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Factors Affecting Gunnison Sage-Grouse (*Centrocercus minimus*) Conservation in San Juan County, Utah

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FACTORS AFFECTING GUNNISON SAGE-GROUSE (*CENTROCERCUS MINIMUS*) CONSERVATION IN SAN JUAN COUNTY, UTAH

by

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ABSTRACT

Factors Affecting Gunnison Sage-Grouse (*Centrocercus minimus*)

Conservation in San Juan County, Utah

by

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Utah State University, 2010

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Due to loss of habitat, Gunnison sage-grouse (*Centrocercus minimus*) currently occupy 8.5% of their presumed historical range. One population survives in Utah, occurring in San Juan County. The Gunnison Sage-grouse Rangewide Conservation Plan and the San Juan County Gunnison Sage-grouse Conservation Plan recommended management strategies to address identified conservation threats to the Utah population. I addressed three conservation strategies identified in the plans: 1) creation and enhancement of brood-rearing areas; 2) assessment of habitat conditions within the Gunnison Sage-grouse Conservation Area; and 3) prevention or reduction of perching events by avian predators on distribution line power poles.

From 2007-2009, I addressed the conservation strategy of creating mesic brood-rearing areas in Conservation Reserve Program fields and native sagebrush areas by evaluating the role of irrigation and dormant season cattle grazing on habitat. Vegetation and arthropod diversity in irrigated versus non-irrigated plots did not differ (p>0.01).

Conservation Reserve Program plots exhibited greater arthropod abundance and cover of perennial grass than the native sagebrush plots, but lower diversity of perennial grasses and abundance and diversity of forbs ($p<0.01$).

The second conservation strategy I addressed was the completion of an assessment of habitat conditions within the Gunnison Sage-grouse Conservation Area. I measured vegetation conditions within habitat occupied and unoccupied by Gunnison sage-grouse. Cover and height of grasses exceeded guidelines for occupied and unoccupied habitats. Forb cover was below recommended guidelines in occupied habitat. Sagebrush cover was below guidelines for winter habitat. Habitat restoration efforts should focus on retaining existing sagebrush cover and establishment of sagebrush, forb, and grass cover within Conservation Reserve Program fields.

The third conservation strategy I evaluated was the retrofitting of distribution line power poles with perch deterrents to discourage avian predators from perching. I evaluated the efficacy of five perch deterrents. The perch deterrents did not mitigate potential avian predators from perching. A deterrent designed for insulators, in combination with physical deterrents we tested, has potential to prevent perching.

These studies provided a sound first step that can be built upon by the Monticello/Dove Creek Local Working Group to improve habitat conditions, reduce the threat of avian predation, and plan future conservation activities within the Conservation Area.

(138 pages)

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Phoebe R. Prather

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CHAPTER 1

INTRODUCTION

BACKGROUND

In the mid 1970s the Colorado Division of Wildlife began studying sage-grouse (*Centrocercus* spp.) populations located within the state. These studies included the collection of wings from hunted sage-grouse (Young et al. 2000). Biologists noted that primary wings collected from sage-grouse in the Gunnison Basin of Colorado were smaller than those of other populations. These observations prompted further studies on the Gunnison Basin populations. The subsequent studies discovered differences in morphometrics, breeding behavior, plumage and genetics, leading to the reclassification of the grouse species that inhabits the Gunnison Basin in Colorado and southeastern Utah as the Gunnison sage-grouse (*C. minimus*) in 2000 by the American Ornithologists' Union (Young et al. 2000, AOU Checklist Committee 2002, Gunnison Sage-grouse Rangewide Steering Committee 2005).

Species Description

The Gunnison sage-grouse is substantially smaller than the greater sage-grouse (*C.urophasianus*), with shorter tarsus, culmen, and carpal measurements (Schroeder et al. 1999). The average mass of male Gunnison sage-grouse ranges from 1.5-1.82 kg., while the average mass of a male Greater sage-grouse ranges from 2-3 kg. The male Gunnison sage-grouse has considerably larger and thicker filoplumes and shorter rectrices that have more distinct barring. The males of the two species also differ in their strutting displays.

Species Distribution

Gunnison sage-grouse currently occupy 8.5% of their presumed historical range (Schroeder et al. 2004). The Gunnison sage-grouse was thought to have historically occurred in Colorado, Kansas, Oklahoma, New Mexico, Arizona, and Utah before rapid settlement of the west in the 1800s (Young et al. 2000). After a more thorough investigation the species is now believed to have occurred in southwestern Colorado, northwestern New Mexico, northeastern Arizona, and southeastern Utah (Schroeder et al. 2004). The distribution of presumed historic habitat encompassed 46,521 km^2 (21,376 mi^2), but the species is now estimated to have a range of 4,787 km^2 (1,822 mi^2, Schroeder et al. 2004, Fig. 1.1). This decline in the range of the species has been attributed to the loss or conversion of sagebrush (*Artemisia* spp.) to other land uses. The quality of the remaining habitat has been impacted by urbanization, grazing, agriculture and fragmentation (Schroeder et al. 2004). The historic distribution of the species was probably always somewhat patchy, but the patchiness has been greatly exacerbated by habitat loss (Gunnison Sage-grouse Rangewide Steering Committee 2005).

Habitat fragmentation has reduced the Gunnison sage-grouse to seven known populations in Colorado and one population in southeastern Utah (Fig. 1.2). In 2004, the Gunnison sage-grouse population was estimated to be fewer than 3,200 birds; with 2,400 occurring in the Gunnison Basin, Colorado, population (Gunnison Sage-grouse Rangewide Steering Committee 2005). The only known Gunnison sage-grouse population in Utah occurs in San Juan County, Utah, near the town of Monticello. The Monticello, Utah, and the Dove Creek, Colorado, populations are now treated as one population due to genetic similarities and close geographical proximity (Gunnison Sage-grouse Rangewide Steering Committee 2005).

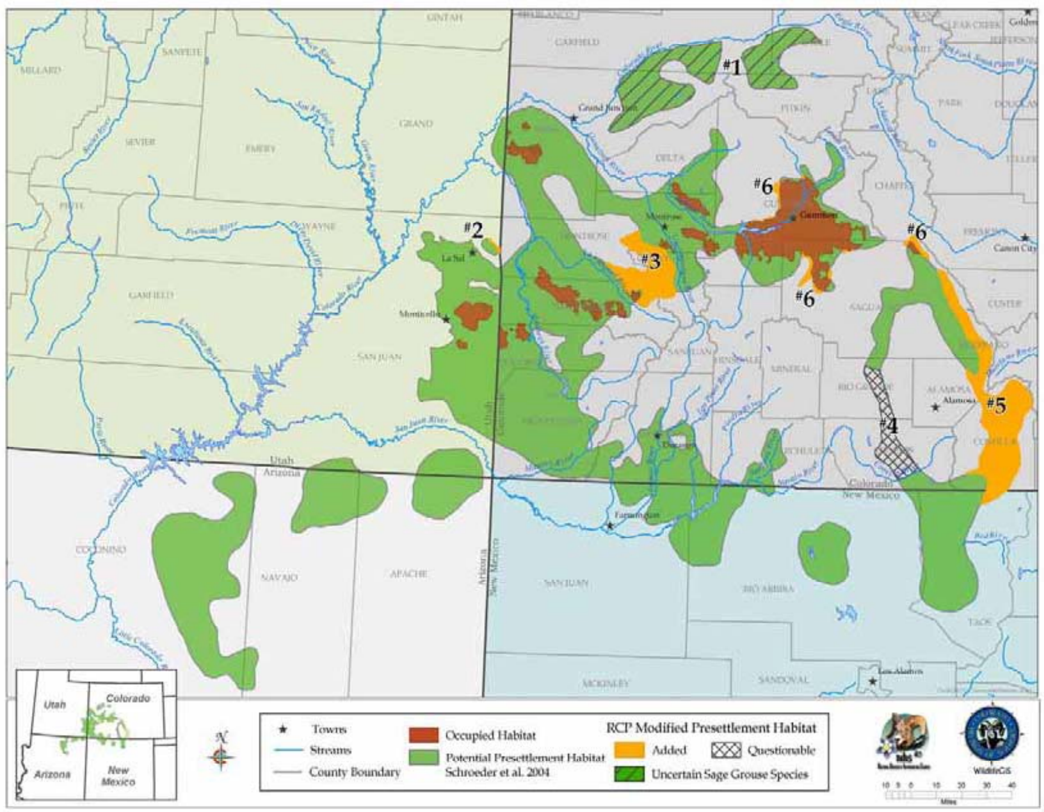

Figure 1.1. Current and historical Gunnison sage-grouse (*Centrocercus minimus*) range (Gunnison Sage-grouse Rangewide Steering Committee 2005).

Species Status and Conservation

Gunnison sage-grouse are considered a species of special concern for management purposes because the rapid decline in the species distribution and abundance

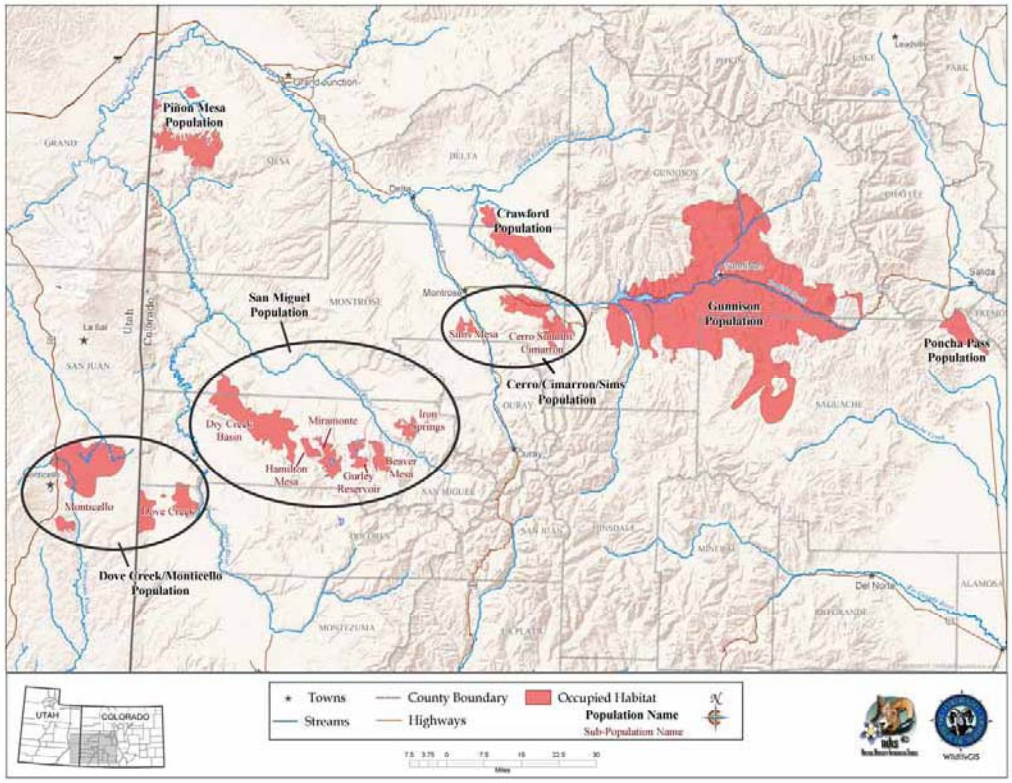

Figure 1.2. Locations of current Gunnison sage-grouse (*Centrocercus minimus*) populations. The discontinuity in occupied habitat at the state line in the Dove Creek/Monticello area is where there is an abrupt change from occupied habitat on the Colorado side to cropland on the Utah side of the border (Gunnison Sage-grouse Rangewide Steering Committee 2005).

has caused the remaining populations to be unusually small and isolated (Oyler-McCance et al. 2005). Identified potential threats to the Gunnison sage-grouse include low genetic diversity, genetic drift from small population sizes, habitat loss, degradation and fragmentation, impacts of drought, predator communities, and the interactions of all these threats (Gunnison Sage-grouse Rangewide Steering Committee 2005). The greatest threat is the loss, fragmentation, and degradation of sagebrush habitats because of urban development and conversion.

Concern about the small population sizes began in the 1990's. In 1995, before the separation of the sage-grouse into two separate species, the first local working group had formed in the Gunnison Basin of Colorado, with a conservation plan created in 1997 (Gunnison Sage-grouse Rangewide Steering Committee 2005). The formation of local working groups and conservation plans for the other populations soon followed. The San Juan County Gunnison Sage-grouse Local Working Group (SWOG) was formed in 1996 with the purpose of implementing management strategies that would conserve the local population (SWOG 2000). SWOG completed the San Juan County Gunnison Sage-grouse Conservation Plan (SJCCP) in 2000. The local working group in Dove Creek, Colorado published a local conservation plan in 1997 with the same purpose.

Continued concerns lead environmental groups to petition the United States Fish and Wildlife Service (USFWS) in January, 2000 to list the Gunnison sage-grouse as endangered (Gunnison Sage-grouse Rangewide Steering Committee 2005). In March, 2000 the USFWS designated the Gunnison sage-grouse as a candidate species for threatened or endangered species status. Under this designation the status of the species was reviewed annually to determine if a listing was still warranted and to determine its listing priority. In 2006 the USFWS ruled to remove the Gunnison sage-grouse from the Candidate Species list.

In 2005, the Gunnison Sage-grouse Rangewide Steering Committee produced the Gunnison Sage-grouse Rangewide Conservation Plan (RCP) to help guide local working groups (Gunnison Sage-grouse Rangewide Steering Committee 2005). In 2006, SWOG merged with the Dove Creek, Colorado, local working group to form the Monticello/Dove Creek Local Working Group (LWG). The merger took place in response to treatment of sage-grouse in Dove Creek and Monticello as one distinct subpopulation in the RCP (Gunnison Sage-grouse Rangewide Steering Committee 2005).

Gunnison Sage-grouse Rangewide Conservation Plan (RCP)

The Gunnison sage-grouse Rangewide Conservation Plan (RCP) was published in 2005 by the Gunnison sage-grouse Rangewide Steering Committee to serve as a guide to aid in the Gunnison sage-grouse conservation efforts (Gunnison sage-grouse Rangewide Steering Committee 2005). The RCP is the first up-to-date and rigorous assessment of the rangewide population and habitat data for the Gunnison sage-grouse. The RCP is intended to supplement local plans and offer a rangewide perspective to help ensure that the cumulative result of conserving local populations is in fact conserving the species. One of the guiding principles of the RCP is to create a plan that will be flexible enough to incorporate Gunnison sage-grouse research findings and successful management practices into conservation actions.

San Juan County Gunnison Sage-grouse Conservation Plan (SJCCP)

The San Juan County Gunnison Sage-grouse Working Group (SWOG) was formed in 1996 to identify and implement community-based conservation strategies to reverse the decline in the Gunnison sage-grouse population in San Juan County, Utah (SWOG 2000). The purpose of SWOG was to develop a conservation plan that could be implemented by state and federal wildlife resource agencies, private landowners, and local governments. Implementation of the San Juan County Gunnison Sage-grouse Conservation Plan (SJCCP) helped ensure local ownership of future management and land use decisions, and respect for private property rights.

The SJCCP was initiated to conserve the species by reducing threats, stabilizing populations, and maintaining ecosystems. It was committed to conserving and enhancing Gunnison sage-grouse populations that occurred on privately owned land in the county and to contribute to the economic viability of farms, ranches and the local community. The SJCCP identified conservation strategies that have been and will continue to be implemented by private and public partners to restore Gunnison sage-grouse habitats and populations. The plan's primary purpose was to conserve the species by implementing voluntary conservation actions.

The SJCCP contained two main parts: Habitat Conservation Assessment and Conservation Strategies. The Habitat Conservation Assessment described SWOG's current understanding about the status of the Gunnison sage-grouse distributions, habitat conditions, and factors that may be affecting the county's population. The Conservation Strategies identified goals and objectives, conservation actions, implementation schedules and responsibilities, evaluation guidelines, and monitoring requirements. The SJCCP was designed to be an adaptive document, capable of being updated with new information, identified issues, and ongoing management and research activities conducted in the county to guide future implementation.

Utah Population Status

The historic range and population size of the Utah population of the Gunnison Sage-grouse is not well documented (Gunnison Sage-grouse Rangewide Steering Committee 2005). Prior to 1968 there is no known written documentation of Gunnison sage-grouse in the Monticello area, but personal accounts of sage-grouse observations from long-time residents indicate that the sage-grouse range extended considerably farther in all directions than the currently occupied area (Fig. 1.3). The Gunnison sage-grouse occur primarily on private land and population declines in the county coincided with land use changes. Lek counts and population monitoring began in 1968. Since 1968, three active leks have been converted from sagebrush to crops or grazed pastures (Gunnison Sage-grouse Rangewide Steering Committee 2005). The number of birds on these leks declined rapidly and the leks were eventually abandoned (Fig. 1.4). In 2003, the population was estimated to be between 100-120 individuals (Gunnison Sage-grouse Rangewide Steering Committee 2005).

Land use in this area changed between 1984 and 1998. These land use changes included declines in non-irrigated agricultural land, black sagebrush (*Artemisia nova*), water areas, pinyon-juniper (*Pinus* spp., *Juniperus* spp.) and big sagebrush (*A. tridentata*), and conversion of land to Conservation Reserve Program (CRP) fields.

In 1997, SWOG designated a Gunnison sage-grouse priority conservation area northeast of the town of Monticello (Fig. 1.5, SWOG 2000). The Conservation Area (CA) contains 1,392,812 ha, 38% (127,170 ha) of which are privately owned. The CA was identified by encompassing historic and current lek sites, potentially suitable sage-grouse habitat, and sage-grouse observations. Within the CA, SWOG identified a Core Conservation Area (CCA) that consists of 136,249 ha, of which 89% (88,420 ha) are privately owned. Within the CCA, a Conservation Study Area (CSA) has been identified. The CSA consists of 24,177 ha, over 93% (22,556 ha) of which is privately owned. The CSA contains the year-round range of the population.

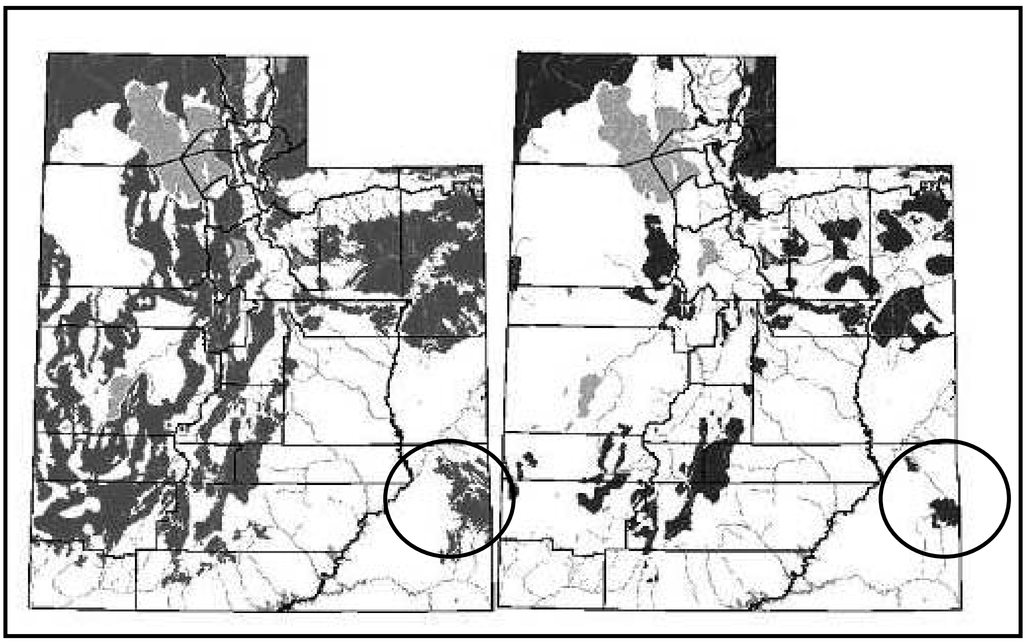

Figure 1.3. Historic (left) and current (right) distribution of Greater sage-grouse (*Centrocercus urophasianus*) and Gunnison sage-grouse (*C. minimus*) in Utah (Beck et al. 2003). Gunnison sage-grouse distributions in San Juan County, Utah are circled.

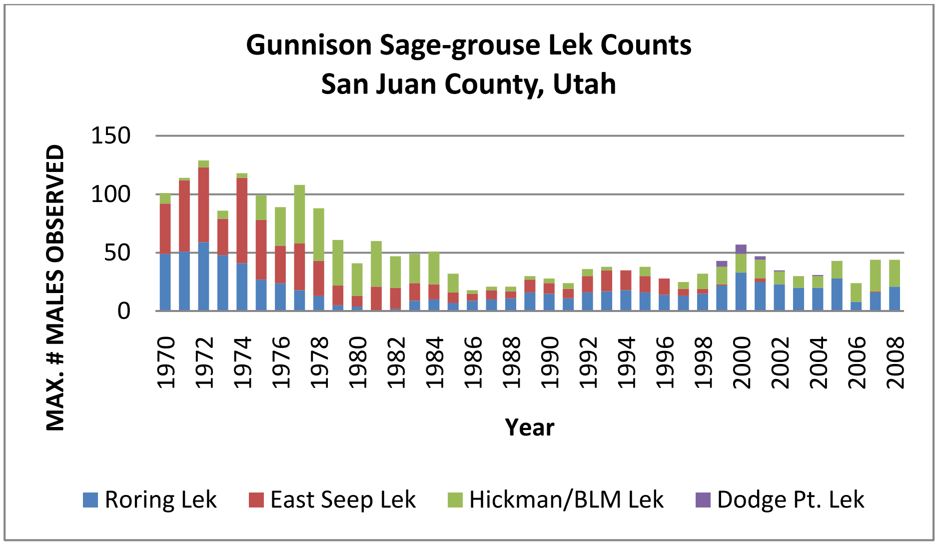

Figure 1.4. Gunnison Sage-grouse (*Centrocercus minimus*) lek counts from San Juan County, Utah. Maximum number of males observed is recorded. Data from Hickman and BLM leks have been combined because of daily movements of males between these two leks (SWOG 2008).

Ecology of the Utah Population

Intensive monitoring of radio-collared Gunnison sage-grouse and their habitats began in 2001 to initiate the process of implementing the SJCCP (SWOG 2003). These studies provided SWOG with information on the basic population ecology and dynamics, habitat use, and the response of the population to management actions. These were the first studies conducted on the Monticello, Utah, population.

Lupis (2005) investigated the movement and habitat use patterns, nesting, brood-rearing and summer habitat use, and factors that might be limiting the San Juan County population in a study conducted from March to September of 2001 and 2002. The objectives of the study were to: 1) Identify and evaluate nesting and brood-rearing habitat

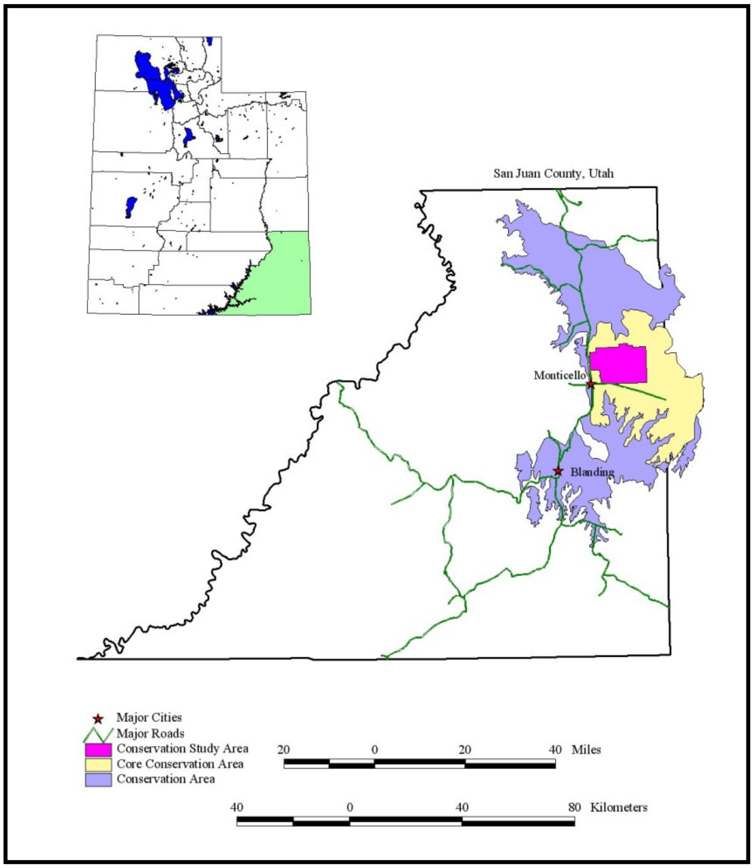

Figure 1.5. Gunnison sage-grouse (*Centrocercus minimus*) Conservation Area, San Juan County, Utah (Lupis 2005).

used by radio-collared hens; 2) Identify and evaluate summer habitat used by radio-collared males and broodless hens; 3) Assess movement patterns, reproductive success, survival, and mortality for radio-collared grouse; and 4) Determine use of CRP lands by Gunnison sage-grouse and their response to management practices. The information gained was compared to that of other Gunnison sage-grouse populations.

Ward (2007) conducted a study from 2002-2004 to determine: 1) reproductive success, survival, and mortalities of Gunnison sage-grouse in San Juan County; 2) nesting and brood-rearing success for Gunnison sage-grouse hens; 3) winter habitat use of Gunnison sage-grouse; and 4) arthropod abundance and diversity related to vegetative composition at nest (sagebrush) and potential brood-rearing sites (CRP lands) for Gunnison sage-grouse hens.

Nesting. - Three nests, located 0.48 km to 3.3 km from the nearest active lek site, were monitored (Lupis 2005). All nests successfully hatched some eggs between 21-23 May, with clutch sizes ranged from 6-10 eggs. Using background research from other populations in combination with the hatch dates from this study, nest initiation was estimated to occur between 25-27 April, with peak mating occurring between 14-16 April. All nests were laid under sagebrush, with one hen nesting in black sage (*A. nova*) and two nesting in CRP/grassland. The dominant shrub at nest sites was big sagebrush (*A. tridentata*), the dominant grass was crested wheatgrass (*Agropyron cristatum*), and the dominant forb was alfalfa (*Medicago* spp.). The height of the nest bush ranged from 21-22 cm.

The SJCCP identifies the breeding complex as all land within two miles of a known lek site (SWOG 2000). The desired vegetation conditions include a canopy cover of 20-40% big sagebrush with an average height of 40 cm, a 30% minimum grass canopy cover, and a 10% minimum forb canopy cover. From 2000-2001 the mean percentages of vegetation cover types at monitored nest sites included 27.5% shrubs, 6% grass and 0.5% forbs (Lupis 2005, Ward 2007). Reference sites randomly selected in black sagebrush and CRP/grassland cover types were composed of 10.4% shrubs, 34.7% grass and 8.8% forbs. From 2003-2004 the mean percentage of vegetation cover types at monitored nest sites included 42.9% shrubs, 2.7% grass and 1.4% forbs, compared to reference sites with 36.8% shrubs, 0.7% grass and 0.4% forbs (Ward 2007).

Brood-rearing. - Two radio-collared hens with broods and one uncollared hen with a brood were monitored for approximately 90 days post-hatch (Lupis 2005). One hen fledged two or three chicks (a final count was unattainable), one hen fledged two chicks, and one hen failed to fledge any chicks. The two broods moved a distance of 2.7 km and 3.0 km from the nest site, with home range size ranging from 3.03 km^2 to 3.54 km^2. The hen with no brood had a home range of 12.6 km^2. Broods preferred CRP/grassland and big sagebrush habitat to any other cover type, such as black sage, bare ground, and grazed lands with little vegetation. Brood locations supported more forb cover, and less grass and shrub cover than reference sites.

The SJCCP identifies the need to establish and maintain a canopy cover of 20-40% big sagebrush, 30% minimum grass canopy cover, and a 10% minimum forb canopy cover in brood-rearing areas (SWOG 2000). In 2001, brood location sites consisted of 6.1% shrubs, 14.8% grass and 9.5% forbs with an average height of 18.8 cm (Lupis 2005, Ward 2007). In 2002 the vegetation characteristics of brood locations consisted of 2.8% shrubs, 5.7% grass and 1.7% forbs with an average height of 12.2 cm. The percent cover types for reference sites consisted of 10.4% shrubs, 34.7% grasses, and 8.8% forbs.

From May to August of 2003 and 2004 female Gunnison sage-grouse were monitored to determine nest site selection and nest success (Ward 2007). Vegetation characteristics and arthropod abundance and diversity were collected in sagebrush cover types and compared with random CRP sites. The CRP fields yielded a greater forb and grass cover than other habitats. Seventy-five percent of the bird habitat use locations and 60% of the total number of arthropods collected were in CRP fields. A larger number of arthropod families were found within CRP fields than other habitats. A higher number of arthropods were collected in 2004 than 2003 possibly because the higher amount of precipitation that year contributed to more vegetation growth. In San Juan County CRP appears to serve as a substitute habitat for arthropod populations in lieu of irrigated pastures, and wheat and bean fields. It now appears to provide critical seasonal use for grouse. Because of this, it has become a conservation priority for continued enrollment and management of current CRP fields and the enrollment of other fields in the program.

Males and Broodless Hens. - Radio-collared males and hens without broods used similar habitats to those utilized by hens with broods described above (Lupis 2005). Males remained within 3.6 km of the lek of capture and selected CRP/grassland and big sagebrush habitats in preference to the other cover types available. Broodless hens selected woodlands, CRP/grasslands and rangelands, and remained within an average of 4.4 km of the lek of capture, but one hen moved a distance of 7.4 km. Birds captured on the Hickman Flat lek were found in mixed-sex flocks of two to eighteen individuals. Birds captured on the Roring lek remained in single-sex flocks of one to sixteen individuals.

Winter. - In the winter of 2002-2003 the Gunnison sage-grouse used black sagebrush and big sagebrush with a canopy cover of 15-25% more than expected based on availability (Ward 2007). In the winter of 2003-2004 black sagebrush and big sagebrush within CRP were selected in greater proportion based on availability. Shrub height at bird locations ranged from 17.8-91.4 cm. The ideal combination appeared to consist of black sage intermixed with patches of Wyoming big sagebrush. Black sage only occupies 7% of the eastern portion of the area occupied by the population and it was discovered that the majority of the radio-collared birds moved to the eastern side of the study area to winter in the black sage area. The distance traveled between summer and winter habitats for adult grouse ranged from 0.3 to 5.6 km for males, and 2.5 to 8.2 km for females. Average winter home range for males was 2.5 km^2 and 3.0 km^2 for females. Flock sizes were found to be between two and thirty plus individuals.

Suitable winter habitat appears to be limited in the area occupied by the Gunnison sage-grouse population. Because of this, conservation efforts should be directed at preserving and enhancing the remaining black sage patches and establishing additional areas of Wyoming big sagebrush and black sage within CRP fields throughout the study area. The SJCCP calls for the establishment of vegetation conditions on 50% of the areas within the CSA and 25% of the buffer area around the CSA (SWOG 2000). The desired conditions stated within the plan consist of a minimum 15% canopy cover of big sagebrush averaging a height of 30 cm on south and west facing slopes interspersed with small areas of dense big sagebrush with a canopy cover of 40% and an average height of 40 cm. Drainages should support a minimum canopy cover of 30% big sagebrush with an average height of 50 cm.

STUDY PURPOSE

This study addressed three conservation strategies identified in both the RCP and SJCCP. The first conservation strategy addressed was the creation or enhancement of brood-rearing habitats. I attempted to create or enhance brood-rearing habitats using irrigation and dormant season cattle grazing. My objective was to evaluate the effect of irrigation and dormant season cattle grazing of CRP fields and native sagebrush fields on sage-grouse productivity potentials as measured by changes in vegetation composition and structure, arthropod diversity and abundance, and bird use.

The second conservation strategy I addressed was the assessment of vegetation conditions and habitat quality of current and historical Gunnison sage-grouse habitats in Utah. My objective was to collect vegetation data in occupied and potential habitats as identified in the RCP and SJCCP to assess the status of existing and potential Gunnison sage-grouse habitat in the CA. Managers will be able to use this information to quantify the relative contribution of occupied and potential habitats to the overall RCP goals. This information can also be used to update the current SJCCP and the information in the RCP and prioritize conservation efforts.

The RCP and SJCCP also identified the presence of man-made vertical structures such as power poles and fence lines as a threat to Gunnison sage-grouse conservation. Connelly et al (2000) reported that vertical structures in areas occupied by sage-grouse provide raptors and corvids with new perches that could result in increased predation on adults, chicks, and nests. The RCP and SJCCP recommended as a conservation strategy that power poles within areas occupied by Gunnison sage-grouse be fitted with deterrents to discourage perching by potential sage-grouse avian predators. However, little information was currently available regarding the efficacy of commercially available perch deterrents. To address this management need, I evaluated the effectiveness of five types of perch deterrents in the reduction or prevention of corvid and raptor perching events on poles of a power distribution line with the objective of determining if raptor or corvid use of the distribution line differed by perch deterrent type and/or control.

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CHAPTER 2

EFFECT OF IRRIGATION AND DORMANT SEASON CATTLE GRAZING ON VEGETATION DIVERSITY AND ARTHROPOD ABUNDANCE IN CONSERVATION RESERVE PROGRAM AND NATIVE SAGEBRUSH IN SAN JUAN COUNTY, UTAH

ABSTRACT Gunnison sage-grouse (*Centrocercus minimus*) populations currently occupy 4,787 km^2 (8.5% of the original range) in Colorado and Utah. Declining populations are characterized by reduced recruitment attributed to breeding habitat (lekking, nesting, and brood-rearing) loss and fragmentation. Increased availability of forbs and arthropods in brood-rearing habitats has been positively associated with survival and recruitment of sage-grouse chicks. Concomitantly, the Gunnison Sage-grouse Rangewide Conservation Plan (RCP) and the San Juan County Gunnison Sage-grouse Conservation Plan (SJCCP) identified protection and enhancement of mesic brood-rearing habitats as a priority conservation strategy.

From 2007-2009, I evaluated Gunnison sage-grouse use, vegetation and arthropod responses to irrigation and dormant season cattle grazing on 32 randomly selected 0.1 ha plots, with 12 plots located in agricultural lands enrolled in the Conservation Reserve Program (CRP) and 12 plots in a native sagebrush area. Specifically, I evaluated the role of irrigation and dormant season cattle grazing in creating mesic wet meadow environments and their effect on habitat quality as measured by changes in vegetation structure and composition, arthropod abundance and diversity, and sage-grouse use. Vegetation in the irrigated plots remained greener longer through the growing season

than in the non-irrigated plots, but vegetation diversity did not differ ($p>0.01$). Overall, the CRP plots exhibited greater arthropod abundance and percent cover of perennial grass than the native sagebrush plots, but lower diversity of perennial grasses and abundance and diversity of forbs ($p<0.01$). Crested-wheatgrass (*Agropyron cristatum*) was the dominate vegetation in CRP and may have out-competed native forbs. Dormant season grazing of CRP did not have a positive or negative effect on crested wheatgrass cover. Lastly, I did not detect any increased sage-grouse use of the treatment plots.

The sprinkler irrigation system used in this study allowed quantification of water application rates leaving the nozzle but not actual application rates because of frequent winds that resulted in non-uniform plot coverage and increased evaporation. Thus, creation of mesic areas in brood-rearing habitats may best be accomplished by a system of terraces, ditch plugs or small check dams that retain moisture longer, and by providing flood irrigation. To increase forb and grass diversity in CRP, managers should evaluate the use of mechanical treatments, coupled with spring grazing, and reseeding to mitigate the potential competitive effects of crested wheatgrass.

INTRODUCTION

Connelly et al. (2000) identified several factors contributing to the continued decline of sage-grouse (*Centrocercus* spp.) populations range-wide. Of these, the loss, degradation, and fragmentation of the sagebrush (*Artemisia* spp.) ecosystem remain paramount. As sagebrush obligates, sage-grouse require this habitat type to complete their life cycle. The structure and composition of plant communities within sagebrush ecosystems influence sage-grouse nesting, breeding, brood-rearing, fall, and winter habitat selection.

Gunnison sage-grouse (*C. minimus*) currently occupy 4,787 km^2 (8.5% of their original range) in Colorado and Utah. The Gunnison Sage-grouse Rangewide Conservation Plan (RCP) and the San Juan County Gunnison Sage-grouse Conservation Plan (SJCCP) recommend management strategies to conserve the species by restoring impacted habitats (SWOG 2000, GSRSC 2005). Both plans identified the lack of brood-rearing habitat as limiting sage-grouse productivity and recommended the creation of mesic areas for broods as a priority conservation strategy.

Sage-grouse Brood-rearing Habitats

Good brood-rearing habitat includes areas with an abundant diversity of forbs and insects high in calcium, phosphorus and protein, and the availability of herbaceous plant species during the late-growing season (Peterson 1970, Wallestad 1971, Klott and Lindzey 1990, Johnson and Boyce 1990, Sveum et al. 1998, Connelly et al. 2000, Crawford et al. 2004). The quality of brood-rearing habitats changes as summer progresses and food availability shifts. The habitats tend to become more xeric resulting in desiccation of forbs. Increased sage-grouse brood use of wet meadow areas has been related to the amount of desiccation occurring.

Wallestad (1971) documented the summer movements and habitats used by broods in central Montana. He observed that hens with broods occupied areas characterized by mixed sagebrush and open areas exhibiting succulent forbs and clumps of tall sagebrush for hiding and roosting cover. As the season progressed into late August and early September the broods shifted to areas where sagebrush was more common and dense. He concluded that large tracts of dense sagebrush appeared to have little value as sage-grouse brood habitat, even though it is essential as winter habitat. Peterson (1970) and Klott and Lindzey (1990) reported that an important component of juvenile sage-grouse habitat appears to be an abundance and diversity of forbs with sagebrush cover <20%. Broods used areas with less shrub cover than what was average for that habitat.

Crawford et al. (2004) suggested that the availability of forbs and invertebrates is positively associated with survival and recruitment of chicks. Johnson and Boyce (1990) conducted a study on captive-reared sage-grouse chicks and the influence of insect reduction in their diet on survival. They reported a correlation between the quantity of insects in the diet and chick survival and growth. Chicks less than 21 days old needed insects to develop and survive. All chicks hatched in captivity that were not given insects died between the ages of 4 and 10 days. Insects decreased in the diets of chicks >21 days of age but were still required for optimum development.

The diets of broods in Oregon included 34 genera of forbs and 41 families of invertebrates (Drut et al. 1994). Klebenow and Gray (1968) recorded weekly diet selection data for age classes of sage-grouse chicks from hatch until brood break up at eight to ten weeks of age. During the first week insects were predominant, composing 52% of the total diet. After the first week, insects decreased in importance but were still part of the diet. As insects decreased, forbs became the most important food source for chicks. At four weeks, as plants began to dry, sagebrush appeared in the diet in small amounts, progressively increasing as the season progressed and the availability of forbs decreased. Similar findings were also reported by Peterson (1970).

Drut et al. (1994) quantified the importance of forbs and invertebrates in sage-grouse productivity in Oregon. They reported higher productivity in a population where 80% of the dietary mass in chicks diets consisted of forbs and arthropods compared to another study area where chick diets consisted of 65% sagebrush. Sveum et al. (1998) suggested a brood that needs a larger home range due to limited availability of forbs may also have a lower survival rate than a brood using a smaller area exhibiting a greater abundance in forbs.

Gunnison Sage-grouse Brood-Rearing Habitat in Utah

In 1997, the San Juan County Gunnison Sage-grouse Local Working Group (SWOG) designated an area northeast of the town of Monticello, Utah, as a sage-grouse priority conservation area (SWOG 2000). The Conservation Area (CA) consisted of 1,392,812 ha, 38% (127,170 ha) of which is privately owned. The CA was identified by encompassing historic and current lek sites, potentially suitable sage-grouse habitat, and sage-grouse observations. Within the CA, SWOG identified a Core Conservation Area (CCA) that consisted of 136,249 ha, of which 89% (88,420 ha) is privately owned. Within the CCA, a Conservation Study Area (CSA) was identified. The CSA consisted of 24,177 ha, over 93% (22,556 ha) of which is privately owned. The CSA contains the year round range of the Utah population.

The SJCCP stated that the desired brood-rearing habitat conditions should include a canopy cover of 20-40% sagebrush with an average height of 40 cm, a minimum of 30% grass canopy cover, and a minimum of 10% forb canopy cover. The SJCCP further recommended that the height of the vegetation in wet meadow areas is to be greater than 10 cm between 15 June and 31 July on over 75% of the area considered to be brood-rearing habitat.

The Farm Program and Sage-grouse Conservation

Because over 90% percent of the habitat occupied by Gunnison sage-grouse in San Juan County is privately owned, the implementation of the Conservation Reserve Program (CRP) under the Food Security Act of 1985 was recognized by SWOG as a major species conservation action. The CRP is a voluntary program that provided financial incentives to encourage private landowners to retire cropland from agricultural production by establishing an approved permanent vegetation cover. During the period of the contract, the land could not be cultivated to produce an agricultural commodity. Haying and grazing were allowed on a case-by-case basis to mitigate the effects of drought on local livestock producers. The only techniques allowed to manage CRP fields are burning, spraying for noxious weeds, and mowing.

The Farm Security and Rural Investment Act of 2002 (Farm Bill) reauthorized the Environmental Quality Incentives Program (EQIP) to provide a voluntary conservation program for farmers and ranchers that promotes agricultural production and environmental quality. This program offered financial and technical help to assist eligible participants to install or implement structural and management practices on eligible agricultural land. This study used management practices within EQIP that could be employed by landowners in the CCA to enhance sage-grouse brood-rearing habitat through the creation of mesic environments. These environments could potentially increase forb cover and arthropod diversity in existing CRP fields and provide important seasonal habitats for sage-grouse broods.

Land Use Changes in San Juan County and Gunnison Sage-grouse

Gunnison sage-grouse population declines in San Juan County have coincided with land use changes. The population was at its highest in the 1970s and 1980s (SWOG 2003, Lupis 2005). During this period, the primary agricultural crops in the county were winter wheat (*Triticum* spp.) and dryland alfalfa (*Medicago* spp.). Many growers did not use herbicides or insecticides because of the slim profit margin in growing these crops (J. Keyes, Utah State University Extension, personal communication). These practices may have resulted in a greater arthropod abundance as a result of increased green vegetation and forb availability. During this period landowners also frequently reported observing flocks of grouse in their fields during harvest and post-harvest periods.

In the past, many landowners in San Juan County did not have automatic control valves on wells used to fill livestock water tanks (SWOG 2000). This would cause tanks to overflow, inadvertently creating mosaics of ephemeral wet meadow or mesic habitats below the tanks. These overflow areas were not grazed by livestock until late fall when the herds were moved to winter pasture. Landowners reported these holding corrals continually produced more forage, greened-up earlier, stayed greener longer than adjacent areas, and often supported sage-grouse broods. The SWOG believed this activity enhanced Gunnison sage-grouse productivity (SWOG 2000). But with more efficient watering devices the seasonal wet meadows disappeared. The SWOG believed that the loss of these wet meadow or mesic sites in brood-rearing areas could be a potential reason for low sage-grouse numbers and low recruitment because the quality and quantity of herbaceous cover has been reduced.

CRP and Sage-grouse

One of the most comprehensive land use changes to occur in the county was the conversion of thousands of hectares of cropland to CRP. Because of drought conditions many of these CRP fields had to be reseeded, and thus were devoid of vegetation for almost two years (G. Wallace, Utah Division of Wildlife Resources, personal communication). In the two years post-CRP signup the number of males counted on lek sites decreased by 50%.

In 1997 the habitat for the San Juan County population was designated as a priority conservation area for the species (Lupis 2005). This designation increased the amount of land that could qualify as CRP, adding an additional 150 km^2 of land enrolled in the program (Fig. 2.1). However, based on lek counts, the San Juan County population is at a historic low with a 2004 population estimate of 155 to 174 birds (SWOG 2005). Research suggested that CRP habitats appear to provide the greatest arthropod abundance

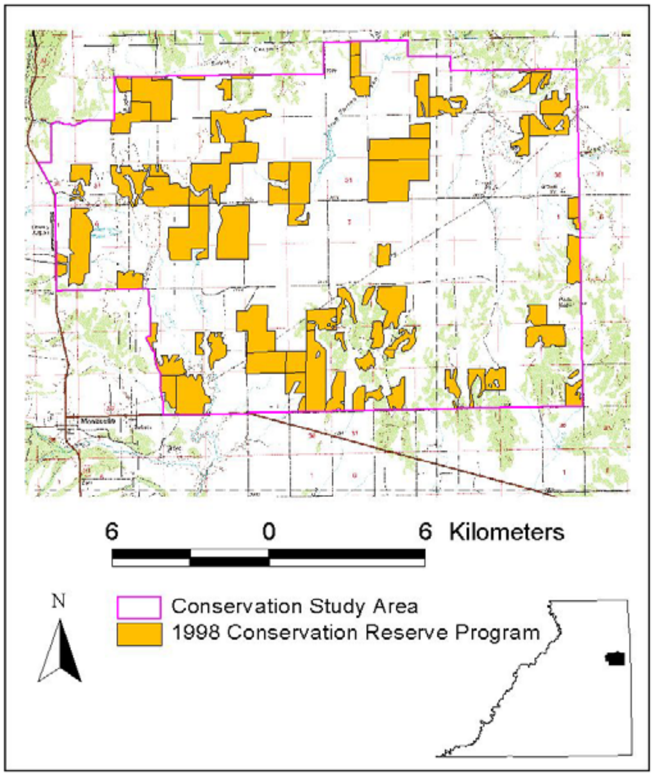

Figure 2.1. Agricultural lands enrolled in the Conservation Reserve Program under the conservation priority initiative in the Conservation Study Area, San Juan County, Utah (Lupis 2005).

(Lupis 2005, Ward 2006). These CRP fields are also preferred over other cover types during the brood-rearing period (Lupis et al. 2006).

Beginning in late 2001, San Juan County experienced a major drought. In response to drought conditions, the FSA opened CRP for late season grazing. Grazing was allowed on several CRP fields in the CSA. Lupis (2005) investigated the effects of domestic livestock grazing of the CRP fields on the movement patterns of Gunnison sage-grouse.

Three males, 2 broodless hens, and 1 hen with a brood were monitored before, during, and after grazing. Males avoided the grazed CRP fields during grazing and did not return after the livestock were removed. Two of the males were located within a CRP field during grazing 15-20% of the time, and 1 male was recorded in a grazed field 40% of the time. Broodless hens also avoided CRP fields during grazing to varying degrees. One hen was in a CRP field during grazing 78% of the time, 1 female 12.8% of the time and returned twice after livestock was removed, and 1 hen was never located within a CRP field during or after grazing. The monitored brood remained within the CRP field during grazing and successfully recruited 2 chicks into the fall population.

STUDY PURPOSE

This study addressed the RCP and SJCCP conservation strategy of evaluating methods to create or enhance brood-rearing habitats. The specific objectives of my research were to evaluate; 1) the role of irrigation in CRP and native sagebrush on sage-grouse habitat potentials as measured by changes in vegetation composition and structure, arthropod diversity and abundance, and bird use; and 2) the role of dormant season cattle grazing on these same potentials.

STUDY AREA

The study was conducted in San Juan County, located in the extreme southeastern corner of Utah (Fig. 2.2). The county is bordered by the Colorado River to the north and west, Arizona to the south, and Colorado to the east. The CSA is part of the Colorado Plateau Province and sits on the extensive Sage Plains tableland on the northeast side of the Abajo Mountains with an elevation between 2,042 m and 2,133 m (Olsen et al. 1962). The surface of the plateau consists of undulating to rolling, low hills of eolian deposits of variable thickness derived from sandstone over colluvium and/or residuum weathered from sandstone. The area is characterized by large grass pastures and agricultural fields interspersed with fragmented patches of Wyoming big sagebrush (*A. tridentate* spp. *wyomingensis*) and black sagebrush (*A. nova*). There are no perennial water sources on the plateau. The CSA consists of 95% privately owned land, most of which is currently enrolled in CRP. The remaining privately owned lands are used as rangeland pastures for cattle grazing or dryland farming.

Long term (1902-2009) precipitation and temperature for the CSA was summarized from local weather station data archived by the Utah Climate Center, Logan, Utah. Precipitation and temperature measurements for the study period (2007-2009) are summarized from data recorded on a portable weather station. The long-term average annual precipitation (1902-2009) in the study area was 39.55 cm, with most arriving from July to October in the form of rain. The mean annual high and low temperatures on the study area were 35.9° C and -21.2° C, respectively. From 2007-2009 the average annual precipitation on the study area was 30.23 cm, with average annual high and low temperatures of 37.5 ° C and -18.3 ° C, respectively.

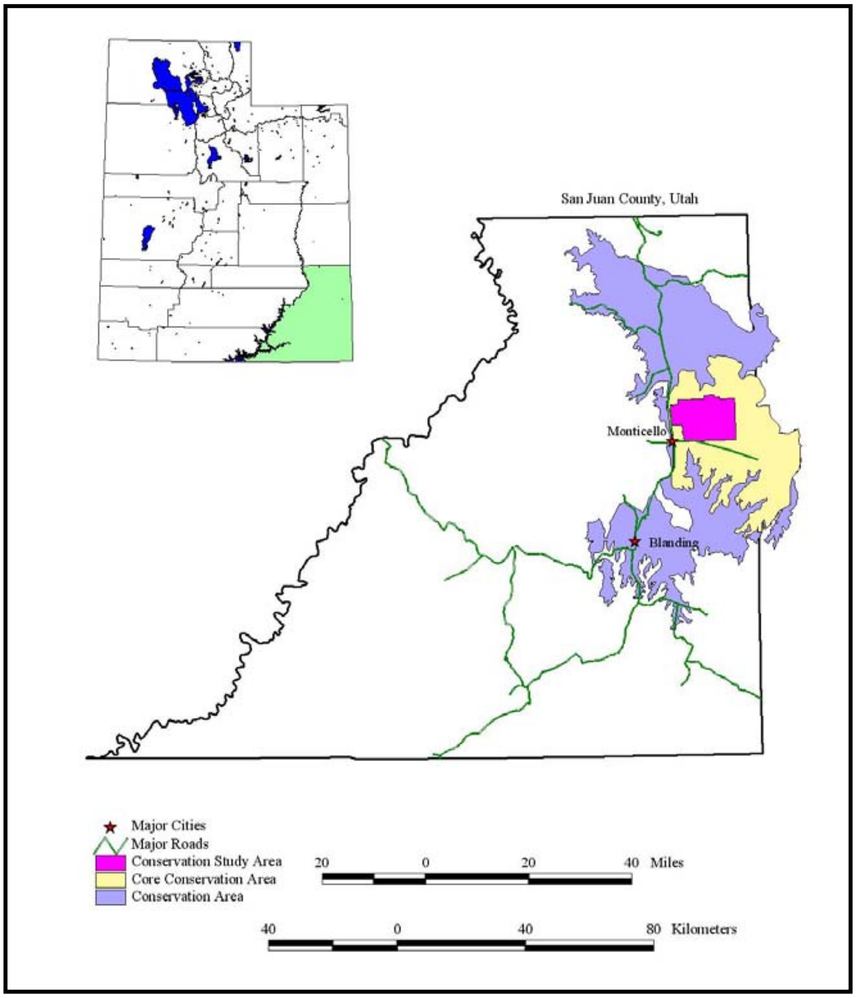

Figure 2.2. Gunnison Sage-grouse Conservation Area, San Juan County, Utah (Lupis 2005).

The CSA is relatively flat with elevations ranging from 2,065-2,149 m. The CSA is a mosaic of habitat types dominated by CRP/grassland and sagebrush cover types (SWOG 2000). The original seed mixture for the CRP fields and the plant species recorded within the CRP and sagebrush plots during this study can be found in

Appendices A and B, respectively. The dominant forb species recorded in the sagebrush plots were scaly globemallow (*Sphaeralcea leptophylla*), sulphur buckwheat (*Eriogonum umbellatum*), hairy golden aster (*Heterotheca villosa*), and cryptantha (*Cryptantha* spp.). Few plants from the original CRP seed mixture were found in the CRP plots. The dominant species in the CRP plots was crested wheatgrass (*Agropyron cristatum*) with occasional patches of Wyoming big sagebrush and rubber rabbitbrush (*Chrysothamnus nauseosus*). Dominant forb species within the CRP plots were Russian knapweed (*Centaurea repens*), African mustard (*Malcomia africana*), and Russian thistle (*Salsola pestifer*). Forbs within Wyoming big sagebrush patches in CRP plots were the same as those found in the sagebrush plots. Cheatgrass (*Bromus tectorum*) was present in both CRP and native sagebrush plots.

METHODS

Experimental Design

I identified one study site in a native sagebrush area and one study site in a CRP field, both sites within the CSA. I identified 16 0.1 ha plots in each study site. I arranged the plots in an experimental randomized block design that controlled for differences in vegetation and landscape topography that could affect the vegetation present at each plot. Each plot was considered a separate experimental unit. At each site, the plots were arranged in 4 blocks, with each block consisting of 4 plots (Fig. 2.3). Within a block, each plot was randomly assigned to one of the 3 irrigation treatments or control. Half of each plot was grazed by cattle. Vegetation transects and arthropod trapping grids were established in both halves of each plot to measure the effects of irrigation and irrigation combined with grazing. This layout resulted in four replications of each irrigation and grazing treatment and control in each habitat.

Irrigation

I evaluated 3 irrigation treatments base on application rates: once a week, every 2 weeks and every 3 weeks. Plots receiving no water served as reference or control sites. Plots were randomly assigned to each irrigation treatment or control within each block. Three groundwater wells in close proximity to the identified treatment plots were used to distribute water to each plot for irrigation. Treatment plots were irrigated with a Rain Bird sprinkler model 65PJ™ with a 30 meter spraying radius (Rain Bird Corporation, Azusa, CA). The treatment and control plots were established in the summer of 2007. Given that there were site-specific differences, we conducted tests before the study began to standardize the capacity of the pumps at each treatment plot. During this period I measured the amount of water distributed on each plot by time. These experiments allowed us to establish a standard rate of flow. Irrigation of the plots began in May 2007 and continued to the end of July. This time period coincided with peak nesting and brood-rearing periods (Lupis 2005, Ward 2006).

All plots were irrigated for an 8-hour period. Due to strong afternoon winds, the irrigation periods occurred in the early morning and evening. Each plot assigned to an irrigation treatment received 1.4 cm of water each irrigation period, the equivalent of the

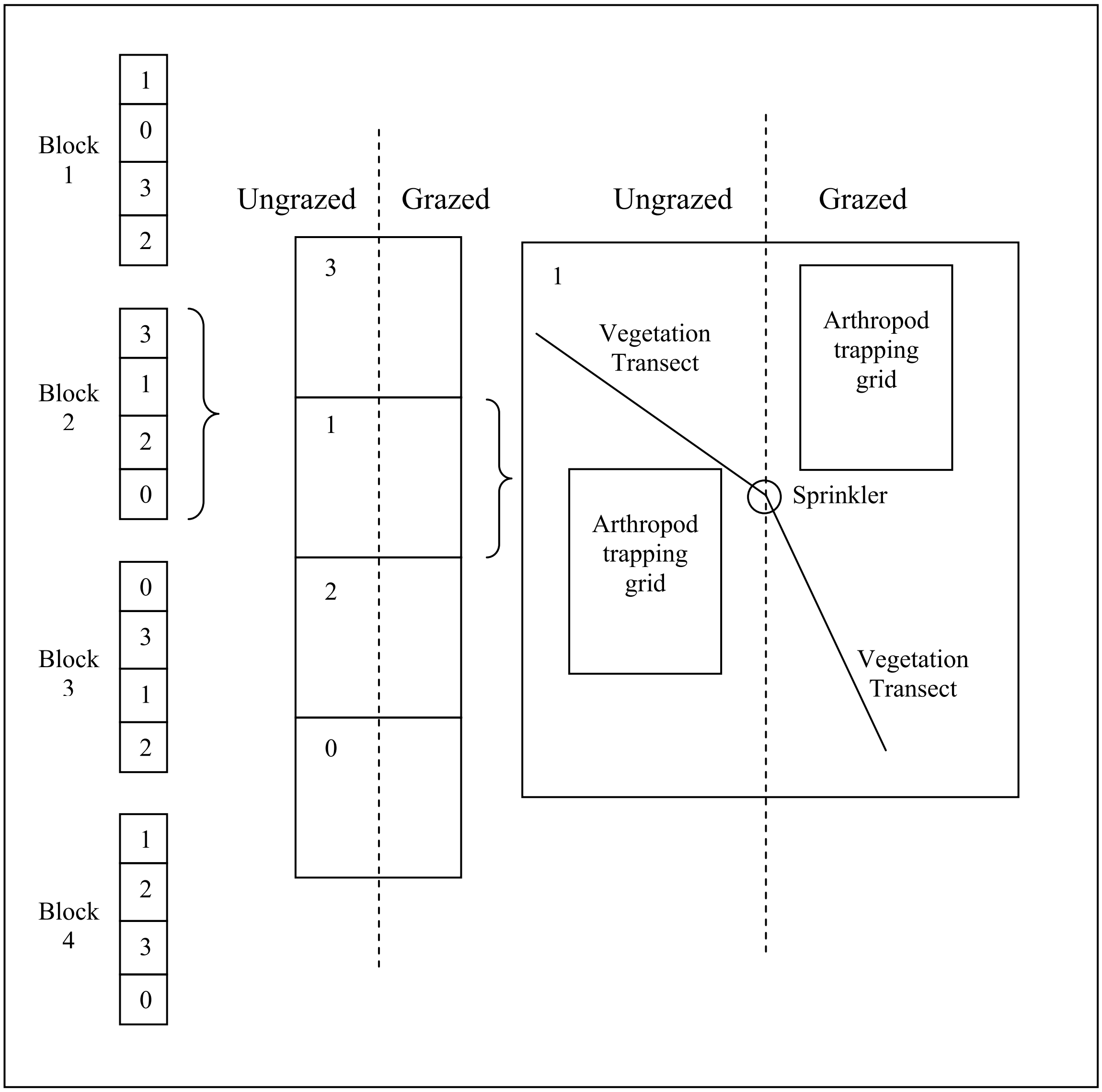

Figure 2.3. Experimental design schematic showing the layout of 4 blocks each containing 3 plots randomly assigned to watering treatments (once a week, every 2 weeks, every 3 weeks) and 1 control (no water) plot, ungrazed and grazed treatments, and location of arthropod trapping grid, vegetation transects, and rain-bird sprinkler. Each 4 block layout occurs within the Conservation Reserve Program and native sagebrush study sites. San Juan County, Utah, 2007-2009.

long term average precipitation this area receives in the months of May, June, and July. Within both CRP and sagebrush sites, the plots that were irrigated weekly over the 7-week period received the equivalent of an additional 10.2 cm of water as measured on test gauges. The plots that were irrigated every two weeks or 4 times over the 7-week period received the equivalent of 5.1 cm of additional water. The plots irrigated every three weeks or 3 times over the 7-week period received the equivalent of 3.8 cm of additional water. The irrigation occurred in May-July of 2007, 2008, and 2009.

Vegetation Monitoring

I used the GSRSC Structural Vegetation Collection Guidelines (SVCG) to measure vegetation parameters (GSRSC 2007). At each site, each treatment and control plot contained one 30-meter vegetation transect. Transects were permanently marked with t-posts with the same transects used in consecutive years. Percent canopy cover of grasses, forbs, and shrubs was visually estimated by placing a Daubenmire frame every 3 m along each 30-m transect (Daubenmire 1959). The SVCG identified six cover classes based on the standardized Daubenmire method. The Daubenmire method lumped too much vegetation into the 5-25% class for the Gunnison sage-grouse vegetation variables, so it was into 2 cover classes. The canopy cover classes used in this study were: 0-5%, 5-15%, 15-25%, 25-50%, 50-75%, and 75-100% (GSRSC 2007).

One height measurement of sagebrush, forb, annual grass, and perennial grass was taken at each Daubenmire frame by selecting the plant closest to the lower left hand corner of the frame. If sagebrush was not found within the frame then the closest sagebrush within 10 m of the frame was used. If no sage was within 10 m of the frame it was marked as not present. Only forbs and grasses within the frame were used to measure height. If no forb or grass was within the frame the plant group was marked as not being present. Height and percent cover of grasses, forbs and shrubs was measured in early June and again the last week of July.

Vegetation was clipped and weighed to measure the forage production of each plot using a 0.5m x 1m frame. All vegetation within the frame was clipped, stored in paper bags, dried, and weighed. The vegetation was separated into the categories perennial grasses, annual grasses, and forbs. Vegetation was clipped along a 30 m transect radiating from the center sprinkler. Frames were placed every 3 m, resulting in 10 frames. A different transect was used each year to prevent clipping the same location more than once. The clipping transect did not overlap the permanent vegetation monitoring transect. Forage production was measured the last week of July.

Any uncertainties in identification of a plant species were documented with photos and pressings. The same survey method and transect lines were used during the collection of data in 2007, 2008, and 2009 to evaluate the effectiveness of treatment plots in increasing grass and forb abundance and diversity.

Arthropod Surveys

Terrestrial arthropods were sampled by using pitfall traps arranged in a pattern that allowed capture data to be used with DISTANCE software to estimate density of total arthropods and of individual taxa (Buckland et al. 2001, Lukacs et al. 2004, Graham et al. 2008). Pitfall traps in each plot were arranged to meet the assumptions of DISTANCE sampling, which are that all invertebrates on the center line are detected and that distances from the center line are accurately measured. Sixty pitfall traps were used at each plot in the arrangement shown in Fig. 2.4. This pattern was generated by using WebSim to simulate a hazard-rate model of invertebrate captures that resulted in estimates with small confidence intervals, and matched trapping results in a pilot study of invertebrate pitfall trapping in Colorado (Lukacs 2001, 2002; Graham et al. 2008).

Pitfall traps were placed by carefully measuring and marking correct locations with flags, then digging in the traps. Pitfall traps were constructed as described by New (1998). For each trap, a 1.5-liter plastic jar was buried below ground level and a 500-mL cup containing 125 mL of soapy water was placed in the cup (Graham et al. 2008). A 15-cm diameter funnel was placed over the jar, centered over the cup, with the top of the funnel at ground level. Each water treatment and grazing treatment plot in each of the sagebrush and CRP habitats contained a pitfall trapping arrangement with 60 traps. I sampled in early June, during the estimated first week after hatch for Gunnison sage-grouse nests in San Juan County, Utah (Lupis 2005, Ward 2006). The traps were opened in sequence and remained open for three days during a 7-day period. When closed, each trap was poured into a 150 mL sample container with the remaining space filled with 91% isopropyl alcohol to assure the sample was stored in a 70% isopropyl alcohol and water solution. Labels affixed to the outside of the sample containers recorded habitat, plot number, treatment, date, and trap number. Samples were stored at room temperature once they were returned to the lab.

In the lab, each sample was washed through a 0.5-mm mesh net (Graham et al. 2008). Everything remaining in the net was placed in a Petri dish. Arthropods were sorted to order. Taxa were identified following Triplehorn and Johnson (2005), and I followed the taxonomic nomenclature of this source. I collected 3,840 total samples each year in 2007, 2008, and 2009. Because of logistical constraints only 2,240 samples were sorted for each year resulting in 35 traps sorted for each trapping arrangement.

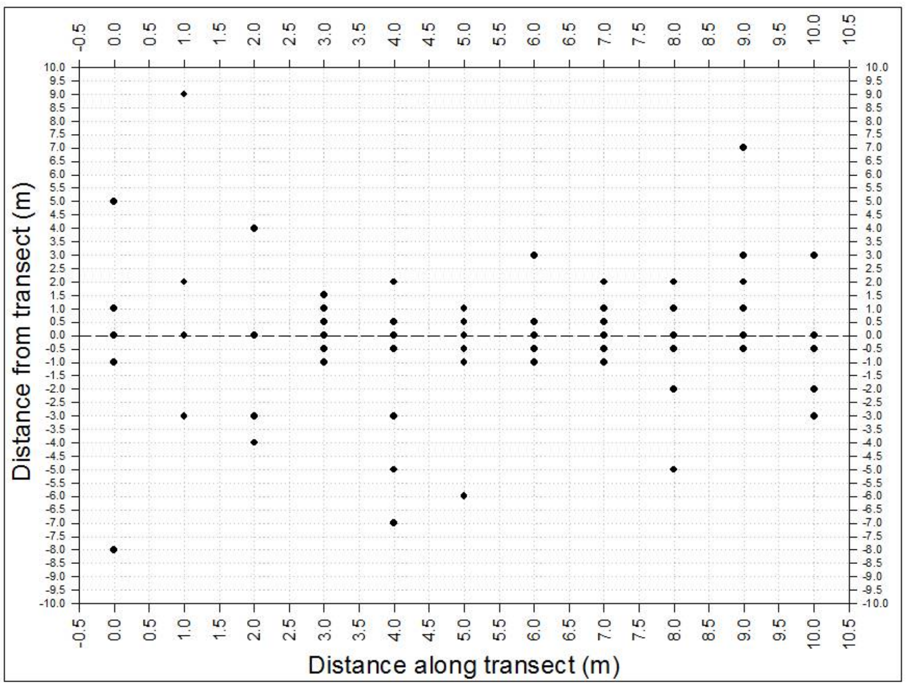

Figure 2.4. Arrangement of pitfall traps at each terrestrial arthropod sampling plot of the study, San Juan County, Utah, 2007-2009 (Graham et al. 2008).

Sage-grouse Pellet Counts

Pellet counts were used to survey sage-grouse use of the treatment and control sites in each habitat (Dahlgren 2005). I established 20 transects two meters apart in each plot. Information collected included pellet type (cecal or regular pellet) and number of pellets or cecal droppings per cluster. Roost piles were counted separately and equaled one cluster occurrence. Once a pellet was counted it was removed from the site to prevent double counting.

Dormant Season Cattle Grazing

Both CRP and sagebrush plots were grazed in November of 2006, 2007, and 2008. Utilization was measured using a paired-plot design. Utilization cages were randomly placed on the grazed portion of each plot, resulting in 32 cages (USDI-BLM 1996). After grazing, forage within each cage was clipped and weighed. A random uncaged plot was identified on the grazed side of the plot and forage within this plot was also clipped and weighed. The difference between the 2 weights equaled the amount of forage consumed. Random plots were also identified on the ungrazed sides of each site and forage was clipped and weighed to determine the amount of forage production. Annually, 60% utilization was achieved each fall grazing occurred.

DATA ANALYSIS

I used a 3-way factorial split-split plot design with whole plots arranged in randomized complete blocks with repeated measures to analyze habitat metrics. The whole block unit included 4 plots, one of each 3 irrigation treatments and a control. The whole block factor was whether the plot was CRP or sagebrush. The split plot unit was the individual plot. The split plot factor was the irrigation assignment. The split-split plot unit was half of each plot. The split-split plot factor was whether the half was grazed or un-grazed. The repeated measure unit was the individual plot. The repeated measure factor was the month the vegetation was measured (June or July).

I addressed the question: Did the vegetation and arthropod communities change in relation to water and grazing treatments in CRP and sagebrush plots in 2007, 2008, and 2009? The model I used compared the means among treatments and controls for the percent cover, height and forage production of perennial grasses, annual grasses, forbs and sagebrush, and arthropods observed in 2007, 2008, and 2009. I used a mixed model with an arcsine-square root scale (SAS Institute, Cary, NC). In essence, the statistical model was three-way in a randomized spatial block design, with plots grouped into spatial blocks to control for spatial heterogeneity in the landscape. Data analyses were conducted using the Mixed Procedure in SAS/STAT for Windows Version 9.1.3 (SAS Institute, Cary, NC).

RESULTS

Vegetation and arthropod responses to irrigation and grazing treatments are presented in a series of Tables in Appendix 3.

Vegetation Response

Vegetation cover results for 2007 are presented in Table A.3.1. Annual grass cover differed (p=<0.01) when analyzed by time, with more cover in June than July. When comparing habitat by time there was a difference (p=<0.01) between habitats. The CRP plots had visibly more cheatgrass than the sagebrush plots, but there was no difference between months within CRP over time with June cover of 5.0 % (SE=2.8) and

July having 4.9 % (SE=2.8). There was a slight difference over time within the sagebrush plots with an annual grass cover of 1.8% in June (SE=1.8) and 0.7 % in July (SE=1.3). Cover of forbs differed when analyzed by time (p=<0.01) with a greater cover of forbs in June (3.3 %, SE=0.7) than in July (0.8 %, SE=0.3). Forb cover also differed when analyzed by habitat and time (p=<0.01) with a greater cover of forbs in June than in July in both habitats. The sagebrush plots had a greater cover of forbs than CRP in both June (5.4 %, SE=1.2) and July (0.8 %, SE=0.7). The CRP plots had a forb cover of 1.7 % (SE=0.7) in June and 0.6 % (SE=0.4) in July. Cover of Wyoming big sagebrush differed by habitats (p=<0.01) with CRP plots having a cover of 0.2 % (SE=0.3) and a cover of 13.3 % in sagebrush plots (SE=2.0).

Vegetation cover results for 2008 are presented in Table A.3.2. Perennial grass cover was greater in the CRP plots (32.7 %, SE=3.7) than in the sagebrush plots (17.1 %, SE=3.0) (p=0.02). When analyzed by time, annual grass had a greater cover in June (6.3 %, SE=2.9) than in July (3.1 %, SE=2.2) (p=<0.01). Forb cover differed when analyzing habitat (p=<0.01) and habitat by time (p=<0.01) with more forb cover in the sagebrush plots (4.4 %, SE 0.8) than the CRP plots (0.2 %, SE=0.2) and a greater forb cover in the sagebrush plots in June 5.8 % (SE=1.0) than in July 3.2 % (SE=0.8). But within the CRP plots there was little difference between the June (0.2 %, SE=0.2) and July (0.3 %, SE=0.3) forb cover. When analyzed by habitat, Wyoming big sagebrush cover was greater in the sagebrush plots (9.6 %, SE=1.3) than the CRP plots (0.1 %, SE=0.2) (p=<0.01).

Vegetation cover results for 2009 are presented in Table A.3.3. Perennial grass cover was greater in the CRP (32.7 %, SE=3.7) than the sagebrush plots (17.1 %, SE=3.0) (p=0.02). When analyzed by time, annual grass had a greater cover in July (6.3 %, SE=2.9) than in June (3.1 %, SE=2.2) (p=<0.01). Forbs had a greater cover in the sagebrush (4.4 %, SE=0.8) than the CRP plots (0.2 %, SE=0.2) when analyzed by habitat (p=<0.01). When analyzing habitat by time forbs had a greater cover in the sagebrush plots in June (5.8 %, SE=1.0) than July (3.2 %, SE=0.8), and greater cover than the CRP plots in both months. Wyoming big sagebrush cover was greater in sagebrush (9.6 %, SE=1.3) than CRP plots (0.1 %, SE=0.2) (p=<0.01).

Vegetation height results for 2007 are presented in Table A.3.4. Perennial grass height differed by time (p=<0.01) and habitat (p=<0.01). Perennial grass was taller in June (13.2 cm, SE=1.1) than in July (9.0 cm, SE=0.9) and was taller in the CRP plots (16.4 cm, SE=1.4) than in the sagebrush plots (6.6 cm, SE=1.0). Annual grass was taller in June (4.0 cm, SE=0.5) than in July (2.3 cm, SE=1.2) (p=0.01). Forbs were taller in June (4.0 cm, SE=0.7) than in July (1.3 cm, SE=0.4) (p=<0.01). Wyoming big sagebrush was taller in the sagebrush plots (4.2 cm, SE=4.1) than in the CRP plots (3.6 cm, SE=1.7) (p=<0.01).

Vegetation height results for 2008 are presented in Table A.3.5. Perennial grass was taller in the CRP (24.7 cm, SE=2.5) than in the sagebrush plots (13.5 cm, SE=2.0) (p=0.01). Perennial grass was taller in the CRP plots that were not grazed (27.7 cm, SE=3.0) than in the CRP plots that were grazed (21.9 cm, SE=2.8) (p=0.02). Perennial grass taller in both habitats in July (21.2 cm, SE=1.7) than in June (16.5 cm, SE=1.6)

($p=<0.01$). Annual grass was taller in June (3.6 cm, SE=1.2) than in July (2.0 cm, SE=0.9) ($p=<0.01$). Forbs were taller in the sagebrush plots (3.8 cm, SE=0.5) than in the CRP plots (0.4 cm, SE=0.2) ($p=<0.01$). Wyoming big sagebrush was taller in the sagebrush plots (43.1 cm, SE=5.0) than in the CRP plots (4.0 cm, SE=2.2) ($p=<0.01$) and was taller in June (21.5 cm, SE=3.0) than in July (17.9 cm, SE=3.0) ($p=<0.01$).

Vegetation height results for 2009 are presented in Table A.3.6. Perennial grass was taller in CRP (24.7 cm, SE=2.5) than sagebrush plots (13.5 cm, SE=2.0) ($p=0.012$) and was taller in July (21.2 cm, SE=1.7) than in June (21.2 cm, SE=1.6) ($p=<0.01$). Annual grass was taller in June (3.6 cm, SE=1.2) than in July (2.0 cm, SE=0.9) ($p=<0.01$). Forbs were taller in sagebrush plots (3.8 cm, SE= 0.5) than the CRP plots (0.4 cm, SE=0.2) ($p= <0.01$). Wyoming big sagebrush was taller in the sagebrush (43.1 cm, SE=5.0) than the CRP plots (4.0 cm, SE=2.2) ($p=<0.01$) and was taller in July (21.5 cm, SE=3.0) than in June (17.9 cm, SE=2.8) ($p=<0.01$).

Forage production results for 2007 are presented in Table A.3.7. Annual grass forage production differed ($p=<0.01$) when I compared habitat by water treatment by grazing treatment. The results suggested that in both habitats annual grass produces more forage in the once a week and every two weeks watering treatments, except in the CRP grazed plots. The result could merely be noise because of a higher order interaction of the three-way comparison. Forb forage production was found to be significant when I compared habitats ($p=0.01$). There was more forb production in the sagebrush plots (1.6 g, SE=0.4)] than the CRP plots (0.2 g, SE=0.2).

Forage production results for 2008 are presented in Table A.3.8. Perennial grass forage production differed by habitats (p=<0.01). The CRP plots produced 17.6 g (SE=2.9), while the sagebrush plots produced 3.1 g (SE=1.4). Forb forage production was greater in the sagebrush plots (1.1 g, SE=0.3) than the CRP plots (0.1 g, SE=0.1) when analyzed in terms of habitat (p=0.01).

Forage production results for 2009 are presented in Table A.3.9. Perennial grass forage production was greater in the CRP (17.6 g, SE=2.9) than sagebrush plots (3.1 g, SE=1.4) (p=<0.01). Forb production was greater in the sagebrush (1.1 g, SE=0.3) than CRP plots (0.1 g, SE=0.1) (p=0.01).

Arthropod Response

Arthropod results for 2007 are presented in Table A.3.10. Differences were found when comparing habitats, but not when comparing grazing and watering treatments. The orders Aranae (p=0.03), Diptera (p=<0.01), and Orthoptera (p=<0.01) were more abundant in CRP plots with means of 237.3 (SE=29.2), 502 (SE=53.0), and 331.4 (SE=32.0) individuals, respectively, than the sagebrush plots with means of 136.8 (SE=22.4), 211.3 (SE=34.8), and 100.3 (SE=17.9) individuals, respectively.

Arthropod results for 2008 are presetned in Table A.3.11. Again, differences were found when comparing between habitats, but not between grazing and watering treatments. Hemiptera (p=0.02) and Orthoptera (p=<0.01) were more abundant in CRP plots with means of 938.5 (SE=271.7) and 330.4 (SE=18.0) individuals, respectively, than in the sagebrush plots with means of 131.5 (SE=112.5) and 121.3 (SE=11.0) individuals. Homoptera (p=<0.01) and Lepidoptera (p=0.01) were more abundant in sagebrush plots with means of 727.0 (SE=66.8) and 53.2 (SE=11.9) individuals, respectively, than in the CRP plots with means of 345.6 (SE=46.5) and 9.8 (SE=5.4) individuals, respectively. When analyzed by habitat and water treatment, Hemiptera differed (p=0.01), but when analyzed further this result did not follow the same pattern.

Arthropod results for 2009 are presented in Table A.3.12. Orthoptera were more abundant in the CRP plots with a mean of 341.7 (SE=23.9) individuals than the sagebrush plots with a mean of 105.7 (SE=13.5) individuals (p=<0.01).

Most of the individuals captured in the CRP plots belonged, in decreasing order, to Hymenoptera (ants, 22%), Hemiptera (21%), Homoptera (19%), Orthoptera (10%), Diptera (9%), Coleoptera (8%), Araneae (7%), Hymenoptera (bees and wasps, 5%), and Lepidoptera (0.3%). The majority of individuals captured in sagebrush plots belonged, in decreasing order, to Homoptera (34%), Hymenoptera (ants, 28%), Coleoptera (10%), Diptera (6%), Araneae (5%), Hemiptera (5%), Hymenoptera (bees and wasps, 5%), Orthoptera (4%), and Lepidoptera (1%). All orders occurred in both habitats.

Sage-grouse Use

Pellet count transects were conducted in May and July of 2007, 2008, and 2009. Pellets were only found during the counts in May 2007. These pellets were found on four adjacent plots in the sagebrush habitat. After examination it was determined that these pellets were left during the winter months and not during the nesting or brood-rearing period. Because of heavy snowfall that winter, I believe grouse used this area because it was located on a windswept ridge, leaving more sagebrush exposed (Ward 2006). In conclusion, I found no evidence of grouse finding and using the brood-rearing areas created by my study.

DISCUSSION

A combination of factors contributed to and continues to exacerbate sage-grouse population declines. Declining populations have been characterized as exhibiting poor recruitment attributed to loss or fragmentation of brood-rearing habitats (Connelly et al. 2004). Concomitantly, the creation or restoration of mesic brood-rearing habitats in xeric environments has been identified as a conservation priority by regional and local sage-grouse working groups. These areas typically provide a higher abundance and diversity of forbs and arthropods essential to the diets of young chicks (Peterson 1970, Wallestad 1971, Klott and Lindzey 1990, Johnson and Boyce 1990, Sveum et al. 1998, Connelly et al. 2000, Crawford et al. 2004). The availability of forbs and arthropods has been positively associated with survival and recruitment of sage-grouse chicks.

The two most important habitats for Gunnison sage-grouse in San Juan County, Utah are CRP fields and areas of native sagebrush (Lupis 2005, Ward 2006). Over time wet meadow areas in each of these habitats have been reduced through changes in land use, therefore decreasing the habitat available to grouse during the brood-rearing season.

My study evaluated the role of irrigation and dormant season cattle grazing as practical management tools to create brood-rearing habitat in CRP and sagebrush. Although irrigated study plots retained their greenness longer in the growing season, I did not record any differences in vegetation or arthropod abundance and diversity because of irrigation or grazing. I did, however, note differences in vegetation and arthropod composition between habitat types. The CRP plots studied contained greater arthropod diversity and abundance than native sagebrush plots. However, CRP plots were not equivalent to the native sagebrush plots in terms of providing vegetation essential for brood-rearing.

Arthropod abundance and diversity was higher in the CRP plots than in the sagebrush plots possibly because of the different vegetation communities the two habitats supported. The highest overall arthropod diversity values were obtained from the non-native CRP grassland habitat even though it had less vegetation diversity than the native sagebrush. This difference was not anticipated but could have occurred because the perennial grass (crested wheatgrass) of the CRP plots better suited the diets and feeding methods of the arthropods. CRP fields have been shown to support a high invertebrate biomass, even after losing their forb component, and have been proven to be an important habitat for songbirds and game birds that feed on arthropods (Hull et al. 1996, McIntyre and Thompson 2003, Doxon and Carroll 2007).

Sagebrush contains secondary metabolites as an antiherbivore defense that may act as toxins or digestion inhibitors with increasing concentration during the growing season of spring and summer (Wallestad and Eng 1975, Shipley et al. 2006, Wiens et al. 1991). Wiens et al. (1991) examined the secondary metabolites of sagebrush leaf tissue, and its effects on the abundance and diversity of arthropods. The study found that after an herbivorous attack by arthropods, sagebrush increased their level of toxins and the number of arthropods on the shrubs decreased. Sap and phloem feeding insects recovered more quickly than chewing insects. The feeding methods of sap and phloem feeders may permit them to be highly discriminatory and avoid plant tissues containing secondary metabolites. Herbivorous leaf chewers were less likely to be able to discriminate among cell and tissue types within leaves and will therefore encounter more chemical compounds.

The differences I observed in the vegetation between the two habitats were expected. Land enrolled in CRP was once plowed agricultural land. This practice eliminated most of the sagebrush from the system and probably most of the seed bank supporting native forbs and grasses, and potentially changed the nutrient content of the soil. The seed mixture used in CRP fields was designed to establish a perennial grass cover, therefore it was expected that the CRP plots would have a greater occurrence of perennial grasses and little sagebrush. It was also expected that what sagebrush had begun to re-establish in the CRP plots would be smaller than those in the native sagebrush plots that had never been cultivated.

After the original seeding of the CRP fields, little if no sagebrush successfully established from seed (G. Wallace, Utah Division of Wildlife Resources, personal communication). Forbs successfully established from the seed mixture and remained in the system for a few years and then began to disappear. For this reason, few of those forbs still remained in the plots. Forbs that did occur in the CRP plots were invasive weeds, such as Russian knapweed (*Centaurea repens*), African mustard (*Malcomia africana*), and Russian thistle (*Salsola pestifer*). Crested wheatgrass was the one plant from the original mixture that remained in the system and was found to dominate the CRP plots.

Crested wheatgrass has been shown to develop monoculture stands and dominate plant communities for decades following establishment (Hull and Klomp 1967, Dormaar et al. 1995). The species has been shown to thicken and spread into adjacent areas (Hull and Klomp 1967). Its rapid dispersal rate and long-term dominance over and exclusion of native species have resulted in it being called an invader (Schuman et al. 1982, Henderson and Naeth 2005). Dormaar et al. (1995) found that altering the plant community from native mixed prairie to sequences of cropping followed by introduced grass monocultures significantly reduced the chemical quality of the soils by decreasing the root mass and organic matter evident in the top 7.5 cm of the soil, therefore reducing the energy flow into the soil system. Crested wheatgrass has been to shown to have less live root biomass and a high accumulation of aboveground dead material (Redente et al. 1989). The species allocated nearly twice the amount of carbon to aboveground photosynthetic tissue than plants in the blue grama ecosystem.

Stands of crested wheatgrass also tend to be very stable (Marlette and Anderson 1986). Stand stability was found to be largely a consequence of its dominance in the seed bank (Marlette and Anderson 1986, Henderson and Naeth 2005). Seed banks in crested wheatgrass stands support little diversity. There is little evidence that propagules from native communities are widely dispersed into adjacent crested wheatgrass stands and accumulate to form a diverse seed bank.

The results of this study support previous studies conducted on crested wheatgrass. It appeared that the native seed bank within the CRP plots had been lost. This probably occurred during the decades the land was under cultivation, time dominated by crested wheatgrass, and lack of native seed dispersal from nearby areas (Marlette and Anderson 1986). The seeds from the original seed mixture seem to have also been lost. This could have occurred because of competition from crested wheatgrass, the effect of the species on the soil, and its dominance of the seed bank (Hull and Klomp 1967, Marlette and Anderson 1986, Redente et al. 1989, Dormaar et al. 1995, Henderson and Naeth 2005).

Seeding crested wheatgrass may inhibit or even preclude the development of a diverse plant community by retarding the recovery of native vegetation (Hull and Klomp 1967, Marlette and Anderson 1986). Monoculture stands have resisted the reintroduction of native species and maintained low species diversity (Marlette and Anderson 1986, Dormaar et al. 1995). A monoculture cannot be restored to a diverse plant community simply by removing some crested wheatgrass plants. If an increase in species diversity is desired, existing crested wheatgrass and their propagules in the soil must be destroyed and other species deliberately introduced. To improve the chances of creating brood-rearing habitat in CRP fields it might be necessary to physically remove or reduce the number of crested wheatgrass plants in the treatment areas and re-seed the plots with a mixture of native annual and perennial grasses and forbs. It may also be necessary to invest in proper seed bank preparation techniques and irrigation to ensure seed germination, seedling survival, and species persistence.

Irrigation of plots within each habitat resulted in the lengthening of the growing season for vegetation, but did not result in the anticipated increase in abundance and diversity of forbs, grasses, and arthropods. Vegetation in watered plots remained green throughout the entire watering season (June to July) while vegetation in the control plots desiccated by the end of July. If a consistent watering pattern is continued over large areas and long periods of time, it might be possible for an abundant and diverse arthropod community to develop.

I found that using a sprinkler irrigation system was not efficient enough to produce the desired results. Using sprinklers was time consuming and required considerable maintenance. In the undulating landscape of the study area it was difficult to maintain water pressure in the pipes. The sprinklers were inefficient in the windy environment and because of strong daily afternoon winds I was forced to split the watering schedule in two, with a morning watering period and an evening watering period. In order for an irrigation method to be developed into a land management practice for creating brood-rearing habitat a different water delivery system will be necessary.

Although, this study did not provide the anticipated results, it did reveal important information about the vegetation and arthropod communities in both CRP and sagebrush that will affect the development of future management techniques, especially when managing CRP. During the study, I recorded an increase in vegetation growth and diversity in areas where leaks occurred in the irrigation system and water kept the soil saturated throughout the summer. This has led me to the conclusion that it is necessary to keep the soil saturated throughout the summer through flood irrigation. Solar panel powered pumps can be used to easily distribute water to certain areas. The use of the solar panel will allow the pump to run under its own power throughout the day while the sun is shining. Distributing the water to low lying areas through a network of pipes will allow a large area of soil to be saturated throughout the summer. This method would reduce maintenance costs and the amount of labor required, while promoting perennial grass, forb, and sagebrush growth.

Future management techniques will also need to control crested wheatgrass. During this study, even under heavy dormant season cattle grazing, crested wheatgrass continued to dominate the CRP plots at the expense of forbs. Techniques should also address possible invasion by cheatgrass and other invasive weeds, while promoting the growth of native perennial grasses, forbs, and sagebrush. Possible techniques to accomplish this are a combination of mechanical disking, grazing, re-seeding of native perennial grasses and forbs, planting of sagebrush seedlings, and irrigation. This information can be used by managers and private landowners to implement brood-rearing restoration projects.

MANAGEMENT IMPLICATIONS

The creation of brood-rearing habitat is crucial for the recruitment of individuals into grouse populations. Techniques employed in these restoration projects could be developed into a cost-share program under EQIP. Restoration projects in CRP will require biological and mechanical treatments. The use of irrigation for the creation of brood-rearing habitat is essential to ensure the establishment and continued propagation of seeded perennial grasses and forbs, and sagebrush seedlings. Irrigation on public and private land is both a feasible and practical method when using solar powered groundwater pumps and flood irrigation. Control of crested wheatgrass will also be necessary. Cattle grazing and mechanical disking are methods that could be used to control crested wheatgrass. These methods should be used in combination with re-seeding and flood irrigation.

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CHAPTER 3

ASSESSMENT OF VEGETATION CONDITIONS OF SAGEBRUSH HABITATS WITHIN THE GUNNISON SAGE-GROUSE CONSERVATION AREA IN SAN JUAN COUNTY, UTAH

ABSTRACT San Juan County supports the only population of Gunnison sage-grouse (*Centrocercus minimus*) found in Utah. The current population estimates are below the minimum desired population objective established in the Gunnison Sage-grouse Rangewide Conservation Plan (RCP) and the San Juan County Gunnison Sage-grouse Conservation Plan (SJCCP). Both plans identified the need to complete periodic assessments of the existing vegetation conditions in occupied and potential (unoccupied) sage-grouse habitat to ensure compliance with recommended guidelines and guide management actions. In the summer of 2009 I completed a habitat assessment of the 1,392,812 ha Gunnison Sage-grouse Conservation Area (CA) in San Juan County using RCP protocols. Using randomly generated points I measured vegetation conditions at 93 sites within occupied and unoccupied sagebrush habitats within the CA. Occupied habitat was defined as use areas contained within the 24,177 ha Conservation Study Area (CSA). Unoccupied habitat was defined as historical areas that previously supported sage-grouse or were in close proximity to areas that were currently or historically inhabited. I compared the current vegetation conditions for breeding, summer/fall, and winter habitats to RCP recommended guidelines. Perennial grass cover and height met or exceeded guidelines for occupied and unoccupied areas for all habitat categories. This was attributed largely to the introduction of crested wheatgrass (*Agropyron cristatum*)

into the system via the Conservation Reserve Program. Forb cover in unoccupied areas for all habitats approximated guidelines. In occupied areas forb cover was below RCP recommendations for all habitats. Forb cover height met the lowest limits of the guidelines for occupied and unoccupied areas for summer/fall but not breeding habitats. Sagebrush cover met or exceeded recommended guidelines for occupied and unoccupied areas for breeding and summer/fall habitats, but not winter habitats. Sagebrush (*Artemisia tridentata*) height met or exceeded guidelines for unoccupied and occupied areas for all habitat categories. To maximize habitat benefits for Gunnison sage-grouse in San Juan County, managers should implement conservation actions that protect existing sagebrush habitats and increase forb and grass cover in currently occupied habitats. This information will assist the Monticello/Dove Creek Local Working Group in prioritizing conservation efforts.

INTRODUCTION

Connelly et al. (2004) suggested that of the factors contributing to range wide declines in sage-grouse (*Centrocercus* spp.), the loss, degradation, and fragmentation of the sagebrush (*Artemisia* spp.) ecosystem were paramount. As sagebrush obligates, sage-grouse require sagebrush habitats to complete their life cycle. Thus, structure and composition of plant communities within sagebrush ecosystems influence sage-grouse nesting, breeding, brood-rearing, fall, and winter habitat selection.

Gunnison sage-grouse (*C. minimus*) currently occupy 4,787 km^2 (8.5% of their original range) in Colorado and Utah. There is one known population in the state of Utah. The Gunnison Sage-grouse Rangewide Conservation Plan (RCP) and the San Juan

County Gunnison Sage-grouse Conservation Plan (SJCCP) recommended management strategies to conserve the species (SWOG 2000, GSRSC 2005). Both plans identified the need for periodic habitat assessments to determine if existing vegetation conditions meet the desired vegetation criteria stated in the RCP. Periodic habitat assessments can assist managers in developing and prioritizing habitat restoration projects (GSRSC 2005).

The RCP established vegetation condition goals for Gunnison sage-grouse seasonal habitats (GSRSC 2005). Breeding habitats include lek, nesting, and early brood-rearing habitat from mid-March through late-June. The RCP defined breeding habitat as sagebrush communities delineated within 6.4 km of a lek. The SJCCP identified a long-term goal of reestablishing desired vegetation conditions on 50-75% of the area within 6.4 km of occupied lek sites (SWOG 2003). The defined vegetation characteristics for breeding habitats included: total shrub canopy cover of 20-40% (15-25% sagebrush canopy cover) with an average sagebrush height of 25-50 cm, 10-30% grass canopy cover with a height of 10-15 cm, and 5-15% forb canopy cover with a height of 5-10 cm (GSRSC 2005).

The RCP defined summer/fall habitat as vegetation communities, including sagebrush, agricultural fields, and wet meadows that are within 6.4 km of lek sites (GSRSC 2005). The SJCCP recommended establishing these conditions on 50-75% of the area (SWOG 2003). The defined desired vegetation conditions identified were: 10-30% total shrub canopy cover (5-15% sagebrush canopy cover) with an average sagebrush height of 20-40 cm, 10-25% grass canopy cover with a height of 10-15 cm, and 5-15% forb canopy cover with a height of 3-10 cm (GSRSC 2005). Mesic areas should support a grass cover of 10-35% with a height of 10-15 cm and a forb cover of 15-35% with a height of 5-10 cm.

The SJCCP further identified the need to reestablish desired vegetation conditions of wintering habitats on 50% of the areas located within the Conservation Study Area (CSA) and 25% within the area buffering the CSA (SWOG 2003). Lupis (2005) and Ward (2007) previously defined the CSA based on location data obtained from radio-collared sage-grouse. The RCP defined winter habitat as sagebrush areas within currently occupied habitats that are available to sage-grouse in average winters (GSRSC 2005). The defined vegetation conditions for winter habitat include: sagebrush canopy cover of 30-40% with a height of 40-55 cm.

I completed a vegetation conditions assessment to determine the habitat conditions for Gunnison sage-grouse that inhabit San Juan County. This information will assist managers in quantifying the relative contribution of occupied and potential habitats to achieving overall SJCCP and RCP habitat and population goals. The results will be used by members of the Monticello/Dove Creek Local Working Group to update the current SJCCP, the RCP, and prioritize future conservation efforts.

STUDY AREA

The habitat assessment was conducted in San Juan County, Utah, during the summer of 2009. San Juan County is located in the extreme southeastern corner of Utah. The county is bordered by the Colorado River to the north and west, Arizona to the south, and Colorado to the east. The San Juan County Gunnison Sage-grouse Working Group (SWOG) previously designated an area northeast of the town of Monticello, Utah, as a

Gunnison sage-grouse priority conservation area (CA, Fig. 3.1, SWOG 2000). The CA consisted of 1,392,812 ha, 38% (127,170 ha) of which was privately owned. The CA was identified by encompassing historic and current lek sites, potentially suitable sage-grouse habitat, and sage-grouse observations. The CA was characterized by agricultural fields enrolled in the Conservation Reserve Program (CRP), active agricultural fields, and grazed interspersed with fragmented patches of Wyoming big sagebrush (*A. tridentata wyomingensis*), black sagebrush (*A. nova*), pinyon pine (*Pinus edulis*), juniper (*Juniperus osteosperma*), and oak (*Quercus gameblii*).

Within the CA, SWOG also identified the Conservation Core Area (CCA) that consisted of 136,249 ha, of which 89% (88,420 ha) was privately owned. Within the CCA, SWOG designated a priority study area, the CSA. The CSA consisted of 24,177 ha, of which 93% (22,556 ha) was privately owned. The CSA encompassed the current year round range of the population (Lupis 2005).

METHODS

In the summer of 2009, I measured vegetation parameters within Gunnison sage-grouse occupied and unoccupied habitats in San Juan County, Utah. I defined occupied habitat as areas located within the CSA. I defined unoccupied habitat as areas that were

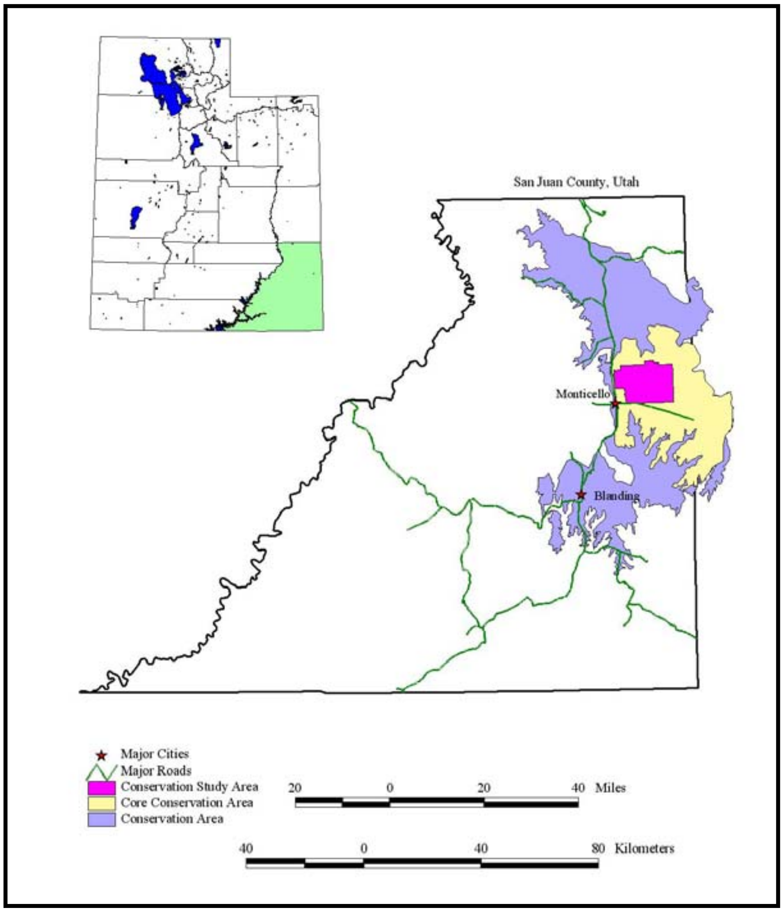

Figure 3.1. Gunnison Sage-grouse Conservation Area, San Juan County, Utah (Lupis 2005).

historically inhabited or were near an area currently or historically inhabited by sage-grouse. Unoccupied habitat largely fell within the CA and CCA. I compared these data to the habitat guidelines identified in the RCP to assess the status of existing and potential habitat in the CA, CCA, and CSA.

I conducted the habitat assessment by ground truthing LandSat imagery of the CA. I used ArcGIS (ArcMap version 9.3.1) to plot historic and current lek locations, which were located within the CSA. I created a polygon by buffering around the leks in

1,500 m increments to incorporate the distances the birds move from the leks throughout the year, such as from the lek to nesting areas, nesting areas to brood-rearing areas, and wintering areas (SWOG 2000, GSRSC 2005, Lupis 2005, Ward 2007). I further extended the buffer to include unoccupied habitat within the CCA and CA. After incorporating all possible movement distances and habitats the buffer totaled 7,500 m from lek sites (Fig. 3.2). Occupied habitats were confined to the CSA. Unoccupied habitats encompassed all other areas in the CA, excluding the CSA.

I generated 1,000 random points within the polygon and randomly selected 150 of these points (Fig. 3.2). Using satellite imagery I eliminated points that were located in agricultural fields, CRP, grazed rangelands, and pinyon-juniper and oak woodlands, focusing on points that encompassed sagebrush habitats, leaving 144 points. I visited each mapped point. Upon field visits some points were eliminated because they did not meet the established criteria. Points that fell within CRP, agricultural fields, woodlands, and grazed rangelands that did not support sagebrush were eliminated. Points that fell within private land posted as no trespassing were also eliminated. This left 93 points, 39 points in unoccupied and 54 points in occupied habitats, respectively.

At points that met the criteria, I measured the vegetation conditions using the Gunnison Sage-grouse Rangewide Steering Committee (GSRSC) Structural Vegetation Collection Guidelines (SVCG, GSRSC 2007). At each point, two 30-m transects were established. Cover of grasses, forbs, and shrubs was visually estimated by placing a Daubenmire frame every 3-m along each 30-m transect (Daubenmire 1959). The SVCG identified six cover classes based on the standardized Daubenmire method. The GSRSC believed the Daubenmire method lumped too much vegetation into the 5-25% class for the Gunnison sage-grouse vegetation variables. Thus, they split the 5-25% category into 2 cover classes. The canopy cover classes used in this study were: 0-5%, 5-15%, 15-25%, 25-50%, 50-75%, 75-100% (GSRSC 2007).

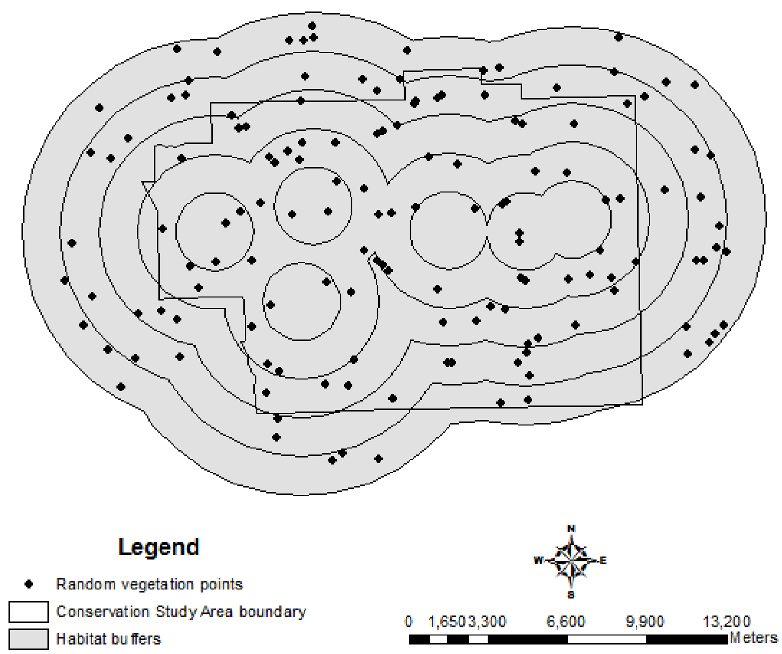

Figure 3.2. Buffer distances from active and historic leks to show seasonal movements of Gunnison sage-grouse (*Centrocercus minimus*) in and around the Conservation Study Area, San Juan County, Utah, 2009. Locations of randomly generated points used to assess habitat conditions in currently, historically, and potential habitat occupied by Gunnison sage-grouse. Occupied habitat is within the boundary of the Conservation Study Area. Unoccupied habitat is located outside of the Conservation Study Area boundary.

One height measurement of sagebrush, forb, annual grass, and perennial grass was taken at each Daubenmire frame by selecting the plant closest to the lower left hand corner of the frame (Daubenmire 1959, GSRSC 2007). If sagebrush was not found within the frame then the closest sagebrush within 10m of the frame was used. If no sagebrush was within 10m of the frame it was marked as not present. Only forbs and grasses within the frame were used to measure height. If no forb or grass was within the frame the plant group was marked as not being present.

DATA ANALYSIS

Vegetation data collected at each point were summed and averaged for each habitat area (occupied and unoccupied). Means for cover and height for each habitat area are reported with 95% confidence intervals. The results were then compared to the defined vegetation conditions recommended in the RCP for breeding, summer/fall, and winter habitat categories.

RESULTS

The RCP defines breeding and summer/fall habitat as the land within 6.4 km of lek sites (GSRSC 2005). This distance encompassed the entire CSA. As a result, all vegetation data collected at points within the CSA (n= 54) fell into the composite category encompassing breeding, summer/fall, and winter habitat.

Because sagebrush was the dominate shrub cover, I report total sagebrush cover in lieu of total shrub cover. The results for occupied and unoccupied habitat relative to RCP guidelines are presented in Table 3.1.

Occupied Habitat

In breeding habitats, perennial grass ($\bar{x}$=17%, CI=3.19) and sagebrush ($\bar{x}$=17%, CI=3.61) cover were within the RCP guidelines of 10-30% and 15-25%, respectively (Table 3.1). Forb cover ($\bar{x}$=3%, CI=1.40) did not meet the guidelines of 5-15%. Height of perennial grass ($\bar{x}$=23 cm, CI=4.39) was slightly above the guidelines of 10-15 cm. The height of sagebrush ($\bar{x}$=51 cm, CI=4.21) was within the upper limit of the guidelines of 25-51 cm. Forb height ($\bar{x}$=3 cm, CI=0.92) was below the guidelines of 5-10 cm.

In summer/fall habitats, cover of perennial grass ($\bar{x}$=17%, CI=3.19) was within the RCP guidelines of 10-25%. Sagebrush cover ($\bar{x}$=17%, CI=3.61) was within the upper limits of the guidelines of 5-15% cover. Cover of forbs ($\bar{x}$=3%, CI=1.40) was below the guidelines of 5-15%. Perennial grass height ($\bar{x}$=23 cm, CI=4.39) exceeded the guidelines of 10-15 cm. Forb height ($\bar{x}$=3 cm, CI=0.92) was at the lower limits of the guidelines of 3-10 cm. Sagebrush height ($\bar{x}$=51 cm, CI=4.21) exceeded the upper limits of 20-40 cm.

In winter habitats, cover of sagebrush ($\bar{x}$=17%, CI=3.6) was below the RCP guidelines of 30-40%. Sagebrush height ($\bar{x}$=51 cm, CI=4.21) exceeded the upper limits of 20-40 cm.

Unoccupied Habitat

In unoccupied breeding habitat, cover of perennial grass ($\bar{x}$=18%, CI=3.77), forbs ($\bar{x}$=6%, CI=1.64) and sagebrush ($\bar{x}$=17%, CI=4.40) were within the RCP guidelines of 10-30%, 5-15%, and 15-25%, respectively. Perennial grass height ($\bar{x}$=15 cm, CI=2.34) was also within the guidelines of 10-15 cm. Height of forbs ($\bar{x}$=4 cm, CI=0.72) was below the guidelines of 5-10 cm. Sagebrush height ($\bar{x}$=46 cm, CI=4.64) was within the guidelines of 25-50 cm.

In unoccupied summer/fall habitats, cover of perennial grass ($\bar{x}$=18%, CI=3.77) and forbs ($\bar{x}$=6%, CI=1.64) were within the RCP guidelines of 10-25% and 5-15%, respectively. Cover of sagebrush ($\bar{x}$=17%, CI=4.40) slightly exceeded the guidelines of 5-15%. Height of perennial grass ($\bar{x}$=15 cm, CI=2.34) and forbs ($\bar{x}$=4 cm, CI=0.72) were within the guidelines of 10-15 cm and 3-10 cm, respectively. Sagebrush height ($\bar{x}$=46 cm, CI=4.64) exceeded the guidelines of 20-40 cm.

In unoccupied winter habitats, cover of sagebrush ($\bar{x}$=17%, CI=4.40) was below the guidelines of 30-40%. Sagebrush height ($\bar{x}$=46 cm, CI=4.64) was within the guidelines of 40-55 cm.

DISCUSSION

Based on the results of my habitat assessment of the vegetation parameters within occupied Gunnison sage-grouse habitats in the CA, CCA and CSA, I recommend that managers focus their attention on protection of existing sagebrush canopy cover and the

Table 3.1. Average percent cover and height of vegetation in occupied and unoccupied habitat in the Gunnison Sage-grouse (*Centrocercus minimus*) Conservation Area in San Juan County, Utah, 2009, reported with 95% confidence intervals. Occupied habitat was defined as land within the Gunnison Sage-grouse Conservation Study Area. Unoccupied habitat was defined as areas that once supported sage-grouse or were in close proximity to areas that support or once-supported sage-grouse. Unoccupied habitat fell within the Conservation Area and Core Conservation Area. Current habitat conditions were compared to habitat guidelines stated in the Gunnison Sage-grouse Rangewide Conservation Plan (GSRSC 2005).

	Percent Cover						Height (cm)					
Habitat	Perennial Grass	CI	Forbs	CI	Sagebrush	CI	Perennial Grass	CI	Forbs	CI	Sagebrush	CI
Measurments												
Occupied	17	3.19	3	1.40	17	3.61	23	4.39	3	0.92	51	4.21
Unoccupied	18	3.77	6	1.64	17	4.40	15	2.34	4	0.72	46	4.64
Guidelines												
Breeding	10-30		5-15		15-25		10-15		5-10		25-50	
Summer/fall	10-25		5-15		5-15		10-15		3-10		20-40	
Winter					30-40						40-55	

restoration of the forb components in CRP and native sagebrush. These observations are in line with the conservation strategies currently outlined in both the SJCCP and RCP.

Although unoccupied habitat in the CA better approximated SJCCP and RCP habitat guidelines, this area is avoided by Gunnison sage-grouse. Gunnison sage-grouse evolved in a landscape free of vertical structures, such as trees, power poles, and fence posts (Connelly, 2000*a*). Because of this evolutionary trait, they will avoid certain areas and will not cross over vertical structures even if the habitat on the other side is of good quality. Much of the area surrounding the occupied habitat confined within the CSA was dominated by pinyon-juniper and oak woodlands, therefore the birds will not cross over the trees to utilize these areas.

While ground truthing the randomly generated points that fell within unoccupied habitats in the CA, I discovered mosaics of open areas among the pinyon-juniper and oak woodlands. In many of these areas sagebrush could be found in small isolated patches, surrounded by or located near woodlands. Upon searching these patches, I did not find any evidence (i.e., pellets) that the sites were used by sage-grouse (Connelly et al. 2000*a*). Furthermore, when I overlaid the random points with known bird locations from previous studies, the locations were concentrated in the CSA (Fig 3.3). The small patches of sagebrush within the woodlands in the CA and CSA were avoided. The CSA was preferred by Gunnison sage-grouse because it contains little vertical structure in terms of oak and pinyon-juniper (Connelly et al. 2000*a*, GSRSC 2005).

Sage-grouse evolved in habitats free of vertical structures, including trees (Connelly et al. 2000*a*). Raptors and corvids prey on sage-grouse adults, young, and

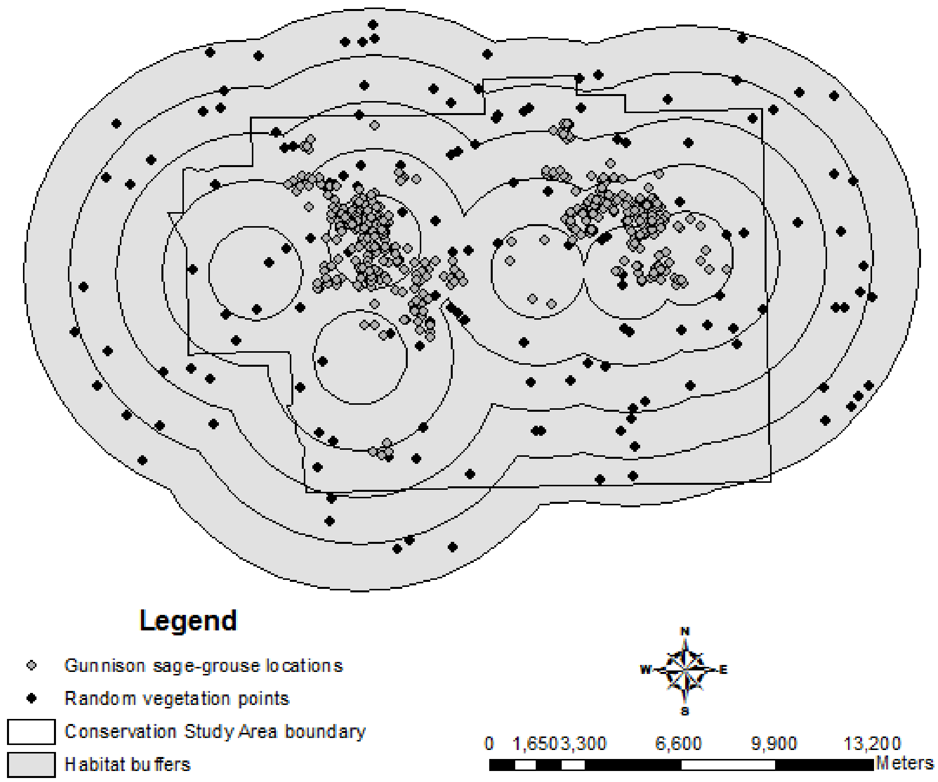

Figure 3.3. Location of vegetation monitoring points and known Gunnison sage-grouse locations within the Conservation Study Area, San Juan County, Utah, 2009 (Lupis 2005, Ward 2007).

nests. Previous research has shown that their presence increases with the presence of vertical structures (Hartzler 1974, Ellis 1984, Connelly et al. 2000*b*, Fletcher et al. 2003, Manzer and Hannon 2005). This not only increases possible predation of sage-grouse but also results in the fragmentation of habitat and populations by acting as a barrier and subdividing suitable habitat. The agricultural history of land use in the CSA may have contributed to the loss and fragmentation of sagebrush and corresponding reduction in grass and forb cover. Currently, the dominant perennial grass throughout the CSA is crested wheatgrass (*Agropyron cristatum*). Crested wheatgrass was established in the CSA when thousands of hectares of cropland were originally enrolled in CRP and planted with a seed mixture that contained the non-native perennial grass (SWOG 2000). Crested wheatgrass has the potential to effectively out-compete native forbs and grasses and spread to adjacent areas (Hull and Klomp 1967, Schuman et al. 1982, Henderson andhas invaded sagebrush areas throughout the entire CSA, and it was more dominant than native perennial grasses at the sites evaluated.

Even though habitat quality in the CSA did not meet SJCCP and RCP habitat guidelines, the Gunnison sage-grouse population has steadily rebounded after an initial drop in the 1980s and has held steady over the past 20 years with only minor increases and decreases in response to drought conditions (Fig. 3.4, SWOG 2000, Lupis 2005).

I believe this rebound can be attributed largely to the advent of the CRP program in the CSA. Although CRP fields do not achieve vegetation habitat guidelines, these areas constitute new permanent contiguous vegetation cover that has provided Gunnison sage-grouse important seasonal habitats (Lupis 2005, Ward 2007). Thus, the retention and habitat restoration of CRP fields in the CSA for Gunnison sage-grouse should remain the highest conservation priority in San Juan County.

Reestablishing sagebrush, grass, and forb cover in CRP fields to approximate SJCCP and RCP guidelines would provide missing components to the habitat. These restoration efforts would help connect native sagebrush areas throughout the CSA, reducing the effects of fragmentation on the population.

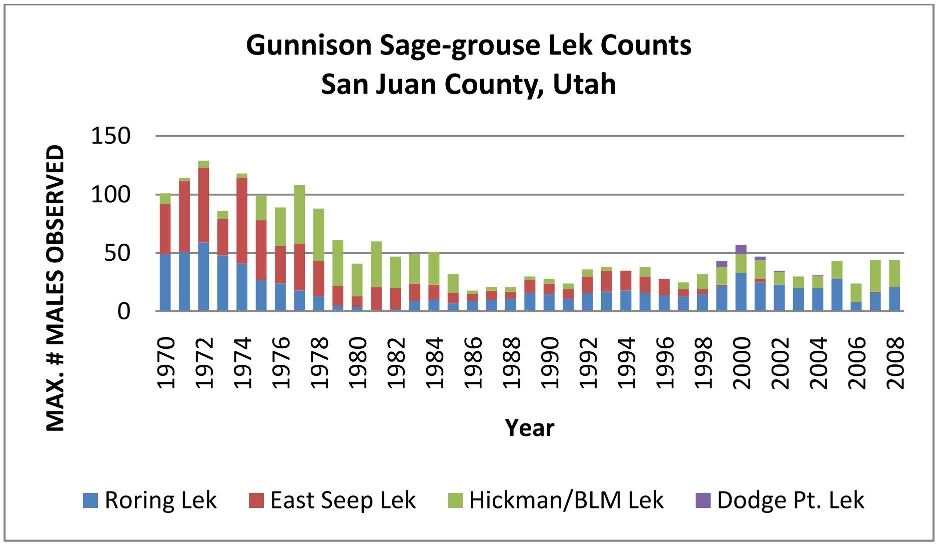

Figure 3.4. Gunnison Sage-grouse (*Centrocercus minimus*) lek counts from San Juan County, Utah. Maximum number of males observed is recorded. Data from Hickman and BLM leks have been combined because of daily movements of males between these 2 leks (SWOG 2004).

Later stages of habitat restoration efforts should focus on identifying areas outside of the CSA that hold promise for providing habitat for the sage-grouse. Restoration efforts designed to remove pinyon-juniper to open corridors would allow Gunnison sage-grouse access to areas exhibiting better habitats and facilitate population exchanges, which could increase genetic diversity. In the interim, managers should consider translocation of birds from both Colorado and Utah to mitigate concerns about low genetic diversity (GSRSC 2005).

MANAGEMENT IMPLICATIONS

The results of the habitat assessment illustrate that the sage-grouse are restricted to occupied habitats in the CSA by the presence of pinyon-juniper and oak woodlands. This exemplifies the need to improve the habitat within the CSA to maximize what little habitat the grouse have available to them. The habitat assessment also illustrated that forbs and grasses are lacking from much of the habitat within the CSA. Habitat improvement projects should be focused on the remaining sagebrush areas within the CSA. Efforts should also be made to re-establish sagebrush, forb, and grass patches within CRP fields throughout the CSA to expand the habitat available to the grouse.

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CHAPTER 4

RAPTOR AND CORVID RESPONSE TO POWER DISTRIBUITION LINE PERCH DETERRENTS IN UTAH

ABSTRACT Increased raptor and corvid abundance has been documented in landscapes fragmented by man-made structures, such as fence posts and power lines. These vertical structures may enhance raptor and corvid foraging and predation efficiency because of increased availability of perch, nesting, and roosting sites. Concomitantly, vertical structures, in particular power distribution lines, have been identified as a threat to sage-grouse (*Centrocercus* spp.) conservation. To mitigate potential impacts of power distribution lines on sage-grouse and other avian species, the electrical power industry has retrofitted support poles with perch deterrents to discourage raptor and corvid use. No published information is available regarding efficacy of contemporary perch deterrents on avian predator use of lower-voltage power distribution lines. We evaluated efficacy of 5 perch deterrents mounted on support poles of an 11-km section of a 12.5-kV distribution line that bisected occupied Gunnison sage-grouse (*C. minimus*) habitat in southeastern Utah, USA. Perch deterrents were mounted on the line in November–December 2006 following a random replicated block design that included controls. During 168 hours and 84 hours of direct observation in 2007 and 2008, respectively, we recorded 276 and 139 perching events of 7 potential avian predators of sage-grouse. Golden eagles (*Aquila chrysaetos*) were the dominant species we recorded during both years. We did not detect any difference in perching events by perch deterrent we evaluated and controls ($p > 0.05$). Perch deterrents we evaluated were not effective

because of inherent design and placement flaws. Additionally, previous pole modifications that mitigated avian electrocutions provided alternative perches. We did not record any raptor or corvid electrocutions or direct predation on Gunnison sage-grouse. The conclusions of this study can be applied by conservation groups and power companies to future management of power distribution lines within areas inhabited by species sensitive to man-made vertical structures.

INTRODUCTION

Transmission lines are defined as power lines designed and constructed to support voltages >60 kV (Avian Power Line Interaction Committee 2006). Distribution lines are defined as a circuit of low-voltage lines, energized at voltages from 2.4 kV to 60 kV and used to distribute electricity to residential, industrial, and commercial customers. The Western Association of Fish and Wildlife Agencies (J. W. Connelly, Western Association of Fish and Wildlife Agencies, unpublished report) reported ≥15,296 km^2 of current sage-grouse (*Centrocercus* spp.) range contained power transmission lines; however, the group was unable to map density of power distribution lines in rural areas.

Connelly et al. (2000b, Connelly, unpublished report) suggested that because of the potential for raptors and corvids to use transmission-line towers and distribution-line poles as new perches and nest sites, placement of these facilities in seasonal sage-grouse habitats could impact the species through increased predation of adults, juveniles, and nests or result in sage-grouse abandoning sites (Knight and Kawashima 1993, Knight et al.1995, Kochert and Olendorff 1999). Corvids and raptors prey on sage-grouse adults, young, and nests. Hartzler (1974), Ellis (1984), Connelly et al. (2000a), Fletcher et al.

(2003), and Manzer and Hannon (2005) reported the impact of avian predators on sage-grouse populations may be exacerbated in human-altered landscapes. Because of these concerns, the Gunnison Sage-Grouse Rangewide Steering Committee (2005) identified retrofitting of distribution line poles with perch deterrents to discourage raptors and corvids from perching as a priority species conservation strategy.

Previous studies have evaluated perch deterrents' effectiveness on transmission-line towers and towers associated with air traffic control (Michener 1928, Janss and Ferrer 1999, Kochert and Olendorff 1999, Avery and Genchin 2004). Lammers and Collopy (2007) studied effectiveness of perch deterrents on towers of a high-voltage (345 kV) transmission line that bisected habitats occupied by greater sage-grouse (*Centrocercus urophasianus*). However, no studies have been published that evaluate efficacy of perch deterrents on distribution lines. We studied raptor and corvid response to 5 types of perch deterrents mounted on a power distribution line that traversed occupied Gunnison sage-grouse habitat in southeastern Utah, USA. Our objective was to determine if raptor or corvid use of the distribution line differed by perch deterrent type or control.

STUDY AREA

We conducted our study during winters of 2007 and 2008 in the Gunnison sage-grouse Conservation Study Area (CSA) located in San Juan County, Utah, USA. The San Juan County Gunnison Sage-grouse Working Group (SWOG) previously identified the CSA. The CSA was located east of the town of Monticello, Utah, USA (SWOG 2005). The CSA contained the primary breeding and wintering complexes of the San

Juan County Gunnison sage-grouse population. The habitat within the CSA consisted of sagebrush (*Artemisia* spp.), grazed rangelands, agriculture fields, and croplands enrolled in the Conservation Reserve Program (CRP).

The study distribution line we selected for study was the longest continuous line located within the CSA. This line paralleled the northern edge of the CSA, which provided Gunnison sage-grouse winter habitat, and was located within 1 km of active leks (Lupis 2005, Ward 2007). The distribution line had a voltage rating of 12.5 kV and paralleled a well-maintained county road. The road allowed access during winter and across private land. The distribution line traversed an undulating landscape and a variety of habitats that included CRP fields, agriculture fields, grazed rangelands, and sagebrush.

METHODS

With the cooperation of PacifiCorp field crews, we established an experimental randomized block design for installation of perch deterrents, which controlled for differences in vegetation and landscape topography that could affect raptor and corvid pole preferences. This design eliminated sampling bias by ensuring that we evaluated each type of deterrent and control relative to habitat types and topography present throughout the length of the distribution line. We considered each pole an experimental unit. We divided the line into 14 blocks consisting of 6 poles each. Within a block, we randomly assigned each pole to one of the 5 treatments or control. The result was multiple replications of each treatment and the control across all habitat types and topographies present. Poles assigned as controls were not fitted with a deterrent.

In November–December 2006 an 11-km section of the selected distribution line, consisting of 84 poles, was modified by PacifiCorp field crews with 5 types of perch deterrents following manufacturer recommendations and in accordance with the established experimental design (Fig. 4.1a–f). Physical deterrents consisted of cones and triangles (Kaddas Enterprises Inc., Salt Lake City, UT), and mini-zenas (Prommel Enterprises Inc., Odenville, AL). The reflective hazing deterrent consisted of displaying single or paired FireFlies™ (P and R Technologies Inc., Portland, OR) suspended on the top and cross arm of the distribution pole. Because of differences in construction, some poles could not support the assigned deterrent, which resulted in incomplete blocks with 14 replications of control poles, mini-zenas, and the 1-FireFly and 2-FireFly arrangements; 16 replications of cones; and 12 replications of triangles.

We conducted perching surveys in 2007 and 2008. We initiated surveys in January and concluded them in April. We selected this survey period because it coincided with the peak number of wintering and migrating raptors and corvids in the area of the distribution line (G. Wallace, Utah Division of Wildlife Resources, personal communication). During this time period raptor and corvid numbers are increased by presence of migrant winter raptor species, including bald eagles (*Haliaeetus leucocephalus*) and rough-legged hawks (*Buteo lagopus*).

Fig. 4.1a.

Fig. 4.1b.

Fig. 4.1c.

Fig. 4.1d.

Fig. 4.1e.

Fig. 4.1f.

Figures 4.1 a-f. Five types of commercially available perch deterrents we evaluated included: a) single and b) paired arrangement of the FireFly™ (P and R Technologies Inc., Portland, OR) hazing deterrent; c) cones (Kaddas Enterprises Inc., Salt Lake City, UT); d) triangles (Kaddas Enterprises Inc., Salt Lake City, UT); e) spikes (Prommel Enterprises Inc., Odenville, AL); and f) control; San Juan County, Utah, 2007-2008.

We surveyed the distribution line twice a day, 5 days a week, weather permitting. We conducted surveys at 0800–1100 hr and 1400–1700 hr (Stahlecker 1978, Fuller and Mosher 1987). We randomly selected the starting point (west or east end) for each survey. We used alternative routes to arrive at the starting points to avoid disturbing any birds already perched. We spent 5 minutes at the starting point and at each mile point thereafter observing and recording any birds seen. While driving to the mile points we maintained speed of the vehicle at 15–25 km/hour.

We recorded all birds perched on the distribution poles. We defined a perching event as an observation of a raptor or corvid perched on a pole. This number of perching events was not a reflection of the density of birds inhabiting the study area, as we could record one bird more than once if it continued down the line perching on different poles. Observations included species, numbers, and perch locations. We recorded exact positions of birds perched on individual poles within the study distribution line.

In our data analysis, we addressed the following questions: 1) did total count of perching events recorded by treatment and control in 2007 and 2008 differ by perch deterrent type and year, and 2) did total count for each species on each type of deterrent and control in 2007 and 2008 differ? The model we used compared means among treatments for total count of perching events and total species counts observed in 2007 and 2008. We used a generalized linear-mixed model with Poisson distribution and log link (SAS Institute, Cary, NC). We made pairwise comparisons among treatment means where necessary. Thus, the statistical model was 1-way in a randomized spatial block design, with poles grouped into spatial blocks to control for spatial heterogeneity in the landscape. We conducted data analyses using the GLIMMIX procedure in SAS–STAT for Windows Version 9.1.3 (SAS Institute).

RESULTS

During 168 hours and 84 hours of direct observation in 2007 and 2008, respectively, we recorded 253 and 136 perching events, respectively, of 7 potential avian predator species of sage-grouse (J. W. Connelly, Western Association of Fish and Wildlife Agencies, unpublished report). The most common perching events by species were golden eagles (*Aquila chrysaetos*), common ravens (*Corvus corax*), and rough-legged hawks. Other species included red-tailed hawks (*B. jamaicensis*), bald eagles, black-billed magpies (*Pica hudsonia*), and ferruginous hawks (*B. regalis*). For analysis we used golden eagle, common raven, and rough-legged hawk counts. Because of the small sample sizes for the other species they were excluded from our statistical analysis.

In 2007, we conducted 112 surveys and recorded 172 (68%) perching events on poles fitted with perch deterrents. Perching events recorded did not differ ($p > 0.05$) for controls (32%), triangles (25%), cones (22%), and minizenas (21%, p=0.31, Table 1). Number of perching events also did not differ by control and perch deterrent type for golden eagles (p=0.07), common ravens (p=0.67), or rough-legged hawks (p=0.71, Table 2). Golden eagles were the most common with 195 (77%) perching events, of which 128 (74%) were on poles fitted with perch deterrents.

In 2008, winter snow conditions periodically closed the survey road and reduced the number of surveys completed. We conducted 56 surveys and recorded 136 avian predator perching events with 91 (67%) events on poles fitted with perch deterrents. Perching events recorded did not differ (p>0.05) for controls (33%), cones (26%), mini-zenas (24%), or triangles (17%, p=0.15, Table 4.1). Number of perching events did not differ by control and perch deterrent type for golden eagles (p=0.33), common ravens (p= 0.22), and rough-legged hawks (p=0.91, Table 4.2). Golden eagles were also most common in 2008 with 110 (81%) perching events, of which 76 (84%) were on poles fitted with perch deterrents. In both survey years, avian predators avoided deterrents, opting for alternative perch sites on the same pole such as insulators, bird guards, and deterrent-free parts of the cross arm, which allowed the birds to perch next to deterrents (Figs. 4.2a–f).

The structural design of the FireFly hazing deterrent could not withstand weather conditions. The FireFly was designed to spin in the wind, creating a reflective strobe effect intended to deter birds from perching. Average wind speed during the 2007 winter surveys was 19 km/hour, with gusts up to 74 km/hour. By the end of the 2007 survey period 10 of the 14 single Firefly arrangements and 11 of 14 double FireFly arrangements were damaged as a result of weather conditions and were largely inoperable, preventing us from evaluating their effectiveness as perch deterrents. Because part of the study design was to assess cost-effectiveness, including maintenance, we did not replace damaged FireFly arrangements prior to 2008 surveys. Thus, we did not analyze these data. Problems included 1) cracking at the site of the swiveling connector causing the reflector to break off of the unit, 2) support arms bending or breaking off under prevailing winds, and 3) swiveling connectors separating from their support base.

Table 4.1. Number of perching events (n) and percentage of perching events (%) by golden eagles, common ravens, and rough-legged hawks recorded documented on each perch deterrent tested and control power poles, and the estimated treatment mean ($\bar{x}$) with standard error (SE). San Juan County, Utah 2007 and 2008. The perch deterrents tested included: a) cones (Kaddas Enterprises Inc., Salt Lake City, UT), b) mini zenas (Prommel Enterprises Inc., Odenville, AL), and c) triangles (Kaddas Enterprises Inc., Salt Lake City, UT).

	2007				2008			
Perch deterrent	n	%	$\bar{x}$	SE	n	%	$\bar{x}$	SE
Cones	56	22	3.9	0.87	36	26	2.0	0.47
Mini zena	54	21	3.9	0.83	32	24	2.1	0.47
Triangle	62	25	4.2	0.92	23	17	2.0	0.49
Control	81	32	5.1	1.05	45	33	3.2	0.62

DISCUSSION

Our study was the first to evaluate commercially available perch deterrents as a means to prevent perching on poles of distribution lines by avian predators that pose a threat to sage-grouse. Perch deterrents we evaluated were ineffective. Our results support those reported by Lammers and Callopy (2007) for 345-kV towers within a transmission line in occupied sage-grouse habitat. Lammers and Callopy (2007) reported that deterrents did not prevent perching but did reduce raptor perching duration. However, the transmission towers in their study were 23–40 m tall and spaced in 366-m intervals.

Table 4.2. Number of perching events (n) documented for golden eagles, common ravens, and rough-legged hawks by perch deterrent type and control, and *F*-statistics (*F*) and *P*-values (*P*), San Juan County, Utah 2007 and 2008. The perch deterrents tested included: a) cones (Kaddas Enterprises Inc., Salt Lake City, UT), b) mini zenas (Prommel Enterprises Inc., Odenville, AL), and c) triangles (Kaddas Enterprises Inc., Salt Lake City, UT).

	2007						2008					
Species	Cones	Mini zena	Triangles	Control			Cones	Mini zena	Triangles	Control		
	n	n	n	n	*F*	*p*	n	n	n	n	*F*	*p*
Golden eagle	42	35	51	67	2.6	0.07	33	24	19	34	1.2	0.33
Common raven	9	13	8	7	0.5	0.46	1	6	3	8	1.5	0.22
Rough-legged hawk	5	6	3	7	0.5	0.71	2	2	1	3	0.2	0.91
Total	56	54	62	81	1.2	0.31	36	32	23	45	1.9	0.15

Fig. 4.2a.

Fig. 4.2b.

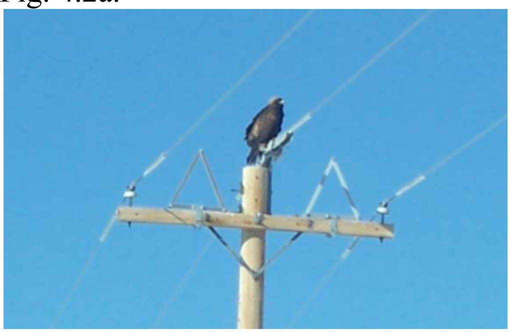

Fig. 4.2c.

Fig. 4.2d

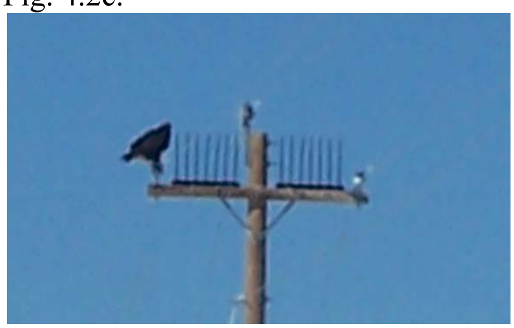

Fig. 4.2e.

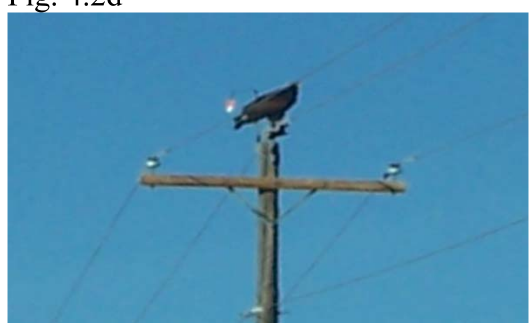

Fig. 4.2f.

Figures 4.2a-f. Typical golden eagle perching events documented relative to perch deterrent type on power distribution poles: a) cones (Kaddas Enterprises Inc., Salt Lake City, UT), b) mini zenas (Prommel Enterprises Inc., Odenville, AL), c) triangles (Kaddas Enterprises Inc., Salt Lake City, UT), d) 2-FireFly™ (P and R Technologies Inc., Portland, OR) arrangement, e) mini zenas, and f) 1-FireFly™ arrangement, San Juan County, Utah, 2007 and 2008.

The deterrent they tested was designed for discomfort and placed on parts of towers where avian predators would most likely perch.

Effectiveness of perch deterrents we evaluated may have been affected by the structure of power poles and the basic design and placement of deterrents. Perch deterrents we tested were partially successful in that they had the ability to prevent perching on parts of the poles. However, birds continued to perch on parts of the poles without deterrents, such as insulators. A perch deterrent that covers insulators, in combination with physical deterrents we tested, has potential to prevent perching of avian predators on power poles of distribution lines.

Before any further evaluation of FireFly as a perch deterrent we recommend the current design be modified. Modifications should include increased durability of plastic reflectors, stronger support bases, and swivel connections that can better withstand weather extremes.

MANAGEMENT IMPLICATIONS

We found that current commercially available perch deterrents used to prevent avian species electrocutions did not mitigate potential avian predators of sage-grouse from perching on poles of a distribution line. For the perch deterrents we evaluated to be successful, they would need to be redesigned to retrofit all parts of the pole, including insulators, rather than just the cross arm. Deterrents must also be designed to better withstand weather extremes.

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CHAPTER 5

CONCLUSIONS

Gunnison sage-grouse (*Centrocercus minimus*) currently occupy 8.5% of their presumed historical range (Schroeder et al. 2004). The decline has been attributed to the loss or conversion of sagebrush (*Artemisia* spp.) to other land uses. The quality of the remaining habitat has been impacted by urbanization, grazing, agriculture and fragmentation. As a result, the Gunnison sage-grouse is limited to seven known populations in Colorado and one population in southeastern Utah (GSRSC 2005). The only known Gunnison sage-grouse population in Utah occurs in San Juan County, Utah, near the town of Monticello.

The San Juan County Gunnison Sage-grouse Working Group (SWOG) previously designated an area northeast of the town of Monticello as a sage-grouse priority conservation area (SWOG 2000). The Conservation Area (CA) consisted of 1,392,812 ha, 38% (127,170 ha) of which is privately owned. The CA was identified by encompassing historic and current lek sites, potentially suitable sage-grouse habitat, and sage-grouse observations. The CA is characterized by large fields enrolled in the Conservation Reserve Program (CRP), agricultural fields, and grazed rangelands interspersed with fragmented patches of Wyoming big sagebrush (*A. tridentata wyomingensis*), black sagebrush (*A. nova*), pinyon pine (*Pinus edulis*), juniper (*Juniperus osteosperma*), and oak (*Quercus gambelii*). Within the CA, SWOG also identified a Core Conservation Area (CCA) that consisted of 136,249 ha, of which 89% (88,420 ha) was privately owned. Within the CCA, a Conservation Study Area (CSA) was also identified.

The CSA consisted of 24,177 ha, of which 93% (22,556 ha) was privately owned. The CSA encompassed currently occupied habitat (Lupis 2005, Ward 2007).

The Gunnison Sage-grouse Rangewide Conservation Plan (RCP) and the San Juan County Gunnison Sage-grouse Conservation Plan (SJCCP) recommend management strategies to address identified conservation threats to the San Juan County population (SWOG 2000, GSRSC 2005). Current management of Gunnison sage-grouse in San Juan County, Utah, was based on studies that gathered information regarding the population's life history, habitat use, and movement patterns (Lupis 2005, Ward 2007). This information was used by the Monticello/Dove Creek Local Working Group to guide conservation and management strategies stated within the SJCCP. The research I conducted addressed three conservation strategies identified in the SJCCP: 1) the creation and enhancement of brood-rearing areas; 2) the assessment of habitat conditions within the CA; and 3) the prevention or reduction of perching events by raptors and corvids on distribution line power poles.

The RCP and the SJCCP identified protection and enhancement of mesic brood-rearing habitats as a priority conservation strategy. Increased availability of forbs and arthropods in brood-rearing habitats has been positively associated with survival and recruitment of sage-grouse chicks (Peterson 1970, Wallestad 1971, Klott and Lindzey 1990, Johnson and Boyce 1990, Sveum et al. 1998, Connelly et al. 2000, Crawford et al. 2004). From 2007-2009, I evaluated the role of irrigation in creating mesic or wet meadow environments and dormant season grazing by cattle on habitat quality as measured by changes in vegetation structure and composition, arthropod abundance and diversity, and sage-grouse use. I conducted the experiment on 24 randomly selected 0.1 ha plots located in agricultural lands enrolled in CRP and native sagebrush.

Observationally, the vegetation in the irrigated plots remained greener longer through the season than in the non-irrigated plots, but vegetation diversity did not differ (p>0.01). The CRP plots exhibited greater arthropod abundance and cover of perennial grass than the native sagebrush plots, but lower diversity of perennial grasses and abundance and diversity of forbs (p<0.01). Crested wheatgrass (*Agropyron cristatum*) was the dominant species in the CRP plots and may have out-competed native forbs and grasses (Hull and Klomp 1967, Schuman et al. 1982, Henderson and Naeth 2005). Dormant season grazing of the CRP plots did not reduce crested wheatgrass cover but did eventually remove residual growth from previous seasons. Lastly, I did not detect any increased sage-grouse use of the treatment plots. This observation may be an artifact of the small plot size and isolated locations.

The increased arthropod abundance in CRP plots relative to the native sagebrush plots and the increased greenness of vegetation because of irrigation suggests a role for irrigation in managing these areas as brood-rearing habitats. The sprinkler irrigation system used in this study allowed quantification of water application rates. However, because of frequent winds, this system did not provide uniform plot coverage and may have resulted in increased evaporation. Thus, creation of mesic areas in brood-rearing habitats may best be accomplished by a system of terraces, ditch plugs or small check dams that retain moisture longer, and by providing flood irrigation. To increase forb and grass diversity in CRP, managers should evaluate the use of mechanical treatments, coupled with spring grazing and reseeding to mitigate the potential competitive effects of crested wheatgrass.

The second conservation strategy I addressed was the assessment of habitat conditions within the CA. In the summer of 2009 I used randomly generated points to measure vegetation conditions within habitat unoccupied and currently occupied by Gunnison sage-grouse. I compared the measured vegetation characteristics with the criteria for desired vegetation conditions outlined within the RCP. The results of the habitat assessment showed that sage-grouse movement and habitat use may be restricted to the CSA by the presence of pinyon-juniper and oak woodlands that surround the area. Because the woodlands occupy larger areas surrounding the CSA and do not provide sagebrush habitats, they may impede population exchanges between Utah and Colorado. These wooded areas are also avoided by the grouse because they provide perch sites for avian predators. These observations highlight the need to improve the habitat within the CSA to maximize the benefits of the habitat the grouse have available to them. Once habitat quality in the CSA approaches SJCCP and RCP guidelines, management actions should focus on opening corridors through these woodlands to facilitate population interchange. In the meantime, managers should consider species translocation between both Colorado and Utah to increase the genetic diversity in both populations.

The habitat assessment verified that forb and grass cover in the CSA is below SJCCP and RCP recommendations. Habitat improvement projects should be focused on retaining and enhancing the habitat quality of remaining sagebrush areas within the CSA. In particular, management efforts should be renewed to re-establish sagebrush, forb, and grass cover within CRP fields throughout the CSA to expand the habitat available to the grouse.

Connelly et al. (2000, Connelly et al., Western Association of Fish and Wildlife Agencies, unpublished report) suggested that because of the potential for raptors and corvids to use transmission line towers and distribution line poles as new perches and nest sites, placement of these facilities in seasonal sage-grouse habitats could impact the species through increased predation of adults, juveniles, and nests or result in sage-grouse abandoning sites (Knight and Kawashima 1993, Knight et al. 1995, Kochert and Olendorff 1999). The RCP identified as a priority conservation strategy the retrofitting of distribution line poles with perch deterrents to discourage raptors and corvids from perching. I evaluated the efficacy of five perch deterrents mounted on support poles of an 11-km section of a 12.5-kV distribution line that bisected the CA and habitat occupied by the sage-grouse population. Perch deterrents were mounted on the line in November-December 2006 following a random replicated block design that included controls. During 168 hours and 84 hours of direct observation in 2007 and 2008, respectively, I recorded 276 and 139 perching events of 7 potential avian predators of sage-grouse. Golden eagles (*Aquila chrysaetos*) were the dominant species recorded during both years. I did not detect any difference in perching events by perch deterrent we evaluated and controls ($p > 0.05$).

The effectiveness of perch deterrents evaluated may have been compromised by the structure of power poles and the basic design and placement of deterrents. The perch deterrents tested were partially successful in that they had the ability to prevent perching on parts of the poles. However birds continued to perch on parts of the poles without deterrents, such as insulators. A perch deterrent that covers insulators, in combination with the physical deterrents tested, may increase the potential to prevent perching of avian predators on power poles of distribution lines.

The results of these studies will help update the information within the RCP and the SJCCP. The results can also be used by the Monticello/Dove Creek Local Working Group to plan future conservation activities within the CA. These studies provided a sound first step that can be built upon to improve habitat conditions within the CA and to reduce the threat of avian predation. Future work should take these results and expand them to larger scale projects.

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APPENDICES

Table A.1. Vegetation mixture seeded on Conservation Reserve Program (CRP) lands within the Gunnison Sage-grouse Conservation Area in San Juan County, Utah (SWOG 2000).

	Species	PLS lbs/acre
Grasses		
	Bluebunch wheatgrass	1.0
	Thickspike wheatgrass	1.0
	Western wheatgrass	1.5
	Crested wheatgrass	0.5
	Pubescent wheatgrass	1.0
Legumes/Forbs		
	Alfalfa (Rambler)	1.0
	Alfalfa (Ladak, Normad)	1.5
	Western yarrow	0.12
	Lewis flax	0.25
	Sainfoin	0.5
	Small burnet	2.0
Shrubs		
	Wyoming big sagebrush	0.5
	Forage kochia	0.5
	Total	11.37

Table A.2. Shrubs, perennial grasses, annual grasses, and forbs measured in Conservation Reserve Program (CRP) and native sagebrush within the Gunnison Sage-grouse Conservation Study Area during the summers of 2007, 2008, and 2009. San Juan County, Utah.

		CRP plots	Sagebrush patches within CRP	Sagebrush plots
Perennial grass				
Crested wheatgrass	*Agropyron cristatum*	x	x	x
Blue grama	*Bouteloua gracilis*			x
Foxtail barley	*Hordeum jubatum*			x
Annual grass				
Cheat grass	*Bromus tectorum*	x	x	x
Forbs				
Russian knapweed	*Centaurea repens*	x		
Scaly globemallow	*Sphaeralcea leptophylla*		x	x
Goatsbeard	*Tragopogon dubius*	x		
Basin daisy	*Erigeron pulcherrimus*		x	x
Pale evening primrose	*Oenothera pallida*		x	x
Spreading daisy	*Erigeron divergens*		x	x
Cisco woody aster	*Xylorhia venusta*		x	x
African mustard	*Malcomia africana*	x	x	
Sulphur buckwheat	*Eriogonum umbellatum*		x	x
Vetch	*Astragalus* sp.			x
Heronsbill	*Erodium cicutarium*		x	x
Uinta groundsel	*Senecio multilobatus*			x
Russian thistle	*Salsola pestifer*	x		x
Common purslane	*Portulaca oleracea*			x
Hairy golden aster	*Heterotheca villosa*		x	x
Alfalfa	*Medicago polymorpha*	x		
Foothill deathcamas	*Zigadenus paniculatus*			x
Cryptantha	*Cryptantha* sp.		x	x
Rose-heath	*Leucelene ericoides*		x	x
Sub-shrub				
Broom snakeweed	*Gutierrezia sarothrae*		x	x
Shrubs				
Rubber rabbitbrush	*Chrysothamnus nauseosus*	x	x	x
Fringed sage	*Artemisia frigida*			x
Spineless horsebush	*Tetradymia canescens*			x
Wyoming big sage	*Artemisia tridentata* spp. wyomingensis		x	x

Table A.3. Tables reporting Type 3 tests of fixed effects and covariance parameter estimates of percent cover, height, and forage production of sagebrush, perennial grass, annual grass and forbs, and arthropod abundance in Conservation Reserve Program and native sagebrush plots for each water treatment (once a week, every 2 weeks, every 3 weeks) and grazing treatment (grazed, not grazed) in 2007, 2008, 2009, San Juan County, Utah (p<0.001).

A.3.1: Type 3 tests of fixed effects and covariance parameter estimates of forage production of perennial grasses, annual grasses, and forbs by Conservation Reserve Program and native sagebrush plots), water treatment (once a week, every 2 weeks, every 3 weeks), and grazing treatment (grazed, not grazed) in 2007, San Juan County, Utah (p<0.01).

		2007					
		Perennial grass		Annual grass		Forbs	
Effect	DF	*F*	*p*	*F*	*p*	*F*	*p*
Habitat	1,6	0.03	0.87	0.51	0.50	11.64	0.01
Water	3,18	0.08	0.97	0.23	0.88	0.21	0.89
Habitat x water	3,18	0.23	0.87	0.26	0.85	0.42	0.74
Grazing	1,24	0.59	0.45	0.91	0.35	2.66	0.12
Habitat x grazing	1,24	4.48	0.05	0.91	0.35	0.46	0.50
Water x grazing	3,24	0.13	0.94	1.31	0.30	0.62	0.61
Habitat x water x grazing	3,24	0.42	0.74	4.14	0.02	0.3	0.83
		Estimate	SE	Estimate	SE	Estimate	SE
Habitat		0.000	.	0.001	0.001	0.000	.
Water x habitat		0.032	0.012	0.003	0.001	0.002	0.001
Water x grazing x habitat		0.000	.	0.000	.	0.000	.
Residual		0.018	0.005	0.002	0.001	0.004	0.001

A.3.2: Type 3 tests of fixed effects and covariance parameter estimates of forage production of perennial grasses, annual grasses, and forbs by Conservation Reserve Program and native sagebrush plots, water treatment (once a week, every 2 weeks, every 3 weeks), and grazing treatment (grazed, not grazed) in 2008, San Juan County, Utah ($p<0.01$).

		2008					
		Perennial grass		Annual grass		Forbs	
Effect	DF	*F*	*p*	*F*	*p*	*F*	*p*
Habitat	1,6	23.82	<0.01	2.17	0.19	12.03	0.01
Water	3,18	0.23	0.88	1.86	0.17	0.86	0.48
Habitat x water	3,18	1.38	0.28	4.1	0.02	0.1	0.96
Grazing	1,24	3.43	0.08	4.6	0.04	0.08	0.78
Habitat x grazing	1,24	0.12	0.73	1.79	0.19	0.44	0.51
Water x grazing	3,24	0.5	0.69	0.53	0.67	1.51	0.24
Habitat x water x grazing	3,24	0.55	0.65	0.65	0.59	0.33	0.81
		Estimate	SE	Estimate	SE	Estimate	SE
Habitat		0.004	0.003	0.003	0.002	0.000	.
Water x habitat		0.000	.	0.000	.	0.000	.
Water x grazing x habitat		0.000	.	0.000	.	0.000	0.001
Residual		0.013	0.003	0.007	0.002	0.006	0.000

A.3.3: Type 3 tests of fixed effects and covariance parameter estimates of forage production of perennial grasses, annual grasses, and forbs by Conservation Reserve Program and native sagebrush plots, water treatment (once a week, every 2 weeks, every 3 weeks), and grazing treatment (grazed, not grazed) in 2009, San Juan County, Utah ($p<0.01$).

		2009					
		Perennial grass		Annual grass		Forbs	
Effect	DF	*F*	*p*	*F*	*p*	*F*	*p*
Habitat	1,6	12.37	0.01	0.49	0.51	13.12	0.01
Water	3,18	5.39	0.01	0.21	0.89	0.28	0.84
Habitat x water	3,18	0.55	0.65	1.96	0.16	1.74	0.20
Grazing	1,24	0.09	0.77	2.09	0.16	0.02	0.90
Habitat x grazing	1,24	12.51	0.00	0.67	0.42	0.76	0.39
Water x grazing	3,24	0.47	0.70	0.5	0.69	0.19	0.90
Habitat x water x grazing	3,24	0.55	0.65	0.55	0.65	0.57	0.64
		Estimate	SE	Estimate	SE	Estimate	SE
Habitat		0.007	0.006	0.002	0.002	0.002	0.002
Water x habitat		0.000	0.004	0.000	.	0.000	.
Water x grazing x habitat		0.000	.	0.000	.	0.000	.
Residual		0.018	0.005	0.005	0.001	0.008	0.002

A.3.4: Type 3 tests of fixed effects and covariance parameter estimates of percent cover of perennial grasses, annual grasses, forbs, and sagebrush by Conservation Reserve Program and native sagebrush plots, water treatment (once a week, every 2 weeks, every 3 weeks), and grazing treatment (grazed, not grazed) in 2007, San Juan County, Utah (p<0.01).

		2007							
		Perennial grass		Annual grass		Forbs		Sagebrush	
Effect	DF	*F*	*p*	*F*	*p*	*F*	*p*	*F*	*p*
Habitat	1,6	3.06	0.13	1.99	0.21	3.6	0.11	67.67	<0.01
Water	3,18	0.86	0.48	1.12	0.37	0.47	0.71	0.41	0.75
Habitat x water	3,18	0.65	0.59	2.35	0.11	0.51	0.68	2.17	0.13
Grazing	1,24	0.58	0.45	2.19	0.15	0.6	0.45	6.6	0.02
Habitat x grazing	1,24	1.58	0.22	1.4	0.25	0.3	0.59	0.77	0.39
Water x grazing	3,24	0.33	0.80	0.74	0.54	0.39	0.76	0.67	0.58
Habitat x water x grazing	3,24	2.16	0.12	0.17	0.92	1.01	0.41	0.34	0.80
Time	1,48	1.77	0.19	8.67	0.01	72.59	<0.01	0.36	0.55
Habitat x time	1,48	0.71	0.40	7.72	0.01	11.97	<0.01	0.33	0.57
Water x time	3,48	1.11	0.35	0.93	0.43	2.16	0.11	0.5	0.68
Habitat x water x time	3,48	1.08	0.37	0.42	0.74	1.91	0.14	0.63	0.60
Grazing x time	1,48	0.66	0.42	1.96	0.17	0.75	0.39	0.34	0.56
Habitat x grazing x time	1,48	4.09	0.05	0.02	0.88	0.81	0.37	0.31	0.58
Water x grazing x time	3,48	0.57	0.64	0.12	0.95	0.32	0.81	0.46	0.71
Habitat x water x grazing x time	3,48	0.09	0.97	0.21	0.89	0.53	0.66	0.65	0.59
		Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Habitat		0.007	0.006	0.009	0.008	0.000	0.001	0.001	0.002
Water x habitat		0.002	0.005	0.004	0.006	0.001	0.003	0.004	0.004
Water x grazing x habitat		0.017	0.006	0.022	0.007	0.012	0.004	0.007	0.004
Residual		0.010	0.002	0.002	0.000	0.004	0.001	0.010	0.002

A.3.5: Type 3 tests of fixed effects and covariance parameter estimates of percent cover of perennial grasses, annual grasses, forbs, and sagebrush by Conservation Reserve Program and native sagebrush plots, water treatment (once a week, every 2 weeks, every 3 weeks), and grazing treatment (grazed, not grazed) in 2008, San Juan County, Utah (p<0.01).

		2008							
		Perennial grass		Annual grass		Forbs		Sagebrush	
Effect	DF	*F*	*p*	*F*	*p*	*F*	*p*	*F*	*p*
Habitat	1,6	10.82	0.02	1.12	0.33	37.71	<0.01	86.6	<0.01
Water	3,18	0.58	0.64	2.26	0.12	0.33	0.81	0.06	0.98
Habitat x water	3,18	1.39	0.28	4.07	0.02	1.82	0.18	1.38	0.28
Grazing	1,24	0.3	0.59	4.38	0.05	1.34	0.26	1.44	0.24
Habitat x grazing	1,24	1.96	0.17	0.46	0.51	0.19	0.67	0.04	0.85
Water x grazing	3,24	0.13	0.94	0.12	0.95	0.43	0.74	0.23	0.87
Habitat x water x grazing	3,24	3.15	0.04	0.12	0.95	0.67	0.58	1.41	0.26
Time	1,48	0.06	0.80	11.88	<0.01	4.16	0.05	0.41	0.53
Habitat x time	1,48	1.32	0.26	0.06	0.81	7.97	0.01	0.12	0.73
Water x time	3,48	0.56	0.64	0.97	0.42	0.63	0.60	1.09	0.36
Habitat x water x time	3,48	0.2	0.89	2.3	0.09	0.53	0.67	0.93	0.43
Grazing x time	1,48	0.44	0.51	0.86	0.36	1.68	0.20	0.23	0.64
Habitat x grazing x time	1,48	0.03	0.87	0.01	0.91	0.23	0.63	0.11	0.74
Water x grazing x time	3,48	2.43	0.08	1.04	0.38	1.6	0.20	0.37	0.78
Habitat x water x grazing x time	3,48	0.53	0.67	0.21	0.89	0.87	0.46	0.59	0.62
		Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Habitat		0.003	0.004	0.017	0.014	0.000	0.001	0.000	.
Water x habitat		0.000	.	0.009	0.009	0.000	.	0.001	0.003
Water x grazing x habitat		0.016	0.005	0.022	0.009	0.006	0.002	0.009	0.004
Residual		0.010	0.002	0.016	0.003	0.006	0.001	0.006	0.001

A.3.6: Type 3 tests of fixed effects and covariance parameter estimates of percent cover of perennial grasses, annual grasses, forbs, and sagebrush by Conservation Reserve Program and native sagebrush plots, water treatment (once a week, every 2 weeks, every 3 weeks), and grazing treatment (grazed, not grazed) in 2009, San Juan County, Utah (p<0.01).

		2009							
		Perennial grass		Annual grass		Forbs		Sagebrush	
Effect	DF	*F*	*p*	*F*	*p*	*F*	*p*	*F*	*p*
Habitat	1,6	24.8	<0.01	0.25	0.63	15.72	<0.01	43.73	<0.01
Water	3,18	0.15	0.93	3.93	0.03	0.17	0.91	1.31	0.30
Habitat x water	3,18	0.4	0.75	3.35	0.04	1.01	0.41	2.4	0.10
Grazing	1,24	0.11	0.74	1.55	0.23	1.56	0.22	2.25	0.15
Habitat x grazing	1,24	1.62	0.22	0	0.97	0.51	0.48	0.38	0.54
Water x grazing	3,24	1.52	0.24	2.39	0.09	0.7	0.56	0.68	0.57
Habitat x water x grazing	3,24	4.59	0.01	1.87	0.16	0.75	0.53	0.15	0.93
Time	1,48	4.29	0.04	0.75	0.39	0.5	0.48	2.9	0.10
Habitat x time	1,48	0.05	0.82	0.94	0.34	0.4	0.53	2.06	0.16
Water x time	3,48	1.01	0.40	0.4	0.75	1.04	0.38	2.63	0.06
Habitat x water x time	3,48	0.52	0.67	1.2	0.32	2.73	0.05	2.17	0.10
Grazing x time	1,48	0.43	0.52	0	0.95	0.17	0.68	0.25	0.62
Habitat x grazing x time	1,48	0.75	0.39	0	0.95	1.49	0.23	0.58	0.45
Water x grazing x time	3,48	1.18	0.33	2.03	0.12	1.25	0.30	0.06	0.98
Habitat x water x grazing x time	3,48	2.26	0.09	1.35	0.27	0.82	0.49	0.16	0.92
		Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Habitat		0.000	.	0.003	0.003	0.000	0.001	0.004	0.004
Water x habitat		0.004	0.002	0.003	0.004	0.002	0.003	0.002	0.004
Water x grazing x habitat		0.000	.	0.006	0.004	0.007	0.003	0.009	0.005
Residual		0.017	0.003	0.011	0.002	0.005	0.001	0.015	0.003

A.3.7: Type 3 tests of fixed effects and covariance parameter estimates of height of perennial grasses, annual grasses, forbs, and sagebrush by Conservation Reserve Program and native sagebrush plots, water treatment (once a week, every 2 weeks, every 3 weeks), and grazing treatment (grazed, not grazed) in 2007, San Juan County, Utah ($p<0.01$).

		2007							
		Perennial grass		Annual grass		Forbs		Sagebrush	
Effect	DF	*F*	*p*	*F*	*p*	*F*	*p*	*F*	*p*
Habitat	1,6	34.98	<0.01	1.54	0.26	1.06	0.34	77.38	<0.01
Water	3,18	1.72	0.20	2.58	0.09	0.38	0.77	0.49	0.69
Habitat x water	3,18	0.42	0.74	2.07	0.14	1.37	0.28	0.43	0.74
Grazing	1,24	1.34	0.26	1.07	0.31	2.75	0.11	2.97	0.10
Habitat x grazing	1,24	1.50	0.23	0.03	0.85	3.56	0.07	2.92	0.10
Water x grazing	3,24	0.10	0.96	0.48	0.70	0.24	0.87	0.81	0.50
Habitat x water x grazing	3,24	1.21	0.32	0.12	0.95	0.22	0.88	0.08	0.97
Time	1,48	19.38	<0.01	7.78	0.01	23.11	<0.01	0.72	0.40
Habitat x time	1,48	0.10	0.75	1.97	0.17	4.71	0.04	1.18	0.28
Water x time	3,48	0.25	0.86	2.30	0.09	1.08	0.37	0.82	0.49
Habitat x water x time	3,48	0.60	0.62	0.54	0.66	0.47	0.70	2.67	0.06
Grazing x time	1,48	1.57	0.22	1.08	0.30	0.34	0.56	0	0.95
Habitat x grazing x time	1,48	0.31	0.58	1.99	0.17	0.08	0.78	0.13	0.72
Water x grazing x time	3,48	2.02	0.12	1.14	0.34	1.18	0.33	0.35	0.79
Habitat x water x grazing x time	3,48	0.37	0.77	0.30	0.83	0.79	0.51	0.48	0.70
		Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Habitat		0.001	0.001	0.007	0.006	0.001	0.001	0.005	0.004
Water x habitat		0.000	.	0.004	0.003	0.000	.	0.000	.
Water x grazing x habitat		0.000	.	0.005	0.003	0.000	.	0.003	0.004
Residual		0.007	0.001	0.010	0.002	0.010	0.002	0.025	0.005

A.3.8: Type 3 tests of fixed effects and covariance parameter estimates of height of perennial grasses, annual grasses, forbs, and sagebrush by Conservation Reserve Program and native sagebrush plots, water treatment (once a week, every 2 weeks, every 3 weeks), and grazing treatment (grazed, not grazed) in 2008, San Juan County, Utah (p<0.01).

		2008							
		Perennial grass		Annual grass		Forbs		Sagebrush	
Effect	DF	*F*	*p*	*F*	*p*	*F*	*p*	*F*	*p*
Habitat	1,6	12.56	0.01	0.38	0.56	48.33	<0.01	52.86	<0.01
Water	3,18	0.47	0.70	2.51	0.09	1.1	0.37	0.52	0.67
Habitat x water	3,18	0.48	0.70	2.91	0.06	0.29	0.83	0.25	0.86
Grazing	1,24	0.22	0.64	3.36	0.08	1.5	0.23	0.65	0.44
Habitat x grazing	1,24	6.37	0.02	0.08	0.78	4.37	0.05	2.85	0.10
Water x grazing	3,24	1.27	0.31	0.14	0.94	0.25	0.86	0.98	0.42
Habitat x water x grazing	3,24	1.55	0.23	0.03	0.99	1.14	0.35	0.39	0.76
Time	1,48	31.36	<0.01	17.45	<0.01	0.38	0.54	9.99	<0.01
Habitat x time	1,48	22.31	<0.01	0.57	0.45	0.12	0.73	0.6	0.44
Water x time	3,48	0.36	0.79	1.81	0.16	0.1	0.96	0.19	0.90
Habitat x water x time	3,48	1.79	0.16	1.63	0.19	0.48	0.70	1.12	0.35
Grazing x time	1,48	0.24	0.63	0.83	0.37	1.7	0.20	0.07	0.79
Habitat x grazing x time	1,48	1.39	0.24	1.08	0.30	0	0.98	0.39	0.53
Water x grazing x time	3,48	0.86	0.47	2.51	0.07	2.09	0.11	0.77	0.51
Habitat x water x grazing x time	3,48	2.04	0.12	0.08	0.97	3.24	0.03	0.93	0.43
		Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Habitat		0.002	0.002	0.005	0.004	0.000	0.000	0.004	0.006
Water x habitat		0.000	.	0.004	0.004	0.000	.	0.011	0.008
Water x grazing x habitat		0.006	0.002	0.010	0.004	0.002	0.001	0.018	0.006
Residual		0.004	0.001	0.005	0.001	0.004	0.001	0.006	0.001

A.3.9: Type 3 tests of fixed effects and covariance parameter estimates of height of perennial grasses, annual grasses, forbs, and sagebrush by Conservation Reserve Program and native sagebrush plots, water treatment (once a week, every 2 weeks, every 3 weeks), and grazing treatment (grazed, not grazed) in 2009, San Juan County, Utah (p<0.01).

		2009							
		Perennial grass		Annual grass		Forbs		Sagebrush	
Effect	DF	*F*	*P*	*F*	*p*	*F*	*p*	*F*	*p*
Habitat	1,6	14.66	0.01	0	0.98	8.82	0.03	31.12	<0.01
Water	3,18	1.4	0.27	6.29	<0.01	0.38	0.77	0.18	0.91
Habitat x water	3,18	0.09	0.97	4.04	0.02	2.47	0.10	0.33	0.81
Grazing	1,24	1.12	0.30	1.93	0.18	0.2	0.66	4.63	0.04
Habitat x grazing	1,24	12.61	<0.01	0.62	0.44	0.46	0.50	7.91	0.01
Water x grazing	3,24	0.64	0.60	0.67	0.58	0.04	0.99	1.91	0.16
Habitat x water x grazing	3,24	0.67	0.58	2.3	0.10	0.68	0.58	1.97	0.15
Time	1,48	17.16	<0.01	26.31	<0.01	0.21	0.65	11.00	<0.01
Habitat x time	1,48	0.21	0.65	1.47	0.23	1.16	0.29	11.00	<0.01
Water x time	3,48	1.23	0.31	0.6	0.62	2.14	0.11	1.03	0.39
Habitat x water x time	3,48	1.61	0.20	1.81	0.16	0.57	0.64	1.03	0.39
Grazing x time	1,48	0.08	0.78	1.03	0.32	0.33	0.57	0.00	0.99
Habitat x grazing x time	1,48	0.03	0.87	0.01	0.94	0.13	0.73	0.00	0.99
Water x grazing x time	3,48	0.49	0.69	1.46	0.24	1.07	0.37	0.43	0.74
Habitat x water x grazing x time	3,48	0.13	0.94	0.23	0.88	0.79	0.50	0.43	0.74
		Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Habitat		0.002	0.002	0.003	0.002	0.000	0.001	0.013	0.010
Water x habitat		0.002	0.002	0.002	0.001	0.002	0.001	0.008	0.007
Water x grazing x habitat		0.000	0.001	0.002	0.001	0.001	0.001	0.021	0.006
Residual		0.007	0.001	0.005	0.001	0.003	0.001	0.002	0.000

A.3.10: Type 3 tests of fixed effects arthropod orders by Conservation Reserve Program and native sagebrush plots, water treatment (once a week, every 2 weeks, every 3 weeks), and grazing treatment (grazed, not grazed) in 2007, San Juan County, Utah (p<0.01).

		2007									
		Aranae		Coleoptera		Diptera		Hemiptera		Homoptera	
Effect	DF	*F*	*p*	*F*	*p*	*F*	*p*	*F*	*P*	*F*	*p*
Habitat	1,6	8.10	0.03	1.46	0.27	23.40	<0.01	2.33	0.18	0.20	0.67
Water	3,18	1.12	0.37	0.22	0.88	0.17	0.91	1.29	0.31	0.35	0.79
Habitat x water	3,18	0.06	0.98	0.38	0.77	1.73	0.20	0.67	0.58	2.29	0.11
Grazing	1,24	0.11	0.75	6.80	0.04	0.07	0.81	1.12	0.33	2.17	0.19
Habitat x grazing	1,24	0.00	0.95	0.00	0.97	0.71	0.43	1.38	0.28	0.00	0.97
Water x grazing	3,24	0.31	0.82	0.76	0.53	1.75	0.19	1.16	0.35	0.58	0.64
Habitat x water x grazing	3,24	0.07	0.98	0.86	0.48	0.24	0.87	2.03	0.15	1.10	0.37

		Hymenoptera (ants)		Hymenoptera (bees and wasps)		Lepidoptera		Orthoptera	
Effect	DF	*F*	*p*	*F*	*p*	*F*	*p*	*F*	*P*
Habitat	1,6	0.17	0.70	2.85	0.14	1.02	0.35	45.4	<0.01
Water	3,18	1.03	0.40	0.79	0.52	0.21	0.89	0.25	0.86
Habitat x water	3,18	3.44	0.04	1.86	0.17	0.37	0.78	0.17	0.92
Grazing	1,24	0.59	0.48	0.16	0.70	0.47	0.52	0.06	0.82
Habitat x grazing	1,24	0.52	0.50	0.48	0.51	3.31	0.12	0.11	0.75
Water x grazing	3,24	1.39	0.28	0.53	0.67	0.68	0.57	0.52	0.67
Habitat x water x grazing	3,24	0.02	0.99	1.79	0.19	1.20	0.34	1.61	0.22

A.3.11: Type 3 tests of fixed effects arthropod orders by Conservation Reserve Program and native sagebrush plots, water treatment (once a week, every 2 weeks, every 3 weeks), and grazing treatment (grazed, not grazed) in 2008, San Juan County, Utah (p<0.01).

2008											
		Aranae		Coleoptera		Diptera		Hemiptera		Homoptera	
Effect	DF	*F*	*p*	*F*	*p*	*F*	*p*	*F*	*P*	*F*	*p*
Habitat	1,6	1.49	0.27	3.61	0.11	0.04	0.85	10.7	0.02	23.9	<0.01
Water	3,18	0.49	0.69	0.68	0.58	2.01	0.15	3.26	0.05	3.36	0.04
Habitat x water	3,18	0.55	0.66	0.75	0.54	0.71	0.56	4.75	0.01	2.26	0.12
Grazing	1,24	0.23	0.65	7.22	0.04	0.55	0.49	0.96	0.37	6.52	0.04
Habitat x grazing	1,24	1.61	0.25	2.08	0.20	1.88	0.22	1.27	0.30	7.65	0.03
Water x grazing	3,24	1.06	0.39	2.20	0.12	1.37	0.29	1.60	0.22	3.94	0.03
Habitat x water x grazing	3,24	1.85	0.17	2.22	0.12	2.01	0.15	2.52	0.09	2.75	0.07

		Hymenoptera (ants)		Hymenoptera (bees and wasps)		Lepidoptera		Orthoptera	
Effect	DF	*F*	*p*	*F*	*p*	*F*	*p*	*F*	*P*
Habitat	1,6	0.09	0.78	0.01	0.94	14.4	0.01	108	<0.01
Water	3,18	0.76	0.53	0.35	0.79	0.42	0.74	0.28	0.84
Habitat x water	3,18	0.77	0.53	3.59	0.03	1.31	0.30	2.85	0.07
Grazing	1,24	3.50	0.11	0.80	0.40	0.45	0.53	0.32	0.59
Habitat x grazing	1,24	1.26	0.30	0.02	0.91	0.22	0.65	0.04	0.84
Water x grazing	3,24	1.70	0.20	2.07	0.14	3.48	0.04	0.72	0.55
Habitat x water x grazing	3,24	0.92	0.45	2.97	0.06	1.05	0.39	0.92	0.45

A.3.12: Type 3 tests of fixed effects arthropod orders by Conservation Reserve Program and native sagebrush plots, water treatment (once a week, every 2 weeks, every 3 weeks), and grazing treatment (grazed, not grazed) in 2009, San Juan County, Utah (p<0.01).

		2009									
		Aranae		Coleoptera		Diptera		Hemiptera		Homoptera	
Effect	DF	*F*	*p*	*F*	*p*	*F*	*p*	*F*	*P*	*F*	*p*
Habitat	1,6	4.23	0.09	0.00	0.99	1.04	0.35	6.10	0.05	0.60	0.47
Water	3,18	0.46	0.72	1.28	0.31	0.60	0.63	2.50	0.09	2.49	0.09
Habitat x water	3,18	1.00	0.42	1.11	0.37	1.31	0.30	2.10	0.14	3.12	0.05
Grazing	1,24	0.94	0.37	0.45	0.53	0.03	0.88	0.13	0.73	2.57	0.16
Habitat x grazing	1,24	1.29	0.30	0.42	0.54	0.05	0.83	0.00	0.97	0.08	0.79
Water x grazing	3,24	1.16	0.35	0.89	0.47	0.75	0.54	0.58	0.64	0.99	0.42
Habitat x water x grazing	3,24	1.62	0.22	0.48	0.70	1.25	0.32	0.66	0.59	3.15	0.05
		Hymenoptera (ants)		Hymenoptera (bees and wasps)		Lepidoptera		Orthoptera			
Effect	DF	*F*	*p*	*F*	*p*	*F*	*p*	*F*	*P*		
Habitat	1,6	0.15	0.71	0.48	0.52	3.95	0.09	83.6	<0.01		
Water	3,18	0.82	0.50	0.27	0.84	1.18	0.35	0.55	0.65		
Habitat x water	3,18	0.70	0.56	3.66	0.03	0.09	0.96	0.24	0.87		
Grazing	1,24	1.11	0.33	0.47	0.52	1.20	0.32	0.32	0.59		
Habitat x grazing	1,24	3.57	0.11	0.10	0.76	1.20	0.32	0.03	0.87		
Water x grazing	3,24	0.59	0.63	0.87	0.48	2.20	0.12	3.34	0.04		
Habitat x water x grazing	3,24	0.40	0.76	0.36	0.78	0.20	0.90	0.28	0.84		

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Name: Phoebe Prather
Address: 255 South 400 East Logan, UT 84321
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Journal Name: The Journal of Wildlife Management
Journal Address: 202 Natural Resources, University of Missouri Columbia, MO 65211-7260

To Permissions Editor:

I am preparing my dissertation in the Department of Wildland Resources at Utah State University. I hope to complete my degree in the summer of 2010.

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CURRICULUM VITAE
Phoebe R. Prather
(May 2010)

CARREER OBJECTIVE:

To obtain a position with an organization that requires technical expertise and communication skills. Special areas of interest: habitat management, habitat restoration, and avian, wetland and riparian ecology and management.

EDUCATION:

B.A. in Environmental Studies, University of California at Santa Cruz, Santa Cruz, California. (06/2002). Emphasis in environmental policy and land management. Received honors on undergraduate thesis. Ph.D. in Ecology, Utah State University, Logan, Utah. (expected 07/2010). Grad GPA: 3.63. Dissertation research in Utah 2006-2009.

EXPERIENCE:

GRADUATE RESEARCH ASSISTANT, Utah State University, Ph.D. Candidate in Ecology, Logan, Utah (06/2006-05/2010).

- Designed, implemented, and analyzed statistically valid field experiments to address conservation strategies identified in the San Juan County, Utah Gunnison Sage-grouse Conservation Plan. Collected, compiled, organized and analyzed field data, and presented the results in both written and oral formats.
- Communicated, collaborated and formed relationships with state and federal agencies, non-profit organizations, and private landowners.
- Supervised field technicians and Youth Conservation Corp work crews.

- Surveyed raptor and corvid use of distribution line power poles fitted with perch deterrents.
- Created wet meadow brood-rearing habitats in sagebrush habitats and Conservation Reserve Program fields through the use of irrigation.
- Proficient in diverse vegetation measurement techniques and methodologies.
- Trapped arthropods using pit-fall traps and sorted them to family using a dissecting scope and dichotomous key.
- Prepared and edited annual reports.
- Presented results at stakeholder conferences and professional meetings to diverse audiences.

RESEARCH ASSISTANT, Delta Waterfowl Foundation, Minnedosa Field Station, Manitoba, Canada (04/2005-08/2005).

- Conducted research on nesting mallard hens. Trapped hens using decoy traps, Weller traps, and nesting tunnel traps. Banded, took measurements, collected feathers, and placed nasal markers on captured hens. Maintained a field notebook and field datasheets.
- Nest searched using ATV's and a drag chain.
- Monitored nests of several upland nesting waterfowl species.
- Used the candling technique to age eggs.
- Banded mallard ducklings using plastacine bands.
- Re-sighted Mallard hens with nasal markers using a spotting scope.

- Assisted other graduate student crews based out of the field station conducting research on American Coots, Ruddy Ducks, and Stripped Skunks. Became familiar with radio-telemetry techniques while assisting the skunk crew.

ENDANGERED SHOREBIRD MONITOR AND NATURALIST, Massachusetts Audubon Society, Cummaquid, MA (04/2004-09/2004).

- Worked at the Mass Audubon Sampson's Island/Dead Neck Wildlife Sanctuary, Cape Cod.
- Monitored nesting Piping Plovers. Visited island daily to determine breeding territories. Fenced off territories and posted signs. Constructed predator exclosures around nests. Intensely monitored broods, keeping a record of number of chicks hatched and fledged. Completed daily observation forms.
- Monitored Least and Common Tern nesting colonies. Fenced off nesting colonies. Conducted weekly counts of nests. Constructed and maintained a solar powered electric predator fence.
- Researched, prepared, and conducted weekend nature walks for groups of 2 to 20 people of all ages.
- Conversed with visitors, checked Audubon memberships, sold memberships, collected day fees, and provided information on nesting birds and the methods taken to protect them.
- Used a 13 foot Boston Whaler to reach and patrol the island.

- Volunteered with Massachusetts Fish and Wildlife to conduct Roseate Tern nesting surveys and assist in banding and weighing Common and Roseate Tern chicks.
- Volunteered with Monomoy National Wildlife Refuge to conduct Herring and Great Black-backed Gull nesting survey and to conduct Horseshoe Crab surveys twice a month on night full and new moon tides.
- Supervised high school student volunteers.

RESOURCE ASSISTANT, Student Conservation Association, Arches National Park, Interpretation Division, Moab, Utah (07/2003-10/2003).

- Researched, composed, and presented an evening slideshow program on the natural histories of raptors for an audience of up to 70 people.
- Researched, prepared, and conducted guided hikes and nature walks for groups of up to 30 people.
- Staffed park visitor desk, provided park and area information, aided visitors in trip planning, responsible for the handling of fees, selling tour tickets, reconciling funds, and completing associated paperwork.
- Educated visitors on the desert ecosystems and the challenges that they face.
- Aided in search and rescue incidents.

RESOURCE ASSISTANT, Student Conservation Association, Arches National Park, Resource Management Division, Moab, Utah (03/2003-07/2003).

- Monitored raptor nests of eight species of birds prey, including determining activity and counting number of young and fledged young at 70 historic nesting sites.
- Monitored a Great-Blue Heron Rookery on the Colorado River throughout the nesting season.
- Conducted a weekly Breeding Bird Survey identifying songbirds of the pinyon-juniper habitat by sight and song.
- Assisted researchers in vegetation transects and riparian bird point count surveys.
- Assisted in boundary fencing projects and rehabilitation of areas damaged by off-road vehicle use.
- Researched and composed the life histories for the raptor and songbird species surveyed.
- Used a four-wheel drive vehicle and hiking in extreme summer desert conditions to reach the nest sites.
- Prepared and edited seasonal reports.
- Aided in search and rescue incidents.

INTERNSHIP, Alaska Audubon Society, Anchorage, Alaska (10/2002-12/2002).

- Aided in the development of the Alaska State Important Bird Area (IBA) program.
- Entered data into the World Bird Database for over 200 Important Bird Areas in the Cook Inlet watershed and along the Bering Sea coast.

- Designed criteria for passerine Important Bird Areas with U.S. Fish and Wildlife biologists.
- Researched and prepared a pamphlet aiming to educate the public on the IBA program.
- Researched and composed the life histories for bird species on the Audubon Alaska Watch List.

BIRD BANDER, Denali Institute, Denali National Park, Alaska (07/2002-09/2002).

- Operated a passerine bird banding station in the heart of Denali National Park at the Denali Institute Migration Station.
- Utilized and maintained 10 nets; banded 7 days a week; recorded specific data on each individual.
- Presented an evening program to 20 to 40 lodge guests and conducted hands-on demonstrations for the guests at the banding station.

AWARDS AND HONORS:

- Received Honors on undergraduate thesis entitled, “What the Heck in as IBA: A case study of the Important Bird Area Program in the Owens Valley, California,” from the University of California at Santa Cruz in 2002.
- Recipient of the Utah Chapter of the Wildlife Society Annual Scholarship in 2007.

PROFESSIONAL PRESENTATIONS:

- Prather, Phoebe R. and T.A. Messmer. 2006. “Use of Artificial Wet Meadow Areas by Gunnison Sage-grouse (*Centrocercus minimus*) in San Juan County, Utah." Presented at The Utah Chapter of the Wildlife Society Annual Conference in Moab, UT.

- Prather, Phoebe R. and T.A. Messmer. 2007. "Raptor and Corvid Use of Distribution Line Power Poles: An Assessment of the Efficacy of Perch Deterrents." Presented at The Utah Chapter of the Wildlife Society Annual Conference in Moab, UT.
- Prather, Phoebe R. and T.A. Messmer. 2007. "Raptor and Corvid Use of Distribution Line Power Poles: An Assessment of the Efficacy of Perch Deterrents." Presented at The Utah Sage-grouse Summit in Salt Lake City, UT.
- Prather, Phoebe R. and T.A. Messmer. 2008. "Raptor and Corvid Use of Distribution Line Power Poles: An Assessment of the Efficacy of Perch Deterrents." Presented at The Gunnison Sage-grouse Summit in Montrose, CO.
- Prather, Phoebe R. and T.A. Messmer. 2008. "Raptor and Corvid Use of Distribution Line Power Poles: An Assessment of the Efficacy of Perch Deterrents." Presented at The Western Association of Fish and Wildlife Agencies Sage-grouse and Sharp-tailed Grouse Conference in Mammoth Lakes, CA.

RESEARCH PUBLICATIONS AND REPORTS:

- Prather, Phoebe R. and T.A. Messmer. 2007. Annual Report. "Gunnison Sage-grouse (*Centrocercus minimus*) Conservation in Utah: A summary of species and habitat response to conservation strategies identified in the Gunnison Sage-grouse Rangewide Conservation Plan." Department of Wildland Resources, Utah State University, Logan, UT.

- Prather, Phoebe R. and T.A. Messmer. 2008. Annual Report. "Gunnison Sage-grouse (*Centrocercus minimus*) Conservation in Utah: A summary of species and habitat response to conservation strategies identified in the Gunnison Sage-grouse Rangewide Conservation Plan." Department of Wildland Resources, Utah State University, Logan, UT.
- Prather, Phoebe R. and T.A. Messmer. 2009. Annual Report. "Gunnison Sage-grouse (*Centrocercus minimus*) Conservation in Utah: A summary of species and habitat response to conservation strategies identified in the Gunnison Sage-grouse Rangewide Conservation Plan." Department of Wildland Resources, Utah State University, Logan, UT.
- Prather, P.R. and T.A. Messmer. In press. "Raptor and Corvid Response to Power Distribution Line Perch Deterrents in Utah." *Journal of Wildlife Management.*

PROFESSIONAL MEMBERSHIPS:

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