood size) was selected for transmitter attachment. A 0.65 g backpack style (Model A1025; nominal battery life is 28 days; Advanced Telemetry Systems, Isanti, MN) transmitter was sutured along the dorsal midline between the wings (Burkepile et al. 2002, Dreitz et al. 2011, Manzer and Hannon 2007, Thompson 2012). Two 20-gauge needles were inserted subcutaneously and perpendicular to the dorsal mid-line, and monofilament suture (Braunamide: polyamide 3/0 thread, pseudo monofilament, non-absorbable, white) material was threaded through the needle barrel. I applied one drop of cryanocrylate glue on the knot, and released the chicks (marked and unmarked) simultaneously at the capture site. Chick survival and movements were monitored 1-2 hours post-release to determine brood female affinity and post-handling chick behavior.

I monitored female and chick movements and survival daily until 14 days-of-age, by circling at a 25 m radius. I documented the position (i.e., distance) of radio-marked chicks in relation to the brood female, systematically searching the area for missing chicks/transmitters. I collected brood locations equally among 4 time periods: brooding (< 2 hour after sunrise or before sunset), morning (0800-1100), mid-day (1100-1400), and afternoon (1400-1800) throughout the study, increasing the location sampling period to every 1-3 days until the brood was 20-30 days of age.

I captured surviving juveniles at two different ages using spotlight techniques (Giesen et al. 1992, Wakkinen et al. 1992). The first capture was at 20-25 days-of-age. I captured 20-25 day-old juveniles approximately 2 hours before sunrise to enhance the possibility of females brooding juveniles. The female and brood were circled using telemetry and approached slowly with the aid of a "red light" on a head lamp and the location was marked using yellow glow sticks. The female and brood were captured using a 1.5 m diameter hoop net. All birds were immediately restrained and the brood female was release at the point of capture. The chick transmitter was removed and replaced with a 3.9 g back-pack style juvenile transmitter (Model A1080, nominal life 6-7 months; Advanced Telemetry Systems, Isanti, MN). I used the same attachment method as described earlier for day-old-chicks (Burkepile et al. 2002, Dreitz et al. 2011, Manzer and Hannon 2007, Thompson 2012). I will attempt to capture surviving juveniles 10-12 weeks following initial radio-marking in late-September and October, and fit juveniles with a12 g adult style necklace-mounted radio transmitters mentioned earlier. I used techniques to capture juveniles using spotlight techniques described earlier.

Data Analysis - I conducted summary statistics and Kaplan-Meier (K-M) function estimates with staggered entry for female and chick survival (Kaplan and Meier 1958, Pollock et al. 1998).

RESULTS AND DISSCUSSION

Results - I captured 32 female CSTG (21 adults: 10 yearlings: 1 unknown) from 15 - 26 April 2014 on four dancing grounds (Big Elk 1, Stokes Gulch 2 & 3, and Postovit). Adult and yearling female mass ($\bar{x}$ ± SE) was 683.5 ± 11.6 g (*n* = 21) and 651.8 ± 11.0 g (*n* = 10), respectively.

From April through August, I documented 13 female mortalities resulting in a 5-month female survival rate of 0.57 ± 0.02 (*n* = 31; 95% CI 0.38 - 0.75) (Fig. 2). Specifically, survival for females equipped with ATS and Holohil transmitters was 0.53 ± 0.03 (*n* = 15; 95% CI 0.28 – 0.79) and 0.60 ± 0.03 (*n* = 16; 95% CI 0.33 – 0.86) (Fig. 3). I did not include two females in the survival analyses (one radio failure and one was euthanized due to an irreversible capture related injury). All other mortalities were predation related and had no sign of crop restriction or impaction.

My overall nest initiation rate was 90% (*n* = 18/20) for 12 adults and 8 yearlings that specifically exhibiting a100% and 88% nest initiation rate, respectively. I documented a 41% (*n* = 9/22) apparent nest success and a 47% (*n* = 9/19) apparent female success. No renesting adult females were successful and one renesting yearling was successful. Female movement from the lek of capture to nest averaged 2.16 ± 0.53 km (*n* = 22; range 0.20 - 10.78). Sixty-four percent of the nests were located within 2 km of the lek of capture.

I captured 43, day-old chicks from seven broods with a mean mass of 16.3 ± 0.4 g (range 14.7 - 19.3). I radio-marked 25 of those chicks resulting in an average number of chicks marked/brood of 3.6 ± 0.5 chicks (range 2 - 5). Total brood size was 6.7 ± 1.2 chicks (range 3 - 11). The average time to process an entire brood (radio-mark, weigh, and release) was 31 ± 6 minutes resulting in an average brood processing time/chick of 4.9 minutes (range 2.7 - 8 minutes). I recaptured and marked juveniles that were 18 - 21 days-of-age. Juvenile mass at capture was 94.3 ± 3.7 g (*n* = 15; range 85 - 130 g).

I estimated survival from 1 - 50 days-of-age and for two time periods; chicks from 1 - 17 days-of-age juveniles from 18 - 50 days-of-age. The latter time periods correspond to transmitter exchange. Survival from capture to 30 days-of-age was 0.39 ± 0.02 (*n* = 31; 95% CI 0.22 - 0.56) and 50 days-of-age was 0.32 ± 0.02 (*n* = 31; 95% CI 0.16 - 0.49) (Fig. 4). Chick and juvenile survival was 0.49 ± 0.02 (*n* = 25; 95% CI 0.27 – 0.71) (Fig. 5) and 0.62 ± 0.03 (*n* = 16; 95% CI 0.42 - 0.89) (Fig. 6), respectively.

Discussion – My trapping time frame, although brief, was similar to reports from Boisevert (2002) and Collins (2004). My adult:yearling capture ratio (2.1:1) was different than reported by Collins (2004; 5.0:1) and Boisvert (2002; 3.6:1), but is likely indicative of my shorter trapping period and smaller sample sizes. Adult and yearling female mass was similar to earlier reports (Boivert 2002, Collins 2004).

My 5-month female survival (0.57) was similar to that reported by Collins (2004;0.41 - 0.58) for birds in mineland reclamation, but much lower (0.70 - 0.79) than females in shrub steppe habitat at 150 days exposure post-capture. In contrast, my survival was higher than reported by Boisvert (2002; 0.50). Based on these results, I believe I was successful in addressing and correcting issues from the 2013 research pilot where I experienced low female survival due to the transmitter attachment technique (Apa 2013). To specifically address objective 4, I have selected the elastic necklace style for future research. This decision is based on previous studies and personal experience with both styles.

I documented a similar, but slightly lower (90%), nest initiation rate than reported by Collins (2004;97%) and Boisvert (2002; 97%). My apparent nest success (41%) was less congruent with previous Colorado research. It was similar to nest success reported by Collins (2004;42%) but lower than reported by Boisvert (2002;63%). Although nest success appeared low, it was not abnormally low and likely due to the small spatial and temporal nature of this pilot study.

In my assessment of objective 2, I successfully increased samples sizes from the 2013 pilot study (Apa 2013) and successfully radio-mark CSTG day-old chicks. Transmitter size was ≤ 5% of body mass, averaging 4.0% of a day-old chick's body mass (range; 3.4 - 4.4%). Manzer and Hannon (2007) fit chicks with transmitters similarly to me and reported a transmitter mass of 6 - 8% of chick mass (13.7 - 18 g). Manzer and Hannon (2007) fit chicks with larger (1.1 g) transmitters which resulted in a higher percent of mass than I report, because chick mass for PSTG and CSTG were similar.

My resulting 30-day juvenile survival (0.39) was similar to the 30-day survival (0.41; 95% CI 0.25 – 0.57) reported by Manzer and Hannon (2007). My confidence intervals were also similar. In addition, Manzer and Hannon (2007) reported that 73% of the chick mortality they experienced occurred in the first 15 days. In contrast, I observed that only 48% of the mortalities occurred the first 15 days.

In my assessment of objective 3, transmitter mass averaged 4.1% (range 3.0 – 4.6) of juvenile mass. Although Manzer and Hannon (2007) did not estimate survival past 30 days, Norton (2005) radio-marked juvenile PSTG at 14 - 21 days-of-age in South Dakota. Norton (2005) estimated survival (0.50 0 0.63() from 0 – 18 days-of-age from the literature. Norton (2005) reports survival from 19 days to the end of August (fledging) and it ranged from 0.67 – 0.77. My estimate of chick survival was within his reported confidence intervals.

My survival estimates compare well with Manzer and Hannon (2007) through 30 days-of-age and with Norton (2005) even though he did not mark chicks at hatch. Based on these survival estimates and my success in capturing and marking chicks and juveniles, I suggest that there is reasonable evidence that these approaches can be successfully used in future research.

ACKNOWLEDGEMENTS

I want to thank the CPW Area 10 staff for assistance in landowner contacts, logistics, and trapping. This study occurred exclusively on private land and I thank those private landowners for the assistance and cooperation. Although I used the pronoun "I" throughout this document, I personally collected very little field data; therefore I want to thank R. Schilowsky and R. Harris for the many hours in the field conducting the field observations and data collection and entry. Most importantly, I want to thank R. Hoffman for his assistance, professional guidance, and advice throughout all phases of this research.

LITERATURE CITED

Ammann, G. A. 1944. Determining the age of pinnate and sharp-tailed grouse. Journal of Wildlife Management 8:170-171.

Amstrup, S. C. 1980. A radio-collar for game birds. Journal of Wildlife Management 44:214-217.

Apa, A. D. 1998. Habitat use and movement of sage and Columbian sharp-tailed grouse in southeastern Idaho. Ph.D. Dissertation, University of Idaho, Moscow, ID, USA.

Apa, A.D. 2013. Columbian sharp-tailed grouse chick and juvenile radio transmitter evaluation. Pages 1 – 10 *in*: J.H. Gammonley (Editor), Wildlife Research Reports, Colorado Parks and Wildlife, Fort Collins, CO, USA.

Boisvert, J. H. 2002. Ecology of Columbian sharp-tailed grouse associated with Conservation Reserve Program and reclaimed surface mine lands in northwestern Colorado. M.S. Thesis. University of Idaho, Moscow, ID, USA.

Boisvert, J. H., R. W. Hoffman, and K. P. Reese. 2005. Home range and seasonal movements of Columbian sharp-tailed grouse associated with Conservation Reserve Program and mine reclamation. Western North American Naturalist 65:36-44.

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.

Collins, C. P. 2004. Ecology of Columbian sharp-tailed grouse associated with coal mine reclamation and native shrub-steppe cover types in northwestern Colorado. M.S. Thesis. University of Idaho, Moscow, ID, USA.

Dahlgren, D. K., T. A. Messmer, and D. N. Koons. 2010. Achieving better estimates of greater sage-grouse chick survival in Utah. Journal of Wildlife Management 74:1286-1294.

Dasmann, R. F. 1964. Wildlife Biology. John Wiley & Sons, Inc. New York, NY, USA.

Dreitz, V. J., L. A. Baeten, T. Davis, and M. M. Riordan. 2011. Testing radiotransmitter attachment techniques on northern bobwhite and chukar chicks. Wildlife Society Bulletin 35:475-480.

Giesen, K. M. 1987. Population characteristics and habitat use by Columbian sharp-tailed grouse in northwestern Colorado. Final Report, Colorado Division of Wildlife Federal Aid Project W-37-R, Denver, CO, USA.

Giesen, K. M., T. J. Schoenberg, and C. E. Braun. 1982. Methods for trapping sage grouse in Colorado. Wildlife Society Bulletin 10:224-231.

Gregg, M. A., and J. A. Crawford. 2009. Survival of greater sage-grouse chicks and broods in the northern Great Basin. Journal of Wildlife Management 73:904-913.

Henderson, F. R., F. W. Brooks, R. E. Wood, and R. B. Dahlgren. 1967. Sexing of prairie grouse by crown feather patterns. Journal of Wildlife Management 31:764-769.

Johnson, M. D. 2007. Measuring habitat quality: A review. Condor 109:489-504.

Kaplan, E. L., and P. Meier. 1958. Non-parametric estimation from incomplete observation. Journal of the American Statistics Association 53:457-481.

Knutson, M. G., L. A. Powell, R. K. Hines, M. A. Friberg, and G. J. Niemi. 2006. An assessment of bird habitat quality using population growth rates. Condor 108:301-314.

Manzer, D. L. 2004. Sharp-tailed grouse breeding success, survival, and site selection in relaltion of habitat measured at multiple scales. Ph.D. Dissertation. University of Alberta, Edmonton, Alberta, Canada.

Manzer, D. L., and S. J. Hannon 2007. Survival of sharp-tailed grouse *Tympanuchus phasianellus* chicks and hens in a fragmented prairie landscape. Wildlife Biology 14:16-25.

McDonald, M. W., and K. P. Reese. 1998. Landscape changes within the historical range of Columbian sharp-tailed grouse in eastern Washington. Northwest Science 72:34-41.

Norton, M. A. 2005. Reproductive success and brood habitat use of greater prairie chickens and shapr-tailed grouse on the Fort Pierre National Grasslands of central South Dakota. M.S. Thesis. South Dakota State University, Brookings, SD, USA.

Pollock, K. H., S. R. Winterstein, C. M. Bunck, and AP. D. Curtis. 1989. Survival analysis in telemetry studies: the staggered entry design. Journal of Wildlife Management 53:7-15.

Schroeder, M. A., and C. E. Braun. 1991. Walk-in traps for capturing greater prairie chickens on leks. Journal of Ornithology 62:378-385.

Schroeder, M. A., D. W. Hays, M. A. Murphy, and D. J. Pierce. 2000. Changes in the distribution and abundance of Columbian sharp-tailed grouse in Washington. Northwestern Naturalist 81:95-103.

Sisson, L. 1976. The sharp-tailed grouse in Nebraska. Nebraska Game and Parks Commission. Lincoln, NE, USA.

Snyder, L. L. 1935. A study of the sharp-tailed grouse. Royal Ontario Museum of Zoology, Biological Service, Publication 40, Toronto, Ontario, Canada.

Thompson, T. R. 2012. Dispersal ecology of greater sage-grouse in northwestern Colorado: evidence from demographic and genetic methods. Ph.D. Dissertation. University of Idaho, Moscow, ID. USA.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. Journal of Wildlife Management 47:893-901.

United States Department of the Interior. 2000. Endangered and threatened wildlife and plants; 12-month finding for a petition to list Columbian sharp-tailed grouse as threatened. Federal Register 65:197.

Wakkinen, W. L., K. P. Reese, J. W. Connelly, and R. A. Fischer. 1992. An improved spotlighting techniques for capturing sage grouse. Wildlife Society Bulletin 20:425-426.

Yocom, C. F. 1952. Columbian sharp-tailed grouse in the state of Washington. American Midland Naturalist 48:185-192.

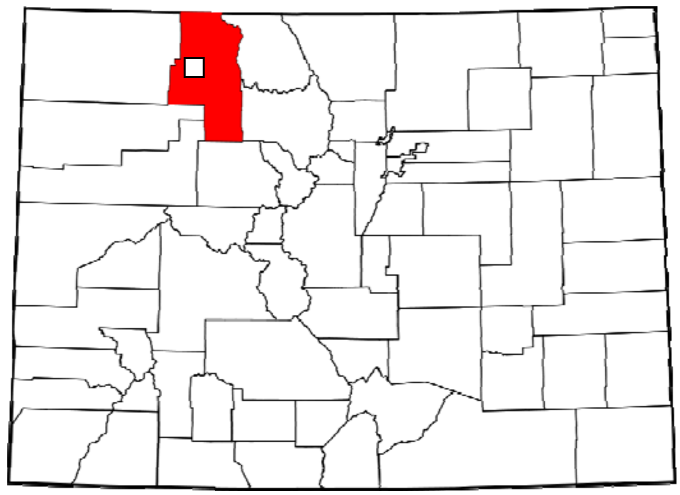

Figure 1. Columbian sharp-tailed grouse study area in Routt County, Colorado, 2013.

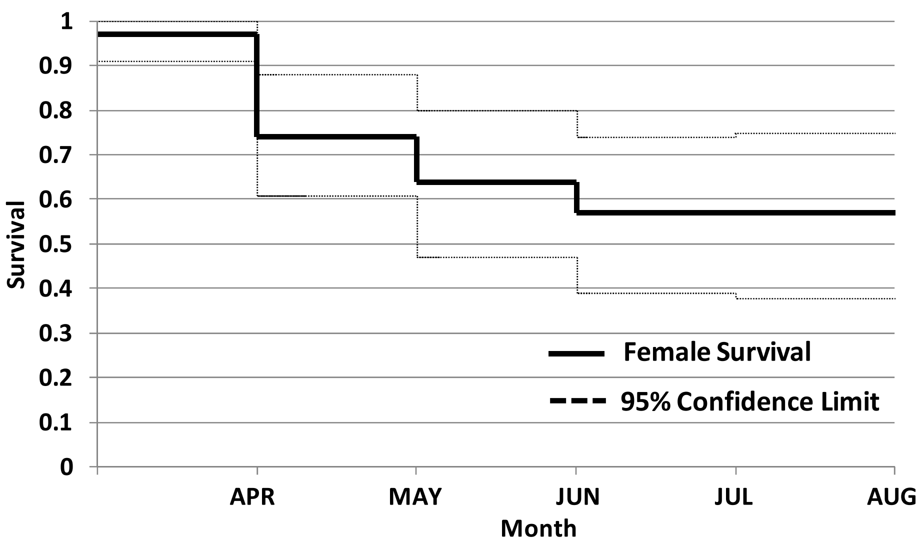

Figure 2. Kaplan-Meier product limit monthly survival with staggered entry of female Columbian sharp-tailed grouse (n = 31) from April - August in Routt County, Colorado, 2014.

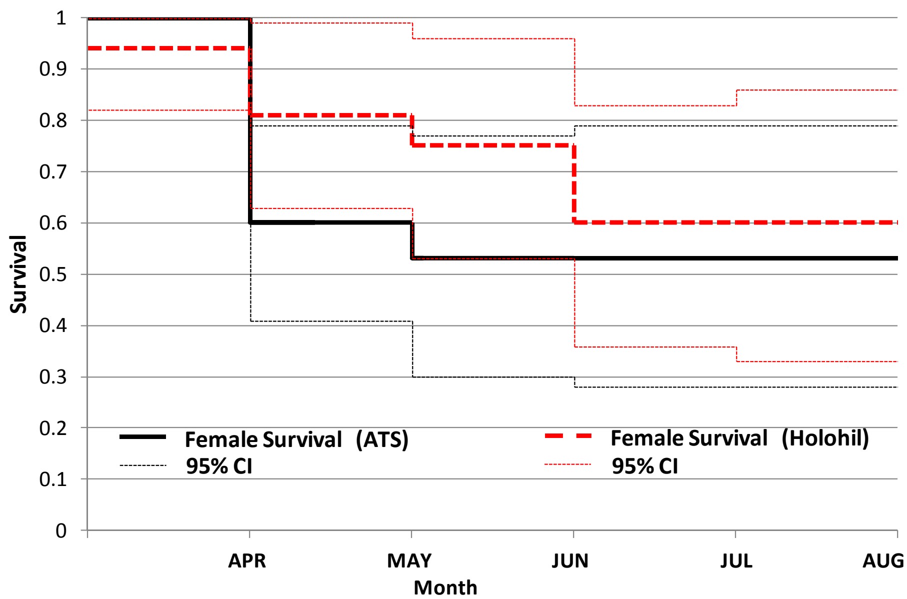

Figure 3. Kaplan-Meier product limit monthly survival with staggered entry of female Columbian sharp-tailed grouse fit with ATS (*n* = 15) and Holohil (*n* = 16) necklace style radio transmitters from April - August in Routt County, Colorado, 2014.

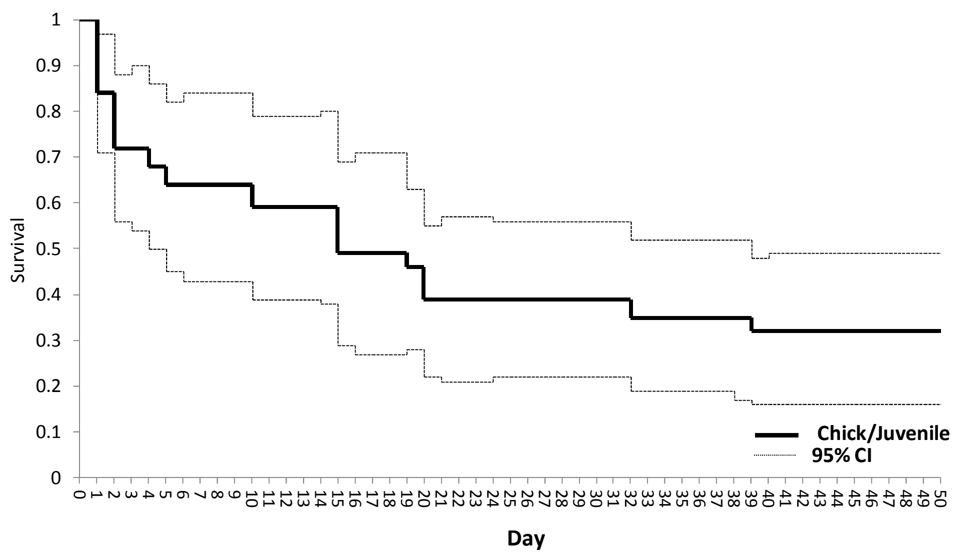

Figure 4. Kaplan-Meier product limit daily survival with staggered entry of chick and juvenile Columbian sharp-tailed grouse chicks (*n* = 31) to 50 days-of-age in Routt County, Colorado, 2014.

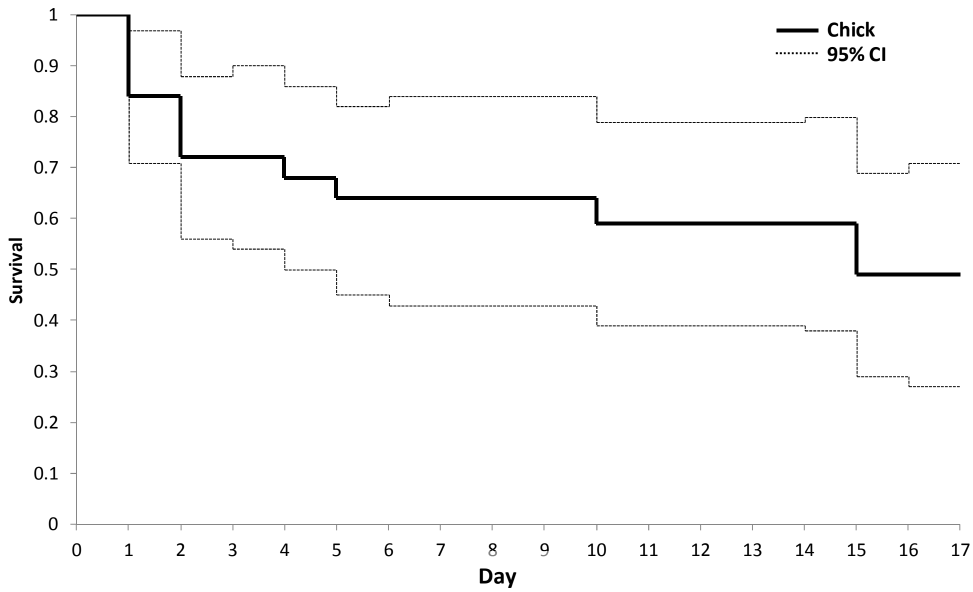

Figure 5. Kaplan-Meier product limit daily survival with staggered entry of Columbian sharp-tailed grouse chicks (n = 25) from hatch to 18 days-of-age in Routt County, Colorado, 2014.

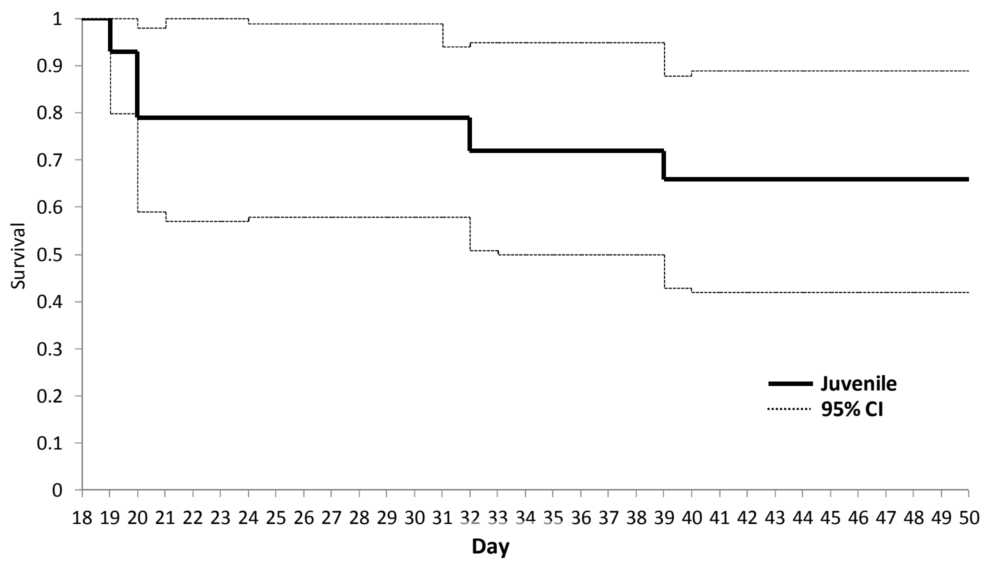

Figure 6. Kaplan-Meier product limit daily survival with staggered entry of juvenile Columbian sharp-tailed grouse chicks (n = 16) from 19 - 50 days-of-age in Routt County, Colorado, 2014.