The Journal of Wildlife Management; DOI: 10.1002/jwmg.620

Note

Greater Sage-Grouse Sex Ratios in Utah: Implications for Reporting Population Trends

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ABSTRACT Greater sage-grouse (*Centrocercus urophasianus*; sage-grouse) are a species of conservation concern throughout western North America. Obtaining valid population estimates is essential to understanding population trajectories and the effects of management. Counts of male sage-grouse attending leks during the breeding season are used directly as a population index or to estimate the breeding population size by assuming a detection probability and sex ratio. In the latter case, managers often assume a 2:1 female-biased ratio. However, this sex ratio has not been validated and may result in biased population estimates. We evaluated sex ratios at hatch, 42 days of age, and at harvest to determine if sex ratios were biased for sage-grouse in Utah. Sex ratios at hatch and at 42 days of age did not differ from parity. Harvest data suggested that sage-grouse may exhibit a slight female-biased sex ratio (1.458:1) in the fall. Wildlife management agencies should use caution when using lek count data to estimate population size if sex ratios have not been validated.

KEY WORDS candidate species, *Centrocercus urophasianus*, greater sage-grouse, population estimation, sex ratio, Utah.

Greater sage-grouse (*Centrocercus urophasianus*; sage-grouse) are a large, sexually dimorphic tetraonid endemic to the sagebrush-steppe habitats of western North America (Schroeder et al. 1999). Recent estimates indicate that sage-grouse populations declined at an average rate of 2% between 1965 and 2003 (Connelly et al. 2004, Garton et al. 2011). Currently, sage-grouse occupy <60% of their former range (Schroeder et al. 2004). In response to declining populations and increasing threats to remaining habitat, the Canadian Committee on the Status of Endangered Wildlife in Canada declared sage-grouse to be an endangered species in 1998 (Harris et al. 2001). The United States Fish and Wildlife Service (USFWS) designated sage-grouse as a candidate for protection under the Endangered Species Act in 2010 (USFWS 2010).

Sage-grouse population status and trends are primarily monitored by counting displaying males on leks (Connelly et al. 2003, Garton et al. 2011). These counts are often used as a population index and counts are compared over time to assess population trends. Alternatively, lek counts are occasionally used to estimate the breeding population by assuming a constant male detection probability and population sex ratio (Utah Division of Wildlife Resources [UDWR] 2009). Sage-grouse biologists have generally assumed that sage-grouse populations exhibit a 2:1 female-biased sex ratio (UDWR 2009, Atamian and Sedinger 2010, USFWS 2010, Garton et al. 2011), although other ratios have been proposed (Hagen 2005). This assumption is based on sex ratios observed during hunter harvest surveys in the fall. Although harvest data are convenient and inexpensive to collect, these data may yield biased results if hunters preferentially harvest 1 sex or if 1 sex is more susceptible to harvest than the other. Sex-biased harvest probabilities have been reported in Idaho where Connelly et al. (2000) found that 42% of adult female sage-grouse mortalities were attributable to hunter harvest, compared to only 15% of adult male mortalities. Unfortunately, few efforts have been made to determine if sage-grouse exhibit biased breeding season sex ratios (Atamian and Sedinger 2010). Additionally, the use of sex ratios observed during the fall harvest season to estimate breeding season populations assumes that wing barrel data are representative of the harvest and the population and that any bias in sex ratio is constant from fall to spring.

Seasonally skewed sex ratios can arise as a function of differential production of the sexes (biased primary sex ratio) or as a result of various factors occurring after birth or hatching (biased secondary sex ratio; Girondot and Pieau 1993). Fisher (1958) posited that the sexes should be produced with equal investment of resources by parents. Therefore, biased primary sex ratios could occur if 1 sex were

Received: 20 November 2012; Accepted: 19 June 2013

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more costly to produce than the other. Subsequent studies have led to the development of at least 11 general hypotheses to explain observed sex-allocation biases (Cockburn et al. 2002). To date, only 1 published study (Atamian and Sedinger 2010) has attempted to determine if sage-grouse exhibit skewed primary sex ratios. The authors found that the hatching sex ratio in the Nevada sage-grouse population they studied exhibited no skew toward either sex (Atamian and Sedinger 2010).

Skewed secondary sex ratios may arise because of differential survival rates, emigration, or age of maturity (Girondot and Pieau 1993). Sage-grouse populations exhibit diverse migratory patterns (Connelly et al. 1988); however, neither sex commonly emigrates permanently from its natal range. Additionally, both male and female sage-grouse are sexually mature by the time of their first breeding season. Hence, of the post-hatching factors that may influence population sex ratios, sage-grouse are likely most affected by differential survival of the sexes.

Zablan et al. (2003) found that average annual survival rates for female sage-grouse in North Park, Colorado were 14% greater than males of similar age in the same area. Various explanations have been offered for higher mortality in male sage-grouse. One possibility is that male juvenile sage-grouse may be more strongly affected by unfavorable climatic conditions than juvenile females because males are substantially larger and therefore require more resources to survive and grow (Swenson 1986). Additionally, Hagen (2011) suggested that male sage-grouse suffer high predation rates during the breeding season because of increased vulnerability while displaying on leks.

Because population data are used to prioritize conservation actions and, in some states, to set sage-grouse harvest regulations, assuming an incorrect sex ratio could result in misallocation of resources and/or overexploitation of populations. To determine if the assumed 2:1 female biased sex ratio is valid in Utah and at what life-stage the bias originates, we employed a 3-pronged approach. We analyzed 1) hatching sex ratios for 3 areas to determine if primary sex ratios were skewed, 2) juvenile sex ratios for 1 population to determine if chick survival differed by sex, and 3) harvest data for 1 of the 3 populations to determine if sex ratios were biased in the harvest.

STUDY AREA

This study was conducted at 3 sites across the state of Utah. The Grouse Creek (GC; 41°42′N, 113°53′W) study site was located in northwestern Utah. During spring and summer, sage-grouse at this site used habitats from 1,700 m to 2,000 m in elevation. Vegetation at this site was dominated by basin big sagebrush (*Artemisia tridentata tridentata*) and mountain big sagebrush (*A. t. vaseyana*). By assuming a detection rate of 0.75 for male sage-grouse and a 2:1 female-biased sex ratio, the UDWR biologists estimated the 2008 breeding season population for GC to be 2,804 birds (UDWR, unpublished data).

The second study site was located on Anthro Mountain (AM; 39°56′N, 110°14′W) in northeastern Utah. Sage-grouse habitat ranged from 2,500 m to 2,900 m in elevation. The dominant shrub species on this site was mountain big sagebrush. The UDWR estimated that the breeding season population for AM in 2008 was 52 birds (UDWR, unpublished data).

Our third study site was on Parker Mountain (PM; 38°17′N, 111°51′W) located in south-central Utah. Sage-grouse habitat on PM ranged from 2,500 m to 3,000 m in elevation. The PM site was dominated by large expanses of black sagebrush (*A. nova*) with Wyoming big sagebrush (*A. t. wyomingensis*) and mountain big sagebrush inclusions. In 2008, the breeding season population was estimated to be 3,972 individuals (UDWR, unpublished data). The state of Utah experienced moderate drought conditions, as measured by the Palmer Drought Severity Index (PDSI), during the summers of 2008 (PDSI = −1.53) and 2009 (PSDI = −1.74; National Oceanic and Atmospheric Administration [NOAA 2012]).

METHODS

Field Methods

We collected data for this study in conjunction with 3 larger studies. We collected data at the GC and PM study sites during 2008 and 2009 and at AM during 2009. We conducted research under Utah State University Institutional Animal Care and Use Committee permits #945R, #942, #1194, and #1404.

At each study site, we trapped female sage-grouse on and around leks at night using spotlights, binoculars, and long-handled nets (Giesen et al. 1982, Wakkinen et al. 1992). We completed all trapping during April before hens began initiating nests. We fitted captured females with a 15- to 19-g necklace style radio-transmitter (Holohil Systems, Carp, Ontario, Canada; Advanced Telemetry Systems, Insanti, MN). We located nests of radio-marked hens using radio-telemetry equipment. Once we located a nest, we marked its location with a rock cairn from ≥15 m. We monitored nests visually ≥2 times per week to determine fate. To avoid nest abandonment, we never intentionally flushed hens from their nests. Once a nest hatched, we collected the shells of all hatched eggs and stored them in a dry environment until genetic sex determination. To avoid double sampling, we only collected the large bottom portion of hatched eggs (i.e., we did not collect caps). We rarely encountered unhatched eggs across sites and years (total unhatched eggs for PM = 12, AM = 1, GC = 0). Although information about the number of unhatched eggs and their sex can provide important information, we did not determine the sex of unhatched eggs because they did not contribute to the realized hatching sex ratio and were therefore not relevant to this study.

We captured broods of radio-marked hens on PM within 3 days of hatching. We captured broods shortly after sunset or before sunrise while they were being brooded by the hen. We used radio-telemetry equipment to locate the hen. Once located, we flushed the hen and collected all of the chicks. We placed chicks in a small-insulated box with a bottle of

warm water to help them maintain body temperature. We fitted each chick with a 1.5-g backpack style radio transmitter (Holohil Systems; American Wildlife Enterprises, Monticello, FL). We attached transmitters with 2 sutures through the skin on the back of each chick (Burkepile et al. 2002).

We collected 1 blood quill from each chick for genetic sex determination (Atamian and Sedinger 2010). We stapled blood quills to a Nobuto blood strip folded in a sheet of filter paper and allowed them to air dry. Once we processed all chicks, we released the entire brood at the capture site. We monitored chicks $\geq$2 times per week until they reached 42 days of age (hereafter juvenile). Occasionally chicks became separated from the brood hen and we could not locate them or confirm them as dead. We did not include missing chicks in calculations of juvenile sex ratios.

The PM and GC sage-grouse population were open to hunting on a permit-only basis during the course of this study. Harvest data were collected by UDWR biologists by placing barrels along all roads accessing sage-grouse hunting zones. Signs were placed above barrels requesting that hunters remove a wing from each sage-grouse they harvested and place it in the wing barrel. Biologists with UDWR determined the sex and age of each bird using the methods of Eng (1955). Unfortunately, wing barrel data have not been consistently collected for the GC population or the other 2 hunted populations in Utah. Therefore, we assessed harvest sex ratios using data collected from PM during the 1999–2003 and 2006–2009 sage-grouse hunting seasons (data were not collected in 2004 or 2005). Season dates, duration, and bag limit (2) were similar across this range of years (UDWR 2009).

Sex Determination Methods

We obtained genomic DNA using the Qiagen DNAeasy blood and tissue extraction kit (Qiagen, Valencia, CA) or with a salting-out protocol from Sunnucks and Hales (1996). We quantified extracted DNA with the Thermo Scientific Nanodrop 1000 and diluted it to approximately 50 ng/μL. We performed sex identification tests with a polymerase chain reaction (PCR) using the 2550-F (5′-GTTACTGATTCGTCTACGAGA-3′) and 2718-R (5′-ATTGAAATGATCCAGTGCTTG-3′) primers from the avian W-chromosome helicase DNA binding gene (Fridolfsson and Ellegren 1999). We carried out the PCR in 10-μL volumes with 0.2 mM dNTPs, 1× PCR buffer (10 mM Tris–HCl, 50 mM KCl, pH 8.3), 1.75 mM MgCl, 0.3 μM of each primer, 0.2 U taq polymerase (New England Biolabs, Inc., Ipswich, MA), and ~50 ng/μL DNA template. The 2-step PCR consisted of an initial denaturation at 94°C for 2 minutes, 11 cycles of touchdown PCR (94°C denaturing 30 s, 60–50°C annealing for 30 s, and 72°C extension for 30 s), followed by 30 cycles (94°C denaturing 30 s, 50°C annealing for 30 s, and 72°C extension for 30 s), and a final extension at 72°C for 5 minutes. We visualized the PCR products along with a size standard on a 1.4% agarose gel stained in ethidium bromide at 83 V for 1.25 hour. We evaluated our methods on blood samples collected from adult sage-grouse of known sex. We did not observe any discrepancies between known sex and genomic sex determination.

Statistical Analysis

We calculated 95% confidence intervals (Hagen and Loughin 2008) based on Wilson scores (Agresti and Coull 1998) for observed sex ratios (number females/number males) to evaluate the hypotheses of 2:1 and 1:1 sex ratios at hatch for each of the 3 populations. We rejected hypothesized sex ratios if 95% confidence intervals did not encompass the hypothesized ratio. To determine if juvenile (i.e., 42 days old) sex ratios on PM were skewed, we calculated 95% Wilson score confidence intervals for the sex ratio of surviving chicks. We also evaluated sex ratios at the time of capture to determine if they deviated from a 1:1 sex ratio. This was necessary because we were not able to mark chicks as soon as they hatched, so capture sex ratios could differ from hatching sex ratios. We compared capture sex ratios with juvenile sex ratios to determine if biases in juvenile sex ratios were the result of sex-biased survival or an artifact of sex ratios at capture.

We obtained wing barrel data for PM from the UDWR. We used 95% Wilson score confidence intervals to determine if the ratio of females to males differed from 1:1 or conformed to the assumption of 2:1 for adults (after second year), yearlings (second year), chicks, and the total harvest. We report ratios of females to males, as well as 95% confidence limits.

RESULTS

We determined chick sex from 338 egg shells collected from 53 nests (Table 1). We only used data from nests in which all hatched shells were successfully sexed. When considered across all populations, the hatching sex ratio did not demonstrate a 2:1 female biased sex ratio (Table 1, sex ratio = 1.074, 95% CI = 0.868–1.328). However, we could not reject the hypothesis that male and female chicks were produced equally because the confidence interval does include 1. We observed the same pattern when we analyzed data from the 3 study sites separately (Table 1).

We radio-marked 126 chicks from 22 broods on PM in 2008 and 2009 (63 in each year). Of the initial 126 chicks marked, we lost 29 during the course of the study and did not include them in sex ratio calculations. The loss of a chick could have been the result of transmitter failure or a predation event that resulted in the chick being removed from the study site or buried too deep for the transmitter signal to be detected. The sex ratio of the remaining 97 chicks at the time of capture was 1.021 (Table 2). Sixty-three chicks (65%) survived to 42 days of age. The juvenile sex ratio showed no signs of deviating from parity (sex ratio = 0.969,

Table 1. Sex ratios (N_{Female}/N_{Male}) of greater sage-grouse chicks as determined by genetic analysis of hatched eggs from Anthro Mountain (AM), Grouse Creek (GC), and Parker Mountain (PM), Utah during 2008 and 2009 with 95% confidence intervals.

Study site	N_{Male}	N_{Female}	Sex ratio	95% CI
AM (2009 only)	40	41	1.025	0.665–1.579
GC	39	41	1.051	0.680–1.624
PM	84	93	1.107	0.825–1.485
Total	163	175	1.074	0.868–1.328

Table 2. Sex ratios (N_{Female}/N_{Male}) of radio-marked greater sage-grouse chicks at the time of capture (capture) and at 42 days of age (survive) from Parker Mountain, Utah during 2008 and 2009 with 95% confidence intervals.

Time of sampling	N_{Male}	N_{Female}	Sex ratio	95% CI
Capture	48	49	1.021	0.687–1.516
Survive	32	31	0.969	0.594–1.580

95% CI = 0.594–1.580) and we rejected the hypothesis of a 2:1 female biased sex ratio (Table 2).

Our analysis of 9 years of wing barrel data from PM indicated that neither the 1:1 nor the 2:1 sex ratio hypothesis was supported by the data when we considered all age classes together or when we only considered the adult or chick sex ratios (Table 3). However, the hypothesis of a 2:1 sex ratio could not be rejected when we only considered yearling sage-grouse (95% CI = 1.580–2.325).

DISCUSSION

We found that sage-grouse hatching sex ratios did not deviate from parity for the Utah populations studied. Hatching sex ratios in our study were similar to those documented in Nevada (proportion male = 0.51 ± 0.03) by Atamian and Sedinger (2010). These results support the argument that biased sex ratios, if they exist within sage-grouse populations, are likely the result of differential survival of the sexes and not biased production of 1 sex over the other as has been documented in some avian species (Zijlstra et al. 1992, Kilner 1998, Ewen et al. 2001).

Other studies have found or theorized that biased juvenile sex ratios can arise in sexually dimorphic species because of higher mortality of the larger sex during years when resources are limiting (Maynard Smith 1980, Slagsvold et al. 1986, Teather and Weatherhead 1989). Our data do not support this conclusion. We conducted our study during a drought period when resources were potentially limited. Even given the drought conditions, we found that male and female sage-grouse chicks had an equal probability of surviving to 42 days of age. Our data likely deviate from the commonly observed pattern of higher mortality of the larger sex because sage-grouse produce precocial offspring that are not directly dependent upon a parent to provide food resources and because juvenile sage-grouse do not display significant sexual dimorphism at 42 days of age.

Swenson (1986) assumed that sage-grouse hatching sex ratios were 1:1 and concluded that apparent biases in juvenile sex ratios in autumn were the result of male chicks being more sensitive to environmental conditions than females, thereby resulting in higher mortality of male offspring. Our results also indicated that male chicks were less commonly harvested by hunters than would be expected if the chick sex ratio were at parity. However, our data also led us to reject the hypothesis that females were twice as prevalent as males in the chick population. In fact, from the harvest data, we rejected the hypotheses of 1:1 and 2:1 sex ratios for all age classes except for yearlings where only the 1:1 hypothesis could be rejected. Our data do not clearly identify why yearling sex ratios would show a stronger female bias than other age classes; although, because of differences in size and molting patterns between male and female yearlings, some males may have been incorrectly classified as adult females thereby violating the assumption that wing barrel data are representative of the harvest and population. If harvest sex ratios are representative of the true population sex ratios (Beck 1977, but see Connelly et al. 2000), our results suggest that mortality may be higher for male chicks than female chicks during the period between chicks reaching 42 days of age (typically late Jul to early Aug for PM) and late-September to early-October when the Utah sage-grouse hunting season is held.

Table 3. Sex ratios ($N_{Females}/N_{Males}$) of greater sage-grouse harvested on Parker Mountain (PM), Utah from 1999 to 2003 and 2006–2009 with 95% confidence intervals. Age classes are those used by the Utah Division of Wildlife Resources.

Age class	N_{Male}	N_{Female}	Sex ratio	95% CI
Adult	126	167	1.325	1.052–1.669
Yearling	156	299	1.917	1.580–2.325
Chick	277	349	1.260	1.076–1.475
Total	559	815	1.458	1.309–1.624

Our results indicate that the overall harvest sex ratio in the Utah population studied most closely approximated a 1.5:1 female skew (Table 3, total sex ratio). This is significant in that replacing the assumed 2:1 sex ratio with our observed 1.5:1 ratio results in a 17% reduction in breeding season population estimates. In states where the number of sage-grouse hunter permits issued is directly related to population estimates, assuming an incorrect sex ratio could result in harvest rates exceeding management objectives. Specifically, the UDWR uses population estimates and hunter success rates in previous years to determine the number of sage-grouse permits that will be issued with the objective being to harvest no more than 10% of the population (UDWR 2009). As such, incorrectly assuming that populations exhibit highly female-biased sex ratios would result in an over-allocation of permits and could result in excessively high harvest rates.

MANAGEMENT IMPLICATIONS

Accurate documentation of population size and trajectory are essential but often elusive components of effective wildlife management. Our results indicate that the assumption that sage-grouse populations in Utah exhibit a 2:1 female-biased sex ratio may not be valid and may lead to inflated population estimates. In the absence of validated sex ratios, wildlife management agencies should adopt the conservative assumption that the breeding season sex ratio is at parity (1:1) to avoid the possibility of overestimating population size. Further, until better information concerning sage-grouse sex ratios and the factors that influence them are available, approaches for estimating harvestable population levels that include assumptions about sex ratios should be avoided. Given the continued use of wing barrel data for estimating harvest rates, sex ratios, and productivity, we also recommend that managers and researchers attempt to

validate the various assumptions associated with the use of harvest data.

ACKNOWLEDGMENTS

We are grateful to the many research technicians who assisted with the various projects that contributed data to this study. Comments by J. Connelly, C. Hagen, D. Musil and 1 anonymous reviewer greatly improved the manuscript. Funding for this research was provided by the Quinney Professorship for Wildlife Conflict Management, Utah State University.

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Associate Editor: Bret Collier.