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RESEARCH ARTICLE

Captive-Breeding of Captive and Wild-Reared Gunnison Sage-Grouse

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Gunnison sage-grouse (*Centrocercus minimus*) distribution in North America has decreased over historical accounts and has received federal protection under the Endangered Species Act. We investigated captive-breeding of a captive-flock of Gunnison sage-grouse created from individuals reared in captivity from wild-collected eggs we artificially incubated. We also introduced wild-reared individuals into captivity. Our captive-flock successfully bred and produced fertile eggs. We controlled the timing and duration of male-female breeding interactions and facilitated a semi-natural mating regime. Males established a strutting ground in captivity that females attended for mate selection. In 2010, we allowed females to establish eight nests, incubate, and hatch eggs. Females in captivity were more successful incubating nests than raising broods. Although there are many technical, financial, and logistic issues associated with captive-breeding, we recommend that federal biologists and managers work collaboratively with state wildlife agencies and consider developing a captive-flock as part of a comprehensive conservation strategy for a conservation-reliant species like the Gunnison sage-grouse. The progeny produced from a captive-rearing program could assist in the recovery if innovative approaches to translocation are part of a comprehensive proactive conservation program. Zoo Biol. 35:70–75, 2016.

Keywords: captive flock; *Centrocercus minimus*; conservation-reliant; founder flock

INTRODUCTION

Gunnison sage-grouse (*Centrocercus minimus*; GUSG) distribution in North America has decreased over the past century [Oyler-McCance et al., 2001; Schroeder et al., 2004] and is federally protected by the Endangered Species Act [USFWS, 2014]. Gunnison sage-grouse are genetically [Oyler-McCance et al., 1999], morphologically, and behaviorally [Young et al., 1994, 2000] distinct from greater sage-grouse (*C. urophasianus*; GRSG; Hupp and Braun, 1991; Young et al., 1994, 2000]. Even though they are behaviorally distinct, both species exhibit pure dominance polygyny (lek polygyny) [Alcock, 1979]. Lek polygyny is characterized by males attending traditional arenas in the spring to conduct breeding displays and attract female mates [Gibson and Bradbury, 1987].

Another polygnous member of Tetraoninae is Attwater's prairie-chicken (*Tympanuchus cupido attwateri*; APC). It has been nearly 25 years since the first captive-rearing attempt [Watkins, 1971] prompted subsequent captive-rearing research with APC [Silvy et al., 1999; Lockwood, 1998; Pratt, 2010; USFWS, 2010] and greater prairie-chickens (*T. c. pinnatus*; GPC) as surrogates [Kruse, 1984; Drake, 1994; Griffin, 1998; Hess, 2004]. The APC captive-breeding program has been successful producing several thousand APC for release [Silvy et al., 1999] with captive-rearing efforts continuing at seven different facilities [Pratt, 2010; USFWS, 2010]. The Association of Zoos and Aquariums (AZA) has an animal care manual for APC in progress [AZA, 2015], but we were unsuccessful finding

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established published captive-breeding protocol for APC or GPC except for mention of paired individuals housed in a wagon wheel aviary design [Drake, 1994; Hess, 2004; Pratt, 2010].

Sage-grouse captive-rearing has garnered interest for nearly 50 years. Most attempts have investigated the husbandry associated with egg incubation, hatch, and rearing juveniles and adults [Pyrah, 1963, 1964; Johnson and Boyce, 1990, 1991; Huwer, 2004; Huwer et al., 2008; Thompson, 2012; Apa and Wiechman, 2015; Thompson et al., 2015]. Less emphasis has been focused on captive-breeding behavior.

Captive-breeding with a polygynous species can present challenges [Holland, 2007]. Oesterle et al. [2005] reported GRSG breeding activity space limitations and aggressive behaviors with wild-reared individuals introduced into captivity as juveniles. Other GRSG captive-breeding studies or observations report modest success, but report issues with breeding success and egg fertility [Johnson and Boyce, 1991]. In contrast, Spurrier et al. [1994] studied captive and wild-hatched GRSG chicks in experimental behavior research and did not report any behavioral abnormalities with either gender. None of the individuals had been previously exposed to strutting behavior in the wild or captivity [Spurrier et al., 1994].

Captive-rearing is commonly used in the restoration of declining wild populations [review by Araki et al., 2007]. Typically, conservation practitioners react and develop a short-term response to a demographic or population crisis [Scott et al., 2010] rather than instituting proactive conservation measures [Drechsler et al., 2011]. If GUSG captive-rearing is to be considered as part of a proactive comprehensive conservation approach, there is a need to build on existing GRSG captive-rearing information [Johnson and Boyce, 1991; Oesterle et al., 2005; Thompson et al., 2015], but additional research is needed to investigate if captive-breeding would be successful with GUSG. Thus, the objectives of our captive-breeding study were to evaluate the breeding behavior and reproduction efforts of captive- and wild-reared GUSG and evaluate the feasibility of captive females hatching and rearing broods in captivity.

MATERIALS AND METHODS

Study Area

Our primary study area was in Fort Collins (40°42′N, 104°54′W) Colorado: the location of the breeding facility. Our secondary study area was located in the Gunnison Basin (38°30′N, 106°54′W) Colorado; the source of wild eggs we incubated, hatched, and raised grouse to establish our captive-flock [Apa and Wiechman, 2015]. The Gunnison Basin population also served as source for the wild birds introduced to our captive-breeding facility.

The Fort Collins captive-breeding facility was intentionally and strategically located outside current and historic GUSG distribution [Schroeder et al., 2004] and near the Colorado State University School of Veterinary Medicine, the Colorado Parks and Wildlife (CPW) Staff Veterinarian, veterinary technicians in Fort Collins, and avian husbandry experts at the Denver Zoological Gardens, Denver, Colorado.

Our captive-breeding facility was located at the USDA National Wildlife Research Center (NWRC) in aviaries that housed subadult (>4 months to 2 years), and adult (>2 years) GUSG. The aviaries had removable net panels between them allowing the segregation and integration of differing genders and ages during the breeding and nesting phases (Fig. 1). We provided small wood shelters and big sagebrush (*Artemisia tridentata*) for cover and food. For additional details, see Oesterle et al. [2005] and Apa and Wiechman [2015]. The CPW Animal Care and Use Committee (ACUC) (Permit #03-2009) and the NWRC ACUC (Permit #QA-1625) approved our captive-breeding research techniques.

Wild Grouse Capture, Marking, and Transport

In 2009, we collected 40 eggs from six wild GUSG in the Gunnison Basin and artificially incubated and hatched them in captivity [Apa and Wiechman, 2015]. This effort yielded three males and eight females that became our core captive population from 2010 to 2011. Additionally, from 2009 to 2011, we captured wild GUSG in the Gunnison Basin. We fitted grouse with individually colored and uniquely numbered aluminum leg bands, and transported them from the Gunnison Basin to Fort Collins via ground transportation for integration into the captive flock.

Breeding In Captivity

We attempted to simulate semi-natural conditions to facilitate polygnous breeding behavior in our captive-flock. We allowed females to select from >1 breeding age males by allowing males to compete for breeding dominance [Holland, 2007], rather than housing monogamous male/female pairs [Drake, 1994; Hess, 2004; Pratt, 2010]. In January 2010 and 2011, we segregated GUSG by gender in advance of the April breeding season. We controlled breeding access to serve two purposes; to synchronize egg production and hatch with wild GUSG in the Gunnison Basin for an ancillary study [Wiechman et al., 2011], and simulate wild GUSG breeding behavior chronology in the Gunnison Basin. In 2010, we prevented all captive-reared first-year males from breeding with captive-reared females due to potential deleterious effects from sibling inbreeding. We isolated non-breeding males in a separate enclosure ($8.2 \times 15.0 \times 15.7$ m; Fig. 1) throughout the breeding season. In 2011, we allowed one captive-reared male to breed because he was not related to any surviving females.

We initiated breeding access by opening the net partition 0.5 h before sunrise and kept it open for ~1.5 hr. We discontinued access by closing the net and returning the females or males to their respective aviary (Fig. 1). On occasion, females entered the male aviary and would not leave. Alternatively, when females did not “attend” the

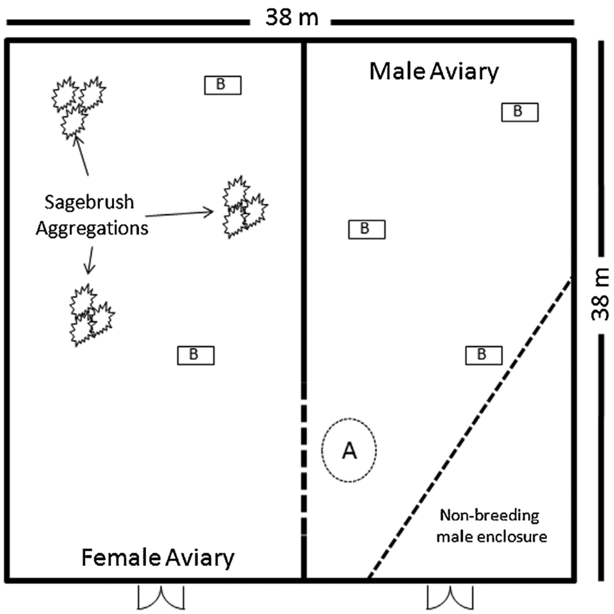

Fig. 1. National Wildlife Research Center aviary design, Larimer County, Colorado, 2009–2011. For additional details for the design of each aviary, see Oesterle et al. [2005] and Apa and Wiechman [2015]. A = established strutting ground in 2010 and 2011; B = wood shelters for cover and obstruction. The number and distribution of sagebrush aggregations and wood shelters changed over time.

strutting ground, the males would pursue females into the female aviary. We limited these behaviors by artificially "concluding breeding" and herding grouse to their respective aviaries. If weather conditions were not conducive to breeding activity, (heavy precipitation, strong winds, etc.) grouse remained segregated. Throughout the breeding season, we documented behaviors (displays, aggression, and copulations) from a blind 10 m from the female-male access point (Fig. 1) with binoculars using the behavior sampling rule [Martin and Bateson, 2007]. After we observed breeding by all of the females, we discontinued breeding access and maintained gender segregation until mid-summer.

Nesting and Brood-Rearing

In 2010, we monitored the construction, maintenance, and incubation of nests by captive females (Fig. 1). We individually and inconspicuously marked deposited eggs with a pencil and monitored for additional egg deposition. If more eggs were laid after 1–2 days, we assigned maternity to the female exhibiting nesting and/or egg-laying behavior. If no additional eggs were laid, we removed the egg(s) from the nest. If new nests were created within 5 min of an existing nest, we removed the eggs to prevent disturbance of the maternal female. We monitored females twice daily to ascertain the onset of incubation and noted female behavioral interactions. In 2011, we made similar behavioral observations but all eggs were collected and females were not allowed to incubate clutches.

We fed captive females with broods at similar rates reported by Apa and Wiechman, [2015]. The females and broods were approached and invertebrates were placed on the ground.

RESULTS

Wild Grouse Capture and Transport

From 2009 to 2011, we integrated 7 (5M:2F) wild-reared GUSG from the Gunnison Basin into the captive flock at the NWRC. We integrated 4 (2M:2F) in September and October 2009, two males in September 2010, and one adult male in March 2011. For wild grouse survival in captivity see Apa and Wiechman [2015].

Breeding in Captivity

Captive males initiated breeding displays in late-January to early-February, and we integrated males and females on April 10, 2010 and April 11, 2011. We allowed female access to males for 17 days (10–28 April) in 2010 and 16 days (11–30 April) in 2011. Across years, breeding access totaled 78.8 hr (SE 5.8; $n = 33$). Access began 71 min earlier in 2010 than 2011, resulting in a average total access time of 93 min (SE 8; range 44–168 min) and 65 (SE 7; range: 30–135 min), respectively. Average breeding access started at 0536 and 0647 in 2010 and 2011, respectively.

In 2010 and 2011, we observed 32 copulations involving 14 females and 3 males. In 2010 we documented 18 copulations involving two males with nine different females, but could not identify the females associated with two additional copulations. In 2011, we observed 12 copulations with one male and five different females. The first and last copulations were observed on 11 and 30 April, respectively. Copulations occurred from 0515 to 0813. In 2010 and 2011, the mean timing of copulations was 0608 ($n = 20$; range 0515–0715) and 0714 ($n = 12$; range 0643–0813), respectively. The mean copulation dates were 17 and 21 April in 2010 and 2011, respectively. Following the conclusion of breeding, we integrated the captive-reared males with the balance of the captive-flock on 15 June 2010 and 17 May 2011. Non-nesting females without broods were integrated with the males on 15 and 22 June in 2010 and 2011, respectively. In 2010, we allowed two males to compete for dominance. As a consequence, the territorial defense was so aggressive, ultimately one male suffered injuries (ruptured aorta) that resulted in a mortality.

Nesting in Captivity

In 2010 we documented 37 eggs deposited in eight nests. We removed five of the eight nests that were adjacent to existing nests and collected 22 eggs, ultimately preserving three nests with 15 eggs. Collected eggs were artificially incubated and hatched for an ancillary study [Apa and Wiechman, 2015; Wiechman et al., 2011]. We collected partial clutches and replaced collected eggs with artificial eggs in two nests. The third nest was abandoned in the first 3 days of incubation, and the remaining two nests were incubated for 28 days, yielding three chicks in each nest. We maintained maternal females with broods in the aviary. Of the six chicks produced, two survived to 20 days post-hatch and four died during brooding. We released the surviving chicks to a wild-reared brood as part of an ancillary study [Wiechman et al., 2011].

When approaching the female and brood during feeding, the females exhibited normal protective behavior exhibited in the wild and ultimately the females consumed all of the food provided. In subsequent efforts, we temporarily isolated brood females from their chicks during feeding to allow the chicks to feed.

DISCUSSION

We report the first successful breeding in captivity by wild- and captive-reared GUSG. We found that GUSG reared in captivity from hatch and wild-reared GUSG introduced into captivity will successfully breed, produce viable eggs [Wiechman et al., 2011; Apa and Wiechman, 2015] and, with limited success, rear broods.

We encountered minimal issues related to the maintenance and control of GUSG breeding in captivity. In 2010 and 2011, although the males successfully established a "strutting ground," we manually controlled access. Grouse breeding access could also be controlled with selection bolts [Holland, 2007]. The individuals we raised in captivity from hatch to adulthood had not observed or participated in previous breeding behaviors. Our observations were consistent with Spurrier et al., [1994] who did not observe any obvious breeding behavior abnormalities during breeding or nesting (nest construction, egg laying, and incubation). In contrast, the wild individuals that we introduced into captivity had previously experienced breeding activity.

Allowing males to compete for territories has advantages and disadvantages. A possible advantage is the promotion of semi-natural breeding conditions to facilitate a polygnous mating system. This could be relevant because authors have raised concerns about behavioral trait modifications with captive-reared individuals that ultimately affect fecundity and/or fertility [Snyder et al., 1996; Berejikian et al., 1997; Lynch and O'Hely, 2001; Araki et al., 2007]. There are also possible disadvantages by allowing territorial encounters by multiple males. Solitary copulations might not be observed and/or multiple copulations with differing males and a single female could complicate accurate pedigree records. Additionally, territory defense and resulting disputes in a small space can result in fatalities or fatal or debilitating injuries (Drake, 1994; this study). Regardless of these disadvantages, we recommend that captive-breeding practitioners promote polygnous breeding behavior. Efforts to reduce conspecific aggression has been successful with other gallinaceous birds [Cornetto and Estevez, 2001; Deeming et al., 2011].

Egg deposition in captivity was mostly indiscriminant, although females also laid eggs in nest bowls. Although we attempted to assign maternity to nests, it was problematic because female identity was difficult to document as females maintained numerous nests (e.g., moving grass or sticks, and covering eggs), and captive-females parasitized or exhibited egg dumping behavior in established nests. Although egg dumping or nest parasitism exists in related species [Labisky and Jackson, 1966], and large clutches have been reported with free-ranging GRSG [Patterson, 1952; Schroeder, 1997; Walker, 2008; Wiechman, 2013], we are unaware of any direct confirmation of egg dumping or nest parasitism behavior by free-ranging GUSG or GRSG. We suspect that these behaviors were facilitated by the restricted captive environment. If nest incubation and hatch is a goal of a captive-breeding program, we suggest that large ($>530\ m^2$) aviaries coupled with intensive nesting territory management should be incorporated into an aviary design. This would reduce nest density, discourage egg dumping or nest parasitism, and/or possibly limit aggressive behaviors among females.

An additional consideration is the proximity of the male and female aviaries. Males consistently displayed to females on nests in adjacent aviaries. The continued harassment caused one female to abandon her nest. Therefore, we suggest that captive-breeding facilities increase the distance between male and nesting female aviaries or provide visual barriers between or within aviaries [Cornetto and Estevez, 2001; Deeming et al., 2011].

Although we allowed captive females to nest and raise broods in 2010, because of complicating and logistical factors, we discontinued this approach in 2011. We do not recommend captive-brood-rearing as a viable husbandry technique, although it should be a subject of future investigation.

Captive-rearing programs for conservation reintroductions have a long history in North America (Kleiman, 1989). More recently, captive-breeding programs have been used to bolster or reestablish declining wildlife populations and endangered species [Snyder et al., 1996; Araki et al., 2007; Redford et al., 2011]. Not all programs with members of Galliformes have been successful, and in one case, the program was discontinued due to a lack of successful introductions [Hernández et al., 2006]. In the case of the APC, captive-breeding is needed to support existing non-captive populations [Silvy et al., 1999]. In response to earlier captive-breeding efforts, Snyder et al. [1996] expressed concerns about captive-breeding programs being used for species' recovery. Snyder et al. [1996] suggested that captive-breeding efforts should be used sparingly with a limited number of endangered species recovery programs and should be used as a last resort when other conservation alternatives are unavailable or have been exhausted.

We agree with Snyder et al. [1996] that captive-rearing has a role in endangered species conservation, but efforts to conserve and restore GUSG habitat should remain a priority.

Although our study was observational and not experimental, we suggest that our findings and anecdotal observations can provide a foundation for future captive-breeding research or founder flock development with GUSG. We also suggest, that while on-the-ground conservation efforts continue, our results [Apa and Wiechman, 2015] provide crucial information that could assist with the proactive and alternative conservation approaches to GUSG. We caution federal biologists and managers to not wait until captive-breeding is the only approach available to sustain the wild GUSG populations and work collaboratively with state wildlife agencies [Scott et al., 2005]. We do not recommend that captive-rearing efforts be "…outsourced…" to outside entities [Hernández et al., 2006:628], but those responsible for such efforts work with GUSG captive-rearing experts to develop a thoughtful, well planned, collaborative comprehensive recovery plan with clear and measurable objectives. We suggest that captive-rearing is a viable recovery approach for GUSG, especially for a species that is conservation-reliant [Scott et al., 2010; Goble et al., 2012]. In addition, any progeny from a captive-rearing program could be used to supply individuals for reintroductions [Seddon et al., 2007] if novel approaches are implemented [Thompson et al., 2015]. Lastly, we caution that captive-breeding is not the only solution to GUSG recovery. Captive populations created through artificial selection can alter natural selection thereby resulting in unintended consequences influencing gene flow and fitness-related traits [Lynch and O'Hely, 2001; Araki et al., 2007; Navarro and Martella, 2008].

CONCLUSIONS

We recommend the following protocol and conclusions for a captive-breeding program for GUSG:

1. Gunnison sage-grouse will successfully breed and produce viable eggs in captivity.
2. Provide for strutting ground establishment and allow for female mate selection and polygnous behaviors rather than monogamous behaviors.
3. Provide appropriate escape cover or barriers for subordinate males to limit excessive and continued territorial disputes.
4. Provide adequate spacing or visual obstruction barriers between aviaries to separate genders during the breeding season.
5. Provide adequate space and/or visual obstructions among females and/or aviaries.
6. Provide shrub and herbaceous vegetation to encourage nesting and/or egg laying behaviors.
7. Conduct additional research on captive-female nesting and brood-rearing behavior.

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