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Response of Obligate Birds to Mechanical Manipulations in a Sagebrush Ecosystem Near Gunnison, Colorado

Patrick A. Magee[1], Jason Brooks[1], Nick Hirsch[1], and Tyler L. Hicks[1]

ABSTRACT

Sagebrush ecosystems across western North America have declined in productivity and biodiversity with significant declines in sagebrush obligate birds. Mechanical methods to reduce sagebrush canopy cover and encourage herbaceous undergrowth have been implemented to restore sagebrush ecosystems. How these treatments affect sagebrush obligate birds has not been documented. In this study, we hypothesized that nesting success would decline in mechanically treated (mowed and dixie harrowed) plots immediately and for two years after treatment. Twelve 6-ha plots within the South Parlin Common Allotment in the Gunnison Basin, Colorado were established in 2005. Four replicates of untreated (control), mowed and disked (dixie harrow) plots were sampled in 2005 (pre-treatment) and in 2006 and 2007. We located nests using the systematic walk and incidental flush method. We revisited nests every three to five days to determine nest fate. We located 142 nests of nine species in 90 nest searches and expended over 600 man hours. Mayfield nest success (proportion of nests that successfully hatch at least one young) and clutch size were similar among treatments. Nest success of artificial nests also was similar among treatments. Predation was the leading cause of nest failure accounting for 71 to 77 percent of all nest failures and small mammals were implicated in 76 percent of the depredations. Least chipmunks may have been the principle predator of sagebrush bird nests in our study. Small scale mechanical treatments to restore sagebrush apparently do not negatively affect sagebrush birds within two years post-treatment, but longer duration studies and larger sample sizes are required to better assess the impact of treatments on sagebrush avifauna.

INTRODUCTION

Sagebrush ecosystems across the western United States have been declining for several decades in terms of habitat quantity and quality, leading some scientists to suggest the sagebrush steppe ecosystem is one of the most endangered ecosystems in North America (Noss and others 1995; Mac and others 1998). Avian ecologists have described the ecosystem as one “teetering on the edge of collapse” (Knick and others 2003).

The avifauna indicates that the system is incapable of supporting historic population densities. For example, 63 percent of shrubland species in western North America declined from the mid 1960s to the late 1990s (Paige and Ritter 1999). According to one summary report of shrubsteppe landscapes, 16 of 25 upland avian species within these systems have experienced significant declines (Dobkin and Sauder 2004). The two species of sage-grouse have exhibited dramatic population declines over the last 30 years. The Gunnison sage-grouse (*Centrocercus minimus*) has declined by more than 50 percent, has a small population size, and a restricted range, and therefore is considered highly imperiled (Dunn and others 2005) and globally endangered (IUCN 2007). Less is known about the approximately 100 other bird species that occupy sagebrush habitats (Braun and others 1976). Breeding Bird Surveys (BBS) from 1966 to 1996 indicate the Brewer’s sparrow (*Spizella breweri*) declined by 3.7 percent annually or more than 50 percent in three decades (Colorado Partners in Flight Land Bird Conservation Plan 2000). In addition, lark sparrows (*Chondestes grammacus*) experienced a similar rate of decline, while vesper sparrows (*Pooecetes gramineus*), lark buntings (*Calamospiza melanocorys*), rock wrens (*Salpinctes obsoletus*), horned larks (*Eremophila alpestris*), and common nighthawks (*Chordeiles minor*) -- all common sagebrush species -- declined from 15 to 49 percent from the mid 1960s to present (Dunn and others 2005). The green-tailed towhee (*Pipilo chlorurus*) and the sage sparrow (*Amphispiza belli*), both highly dependent on shrub ecosystems, are species of concern because of their high vulnerability in a landscape that has declined overall. In addition, their population trends are largely unknown due to data gaps (Dobkin and Sauder 2004; Dunn and others 2005). These trends in avian populations coincide with the alteration of over 60 percent of the sagebrush steppe ecosystem through exotic species invasions and conversion to non-native annual grasses. Of the 63 million has of sagebrush in western North America, little of it has remained unaltered by human activities (Paige and Ritter 1999; Dobkin and Sauder 2004). Over 90 percent of sagebrush streams and springs have been altered causing a hydrological collapse within the sagebrush ecosystem (Dobkin and Sauder 2004). Often, the seeps and springs within the sagebrush are centers for avian biodiversity largely because of the mesic condition of the habitat and the complex vegetation structure (Doyle 2003; Sada and others 2001).

Over much of the sagebrush biome, land managers have implemented habitat treatments in an effort to improve sage-grouse habitat (Dahlgren and others 2006; Sedgwick 2004). Historically, sagebrush “improvement” meant reducing sagebrush cover to promote forage for livestock (Braun and others 1976). In the Gunnison Basin, treatments

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are currently applied to reduce sagebrush cover and simultaneously improve the health of the sagebrush ecosystem. Across the sagebrush biome many areas have been invaded by pinon-juniper or non-native annual grasses, or have successionally developed into mature sagebrush with little herbaceous understory. The treatments frequently involve mechanical methods that reduce sagebrush cover and encourage growth of herbaceous understory vegetation essential for sage-grouse nesting and early brood-rearing habitat. These projects are designed to benefit sage-grouse, however, little information has been gathered to assess the effects of these treatments on sage-grouse populations, other animals inhabiting sagebrush communities, or the general health of sagebrush ecosystems. Therefore, this study was designed in conjunction with sage-grouse habitat improvement treatments implemented by the Bureau of Land Management (BLM) Gunnison Field Office. The purpose of this project is to describe short-term avifaunal responses (primarily passerines) in sagebrush habitats that have been mechanically treated to improve sage-grouse nesting habitat by reducing sagebrush cover. Specifically we addressed the question of how reproductive success of sagebrush bird species was influenced by mechanically treating sagebrush in the Gunnison Basin, Colorado. We predicted that reproductive success would decline in treated habitats as a result of increased fragmentation that would encourage nest parasitism and predation.

STUDY AREA

The study was conducted in Major Land Resource Area (MLRA) 048-A and Bird Conservation Region (BCR) 16 – the Southern Rocky Mountains. More specifically, research occurred in the South Parlin Flats Common Allotment on BLM lands approximately 20 km southeast of Gunnison, Colorado, south of U.S. Highway 50 and east of Colorado Highway 114. All sampling was restricted to the Sage Hen Pasture which was not grazed by livestock from 2005 through 2007. Sage Hen Pasture is 1,478 ha (3,650 ac) and ranges in elevation from 2,500 to 2,600 m m.s.l. (8,200 to 8,500 feet m.s.l.). The pasture is dominated by Wyoming Big Sagebrush (*Artemesia tridentata wyomingensis*) and other varieties of *Artemesia*. The BLM had previously mapped the pasture to delineate ecological types according to The Ecological Types of the Upper Gunnison Basin (Johnston and others 2001). The three primary ecological types in the Sage Hen Pasture include 1) Wyoming big sagebrush/Indian ricegrass (*Oryzopsis hymenoides*) – SB1, 2) Big sagebrush/muttongrass (*Poa fendleriana*) – SS1, and 3) Antelope bitterbrush (*Purshia tridentata*)-sagebrush/needlegrass (*Acnatherum* spp.) – SS2. Our study primarily focused on the first two ecological types. Soils were deep and well-drained and primarily classified as Parlin-Hopkins channery loams (PhF) and Parlin-Mergel gravelly loams (PmF). The climate in the Gunnison Basin consists of cold winters with moderate snowfall and dry springs with a late summer monsoon delivering about 40 percent of the annual precipitation. Snow accumulation in winter is important in dictating soil moisture conditions in spring and early summer. The long-term annual precipitation is 26.3 cm (10.36 inches) compared to the 2005 to 2007 mean of 29.0 cm (11.40 inches). Precipitation varied from 24.1 cm (9.49 inches) in 2007 to 32.8 cm (12.91 inches) in 2005. Long-term mean temperature in Gunnison is 37.5 F and the 2005 to 2007 mean was 37.7 F and ranged from 36.7 F in 2006 to 38.8 F in 2007. Generally, 2005 was a relatively wet year with average temperatures, 2006 was slightly wet with below average temperatures, and 2007 was dry with above average temperatures. During May and June only, 2005 was slightly dry with average temperatures, 2006 was relatively wet with above average temperatures, and 2007 was dry with above average temperatures. The three year period averaged 10 cm (4 inches) per year below mean snowfall with the 2006 to 2007 winter approaching half (26.5 cm) the long-term mean snowfall of 49.9 cm (Climate data obtained from: Western Region Climate Center, http://www.wrcc.dri.edu/summary/climsmco.html).

METHODS

Within the Sage Hen Pasture, twelve 6-ha (300 m x 200 m) sampling plots were established for avian monitoring. Plot sizes varied slightly as a result of landscape and ecological type variations and as a result of small errors in establishing plot borders in the field. Control and treatment plots were established and stratified based on ecological type (Johnston and others 2001) (figure 1). An effort was made to locate all plots within the same ecological type, but some variation occurred within and among plots; plots were located randomly and were selected based on available habitat within the Sage Hen Pasture study area. Four control plots were untreated, and the other eight plots were treated in October or November 2005. Four plots were treated with a brush mower that mowed the sagebrush to a height of 20 to 30 cm (8 to 12 inches) and minimally disturbed the soil. Four plots were treated with a dixie harrow that raked the soil and thinned the sagebrush by uprooting individual plants. Approximately 33 percent of each of the treated plots was manipulated; treatments were applied in a serpentine pattern to avoid uniform patches of disturbed sagebrush. In addition to mechanical manipulation, the plots were seeded with a native uplands grass/forb mixture including Sandberg bluegrass (*Poa sandbergii*), bottlebrush squirreltail (*Elymus elmoides*), western wheatgrass (*Pascopyrum smithii*), Indian ricegrass (*Oryzopsis hymenoides*), alfalfa (*Medicago sativa*), small burnet (*Sanguisorba minor*), sulfur buckwheat (*Eriogonum umbellatum*), and Lewis flax (*Linum perenne* ssp. *lewisii*).

Sampling occurred in 2005 (pre-treatment) and in 2006 and 2007 (post-treatment).

Nest Searches

Nest searching occurred on all plots following the U.S.D.A. Forest Service protocol (Ralph and others 1993) and the systematic walking and incidental flush methods described by Winter and others (2003). In 2005, all plots were searched once and half of the plots were searched twice. Three rounds of nest searching occurred in 2006 and 2007 in all plots. Plots were searched in late May (after 20 May), early June (before 10 June) and in late June (after June 20). Because of the reduced effort and minimal success in locating nests, the 2005 data did not offer a legitimate temporal control. Nests were primarily located by flushing birds from nest sites. In addition, observations of females carrying nesting materials, females moving toward their nest, and males and females feeding chicks (Ralph and others 1993) were used to locate nests. All nest locations were geo-referenced using a Garmin eTrex Vista GPS unit (NAD83 unit system). The species, number of eggs or chicks, nest height, shrub height, species of shrub, percent of live shrub, distance to treatment or roads, and a general description of each nest site were recorded. Photos of each nest shrub and nest were taken. All located nests were rechecked at approximately 3 day intervals. During each site visit, nest status (active, abandoned, depredated, post-fledged) was recorded along with the number of eggs and/or chicks. Nests were monitored until each nest attempt was completed (ending in success or failure).

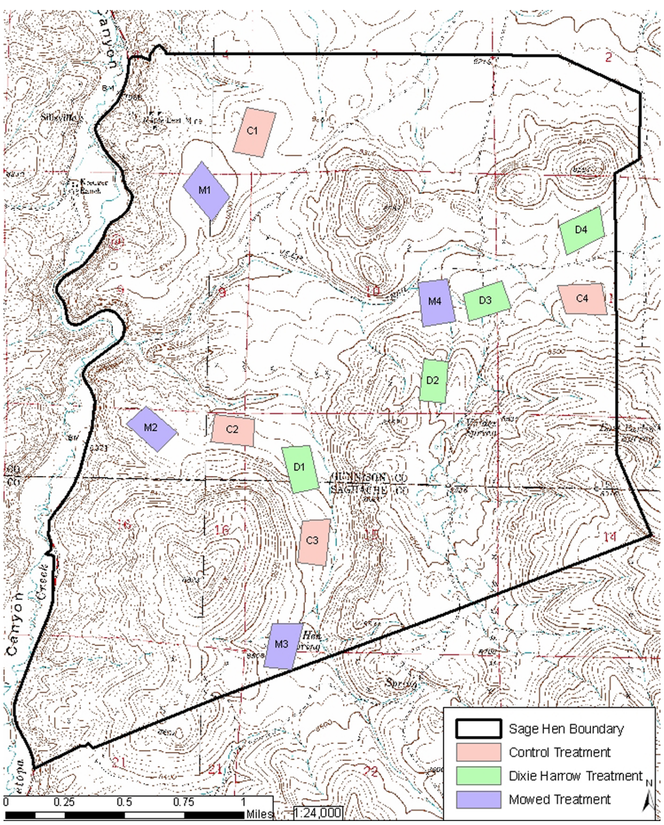

Figure 1—Location and treatment allocation of plots within Sage Hen Pasture in the South Parlin Flats Common Allotment southeast of Gunnison, CO.

Nest Success

We estimated nest success as the probability that a nesting attempt resulted in production of one or more chicks. We focused on this measurement of nest success because our data were less definitive for fledging success (the proportion of nests that produce at least one young that fledges). It is difficult to determine actual nest fate during the transition of nest from nestling to fledged because when we returned to nests after three days and found an empty nest, the nest may have fledged or may have been depredated. We minimized trips to the nest (every three days) to reduce potential researcher impacts. Traditionally, most researchers calculated apparent nest success by dividing the number of successful nests by the total number of nests. However, apparent nest success is biased when applied to samples of clutches that are of different ages (Mayfield 1961; Shaffer 2004). Older clutches are more likely to hatch than the younger clutches as a result of the shorter interval between discovery and hatching (Mayfield 1961, 1975). The longer a nest is exposed to predators and other destructive elements, the more vulnerable it is to nest failure. To avoid bias in success, we used the Mayfield nest success estimator (Mayfield 1961, 1975; Shaffer 2004). This method estimates daily survival by incorporating age of the nest and, therefore, how long nests were exposed to risk while being monitored.

The Mayfield estimator (Mayfield 1961) is calculated using the following equation:

$$\mathbf{P = (1- N_u/E)^h}$$

where,
P = probability of nest success
N_u = number of unsuccessful nests
E = sum of exposure days (number of days from hatch to fate)
h = average incubation period

Mayfield estimates were generated for all species combined and for each species individually. Further, we estimated nest success by treatment type for all species combined and for species with larger sample sizes (Brewer's sparrows, vesper sparrows, and green-tailed towhees). We tested the null hypotheses that there was no difference in clutch size or nest success among the control, mowed, and dixie harrowed plots. We used a non-parametric Kruskal-Wallis test after determining that the data were non-normally distributed and had unequal variances. Our rejection level (α) was 0.05. We also calculated post-hoc power analysis (1 – β) for a two-sample test (Kapadia and others 2005; Jim zumBrunnen, Colorado State University Graybill Statistical Laboratory, personal communication) using the following equation:

$$\mathbf{Z_{\beta}=Z_{1-\alpha/2} - ABS[(\mu_1 - \mu_2)/ (SQRT(2 *Variance/n))]}$$

The β value (or probability of making a type II error) was determined from the normal distribution and the power of the test (1 – β) was determined by subtraction.

Other indicators of reproductive success included clutch size, egg success, hatch success, and fledge success. The fledge fate was approximated based on the length of the nestling period, but for most nests the final observation was an empty nest with no sure way to determine whether the nest successfully fledged young or was depredated during the last three day interval. If nests were empty before they were expected to fledge, they were assumed depredated. Fledge success was not corrected for exposure and was used only as a comparison with nest success.

Artificial Nests

To enhance our understanding of avian nest success and the mechanism of nest loss, we employed artificial nests. We used 5 cm deep by 10 cm wide wicker woven canary nests and placed one handmade 2.5 cm long blue clay egg in each nest attached by a 3 to 5 cm strand of fishing line to prevent removal of the egg from the nest. Additionally, we added a Chinese quail egg to each nest. The nests were sprayed with a human scent remover prior to placement in the field.

In 2006, in each of the twelve plots, we placed 20 artificial nests along two longitudinal transects. Nests were placed alternatively on the ground and at a height of 20 cm in a shrub. Nest locations and heights were chosen to mimic natural placement by Brewer's sparrows and vesper sparrows. Artificial nests were initially placed on 26 June 2006 in two plots and additional nests were placed on subsequent days in the remaining plots. Each artificial nest was checked at 7 days and 14 days for signs of disturbance. Nest disturbances included both physical (wind, rain) and animal. Animals that visited nests were documented by examining teeth and bill marks in clay eggs, remains of quail eggs, and by looking for additional signs around the nest (tracks, fur/feathers, scat). Nest fate was classified as undisturbed, unknown disturbance, avian predator, small mammal predator, and mid-sized mammal predator. The unknown disturbance category included nests that were disturbed but the cause of the disturbance was not determined; this category potentially included depredations where no predator signs were detected or physical disturbances to the nests occurred.

In addition to observations of artificial eggs at nest sites, we also used eight Cuddeback digital cameras (Non Typical, Inc., Park Falls, WI, cuddebackdigital.com) to detect predators at artificial nests. Three of the cameras were placed in a control plot, three in a dixie harrowed plot and two cameras in a mowed plot. In complete darkness the cameras were capable of capturing images by using infrared emitters to illuminate the objects when lasers were triggered. However, no night depredation events were recorded.

In 2007, we placed 120 artificial nests in all twelve plots, with 10 nests randomly placed in shrub locations within the plots (no ground nests were used in 2007). The randomly positioned nests helped to reduce the potential for nest predators to systematically locate a series of artificial nests located along a transect. The nests were placed in the field in mid-June and were monitored as in 2006. Twenty Brewer's sparrow nests that were located in 2006, were collected at the end of the 2006 season and were deployed as artificial nests in 2007. These nests were used to compare nest success of wicker nests with real Brewer's sparrow nests. Five old Brewer's sparrow nests were placed in each of the four control plots. Five Casio Model SY-30B infrared remote video cameras were used to monitor artificial nests in 2007. These were used instead of the Cuddeback digital cameras, which did not successfully capture any predators at nests in 2006.

We tested the null hypothesis that there was no difference in nest success of the artificial nests among the treatments using a non-parametric Kruskal-Wallis test with a rejection level of 0.05.

RESULTS

Sagebrush Bird Nest Locations

A total of 142 nests were located within the twelve sample plots during the three year study. We conducted 18 nest searches in 2005 and 36 each in 2006 and 2007. Of the total nests, 21 were found in 2005, 42 in 2006, and 79 in 2007. Ten nests had unknown fates and were not used in the analyses. Nine species accounted for all of the nests with Brewer's sparrows dominating (61 nests), followed by vesper sparrows (44 nests) and green-tailed towhees (16 nests). Other nesting species within the plots included sage thrasher, mourning dove, sage sparrow, common nighthawk, Gunnison sage-grouse, and mallard (table 1). Two horned lark nests were found adjacent to plot boundaries and nests of Clark's nutcracker, northern flicker, common raven, and American kestrel were located within the study pasture in small forest patches. No rock wren nests were located despite the prevalence of this bird within the study site. The three sage sparrow nests represent the first documented sage sparrow nests in Gunnison County and perhaps only the second documented case of sage sparrows nesting in Colorado (Andrews and Righter 1992).

Table 1—Nest searching effort and number and species of bird nests found from 2005-2007 in the Sage Hen Pasture in the Gunnison Basin, Colorado. BRSP = Brewer's Sparrow, VESP = Vesper Sparrow, GTTO = Green-tailed Towhee, SATH = Sage Thrasher, MODO = Mourning Dove, SAGS = Sage Sparrow, CONI = Common Nighthawk, GUSG = Gunnison Sage-grouse, and MALL = Mallard.

Attribute	2005	2006	2007	Total
Nest Searches	18	36	36	90
Initial Nest Search	1 June 2005	21 May 2006	23 May 2007	
Earliest Nest Found	1 June 2005	18 May 2006	21 May 2007	
Calculated Initiation of Nesting	21 May – VESP	29 April – HOLA	5 May – SATH	
		5 May – MODO	7 May – SAGS	
		15 May – BRSP	11 May – VESP	
Search Effort	104 hours	256 hours	257.5 hours	617.5 hours
Effort Per Nest	4.9 hours	6.1 hours	3.2 hours	
Total Nests	21	42	79	142
BRSP	6	18	37	61 (43%)
VESP	8	8	28	44 (31%)
GTTO	4	5	7	16 (11%)
SATH	0	3	4	7 (5%)
MODO	0	6	0	6 (4%)
SAGS	1	0	2	3 (2%)
CONI	1	2	0	3 (2%)
GUSG	0	0	1	1 (<1%)
MALL	1	0	0	1 (<1%)

Clutch Size

Green-tailed towhees had the largest overall mean clutch size (3.9 eggs), followed by vesper sparrows and sage thrashers (3.7 eggs). Brewer's sparrows had a mean clutch size of 3.5 eggs. The largest clutch was 5 eggs for sage thrashers and vesper sparrows. Sagebrush birds typically laid 3 or 4 eggs with 4 egg clutches being the most frequent (table 2).

Clutch size did not differ significantly among treatments for the three most abundant nesting birds in the study (Brewer's sparrows, vesper sparrows, and green-tailed towhees). Brewer's sparrows tended to nest in control plots more than mechanically treated plots, whereas the number of vesper sparrow nests was highest in mowed plots. Sixty percent of green-tailed towhee nests were located in dixie harrow plots. No difference in clutch size among treatments was observed for green-tailed towhees and clutch sizes for Brewer's sparrows and vesper sparrows were similar among treatments (table 3).

Reproductive Success

Of the 132 nests, 110 nests (83.3 percent) successfully hatched at least one egg (apparent nest success). Of the 22 unsuccessful nests, 10 (45 percent) were vesper sparrow and 8 (36 percent) were Brewer's sparrow nests. Vesper sparrows had the highest rates of nest loss.

Taking into account exposure time, the overall Mayfield nest success estimate was 71.6 percent (all species and all years). Brewer's sparrows had the highest Mayfield nest success rate (81.8 percent, n = 56), followed by green-tailed towhees at 77.9 percent (n = 15). Vesper sparrows had a relatively low nest success rate of 54.2 percent (n = 40). The other species had sample sizes lower than 7 and estimates of nest success were unreliable (table 4).

Of the 460 eggs laid by all species in 132 nests, 348 eggs hatched (egg success = 75.6 percent). The percentage of eggs that hatched from nests that were successful serves as an index of egg viability. Overall, egg viability exceeded 90 percent (table 4).

The total nest failure (percentage of nest attempts in which no young were produced) was 38 percent for all species combined. Every common nighthawk and sage thrasher nest produced young, while total nest failure was 16.7 percent for mourning doves, 32.1 percent for Brewer's sparrows, 33.3 percent for sage sparrows, 38.5 percent for green-tailed towhees, and 55.5 percent for vesper sparrows.

Nest Success by Treatment

Overall nest success for all species combined in 2006 and 2007, the two post-treatment years, did not differ by treatment (Kruskal-Wallis p = 0.672). Brewer's sparrows had the highest nest success in dixie harrow plots (0.916), whereas vesper sparrows had the highest nest success in control plots (0.703). Nonetheless, differences within species among treatments were not significant (table 5).

Table 2—Comparison of mean clutch size among avian species and across years in the Sage Hen Pasture in the Gunnison Basin, Colorado ($\bar{x}$ = mean clutch size, *n* = number of nests, range = variability in clutch size among nests). BRSP = Brewer's Sparrow, CONI = Common Nighthawk, GTTO = Green-tailed Towhee, MODO = Mourning Dove, SATH = Sage Thrasher, SAGS = Sage Sparrow, VESP = Vesper Sparrow.

Species	2005[a]	2006	2007	Overall
BRSP	$\bar{x}$ =3.5 *n* = 2 Range = 1 (3-4)[c]	$\bar{x}$ = 3.6 *n* = 18 Range = 2 (2-4)	$\bar{x}$ = 3.4 *n* = 32 Range = 2 (2-4)	$\bar{x}$ = 3.5 *n* = 52 Range = 2 (2-4)
VESP	$\bar{x}$ = 3.75 *n* = 4 Range = 1 (3-4)	$\bar{x}$ = 3.8 *n* = 8 Range = 1 (3-4)	$\bar{x}$ = 3.7 *n* = 24 Range = 2 (3-5)	$\bar{x}$ = 3.7 *n* = 35 Range = 2 (3-5)
GTTO	$\bar{x}$ = 3.5 *n* = 2 Range = 1 (3-4)	$\bar{x}$ = 4.0 *n* = 4 Range = 0 (4)	$\bar{x}$ = 4.0 *n* = 6 Range = 0 (4)	$\bar{x}$ = 3.9 *n* = 12 Range = 1 (3-4)
SATH	No Nests	$\bar{x}$ = 3.7 *n* = 3 Range = 1 (3-4)	$\bar{x}$ = 3.8 *n* = 4 Range = 2 (3-5)	$\bar{x}$ = 3.7 *n* = 7 Range = 2 (3-5)
MODO	No Nests	$\bar{x}$ = 2 *n* = 6 Range = 0 (2)	No Nests	$\bar{x}$ = 2 *n* = 6 Range = 0 (2)
SAGS	$\bar{x}$ = 3 *n* = 1[b] Range = 0 (3)	No Nests	$\bar{x}$ = 3.5 *n* = 2 Range = 1 (3-4)	$\bar{x}$ = 3.3 *n* = 3 Range = 1 (3-4)
CONI	$\bar{x}$ = 2 *n* = 1[b] Range = 0 (2)	$\bar{x}$ = 2 *n* = 2 Range = 0 (2)	No Nests	$\bar{x}$ = 2 *n* = 3 Range = 0 (2)

[a]Nest monitoring in 2005 was limited and total number of nests with known clutch sizes was small
[b]Where sample size is 1, the clutch sizes are not means
[c]Range = maximum clutch size – minimum clutch size (variation in values of clutch size shown in parentheses)

Nest Failure

Of the unsuccessful nests, lack of hatching of any eggs within a nest was due primarily to depredation. In 2006, 71 percent of the unsuccessful nests were depredated, whereas in 2007, 77 percent of unsuccessful nests were depredated. The remaining nests were abandoned or contained unhatched eggs.

In general, sagebrush birds were slightly more vulnerable to nest losses during the nestling period than during the egg stage. For Brewer's sparrows, 13.2 percent of total nests prior to hatching failed, whereas 18.9 percent of active nests after hatching failed. Vesper sparrows lost 27.8 percent of nests in the egg stage and again during the nestling stage. Green-tailed towhees experienced a 15.4 percent loss of clutches during incubation, compared to 23.1 percent of nests lost during nestling. Mourning doves lost one of seven (14.3 percent) nests during the egg stage, but did not lose any nests during the nestling period. Sage sparrows did not lose any nests during incubation and lost one of three nests during the nestling stage.

Fledging Success

Of the 121 total nests with known fledge fate (includes nests that did not hatch at least one egg), 75 nests (62.0 percent) fledged young. Of the 24 total nest failures between hatch and fledging, 96 percent (23 nests) failed due to depredation. The remaining nest was abandoned. In 2006, 32 of the 42 total nests fledged young successfully (76 percent), whereas in 2007, 43 of the 78 total nests fledged young (55 percent).

Artificial Nest Studies

Because there was no difference in the number of exposure days among artificial nests, the apparent nest success estimator was used to determine nest success. Nest success was similar among treatments for artificial nests or between ground and shrub nests (table 6). Nest success of old Brewer's sparrow's nests was higher than commercially produced wicker nests (but not significantly).

Of the 380 artificial nests, 51.3 percent were depredated. Of these 191 depredated nests, 76.4 percent were depredated by small mammals based on examination of clay and Chinese quail eggs. The small mammal whose teeth most often matched the marks on the clay eggs and that was captured in the act of depredation using infrared video cameras was the least chipmunk (*Tamias minimus*).

DISCUSSION

Nest Success of Sagebrush Birds

Nest success of sagebrush birds in the Gunnison Basin, Colorado varied among species but were similar among treatments. Our prediction that sagebrush birds would experience reduced nesting success in the short-term response to mechanical treatments in sagebrush was not supported. However, our post-hoc power analysis revealed low power to protect against Type II Errors (Power = 1 – β = 0.06). Therefore, if the null hypothesis is rejected (no difference in nesting performance among treatments) we would do so with a 94 percent probability that the null hypothesis was not true. Therefore, the p-values from the Kruskal-Wallis tests should be applied with great caution and conclusions inferred from these data should also be cautionary

Mechanical treatments were done to limit disturbance within the treated area to approximately one third of the landscape (at relatively small scales – here 6 ha). The remaining sagebrush allowed adequate nesting structure for birds to successfully inhabit these treatment sites. That the fragmentation of the sagebrush by mechanical treatments did not lead to higher nest losses over controls may be explained by the lack of nest parasites in the study area (no brown-headed cowbirds) and the lack of avian predators at the site. Loggerhead shrikes (*Lanius ludovicianus*) have been implicated as a prime avian nest predator of Brewer's sparrows, sage sparrows, and sage thrashers (Reynolds 1979, 1981), however, no loggerhead shrikes were observed in Sagehen Pasture during the three year study period. Further, common ravens (*Corvus corax*) and black-billed magpies (*Pica pica*) were present, but according to our artificial nest data, these birds rarely depredated nests.

Lack of nest parasitism and avian predators may also explain the relatively high nest success observed in this study. For all species combined, the Mayfield nest success estimate was 71.6 percent (table 4). Approximately 82 percent of Brewer's sparrow nests hatched at least one young successfully in our study compared to 18 percent in Nevada and 90 percent in Oregon (Rotenberry and Weins 1989). For vesper sparrows, nest success ranged from 11 percent in Michigan (Krueger 1981) to 37 percent in Iowa (Patterson and Best 1996) to 54 percent in Washington (Jones and Cornely 2002), compared to 54 percent in our study. Sage thrashers in Idaho had a 73 percent nest success (Reynolds and Rich 1978), compared to 100 percent (n = 7) in our study. Green-tailed towhees in Arizona had a nest success of 55 percent (Dobbs and others 1998), compared to 78 percent in our study. Higher nest success in the Gunnison Basin may be attributed to overall better ecosystem health of the shrubsteppe here than in other regions of the sagebrush biome.

Birds in the sagebrush ecosystem face high rates of predation on nests primarily by other birds such as loggerhead shrikes, common ravens, and black-billed magpies (Dobbs and others 1998; Jones and Cornely 2002; Martin and Carlson 1998; Reynolds and others 1999; Rotenberry and Wiens 1989; Rotenberry and others 1999). A variety of snakes have also been observed depredating bird nests in the sagebrush, chief among them the gopher snake (*Pituophis melanoleucus*). Western garter snakes were observed occasionally in our study plots, but we did not document depredation by them. Mammals such as skunks, weasels, and ground squirrels are important nest predators (Dobbs and others 1998; Jones and Cornely 2002; Martin and Carlson 1998; Reynolds and others 1999; Rotenberry and others 1999). Townsend's ground squirrel (*Spermophilus townsendii*) has often been cited as the most significant small mammal nest predator (Rotenberry and Weins 1989). The least chipmunk was cited as a potential predator of Brewer's sparrows, sage sparrows, and sage thrashers (Peterson and Best 1987; Rotenberry and Weins 1989) and of rock wrens (Lowther and others 2000). In our study, we captured least chipmunks entering and robbing artificial nests on infrared video. Most of the teeth marks in the clay eggs were attributed to the least chipmunk. Deer mice are probably the most abundant small mammal in the Gunnison Basin – approximately 11 to 40 million estimated in 2004 (Thrift and Magee 2005). Although deer mice have been identified as nest predators (Rogers and others 1997) and recorded on video raiding bird nests (Pietz and Granfors 2000), they were not recorded on video entering and robbing artificial nests in our study. Further, Wyoming (*Spermophilus elegans*) and golden-mantled ground squirrels (*Spermophilus lateralis*) were present, but no direct evidence that either of these species robbed nests or killed birds was observed. During our study, least chipmunks appeared to be the most significant predator of sagebrush bird nests.

Table 3—Comparison of mean clutch size (+ standard error) and sample sizes among treatments for the three most prolific nesting birds in the Sage Hen Pasture study area in the Gunnison Basin, Colorado ($\bar{x}$ = mean clutch size + standard error, n = number of nests, range = variability in clutch size among nests). A non-parametric Kruskal-Wallis statistic was used to test the null hypothesis that clutch size did not differ among treatments. BRSP = Brewer's Sparrow, VESP = Vesper Sparrow, GTTO = Green-tailed Towhee.

Species	Control	Dixie Harrow	Mowed	Kruskal-Wallis
BRSP	$\bar{x}$ = 3.57 $\pm$ 0.13 n = 21 Range = 2 (2-4)[a]	$\bar{x}$ = 3.50 $\pm$ 0.15 n = 16 Range = 2 (2-4)	$\bar{x}$ = 3.40 $\pm$ 0.16 n = 15 Range = 2 (2-4)	p = 0.314
GTTO	$\bar{x}$ = 4.0 n = 2 Range = 0 (4)	$\bar{x}$ = 4.0 n = 6 Range = 0 (4)	$\bar{x}$ = 4.0 n = 2 Range = 0 (4)	Sample Size too Small
VESP	$\bar{x}$ = 3.78 $\pm$ 0.22 n = 9 Range = 2 (3-5)	$\bar{x}$ = 3.75 $\pm$ 0.16 n = 8 Range = 1 (3-4)	$\bar{x}$ = 3.64 $\pm$ 0.17 n = 14 Range = 2 (3-5)	p = 0.952

[a]Range = maximum clutch size – minimum clutch size (variation in values of clutch size shown in parentheses)

Table 4—Mayfield nest success, egg success, egg viability and total nest failure rates overall and for individual sagebrush obligate and near obligate species nesting in the Sage Hen Pasture of the Gunnison Basin, Colorado, 2005 to 2007. Sample size for egg viability includes only the number of successful nests, whereas for total nest failure sample size is the number of nests with known fate, and for other variables sample size is the total number of nests. BRSP = Brewer's Sparrow, CONI = Common Nighthawk, GTTO = Green-tailed Towhee, MODO = Mourning Dove, SATH = Sage Thrasher, SAGS = Sage Sparrow, VESP = Vesper Sparrow.

Species	Sample Size (number of nests)	Mayfield Nest Success Estimate	Egg Success	Egg Viability	Total Nest Failure
Overall – all species combined	132	0.716	75.6% of 460 eggs, 348 hatched	92.7% *n* = 110	38%
SATH	7	1.000	100%	100% *n* = 7	0% *n* = 7
CONI	3	1.000	100%	100% *n* = 3	0% *n* = 3
SAGS	3	1.000	80.0%	80.0% *n* = 3	33.3% *n* = 3
BRSP	56	0.818	82.3%	93.5% *n* = 49	32.1% *n* = 53
GTTO	15	0.779	83.0%	90.0% *n* = 13	38.5% *n* = 13
MODO	6	0.588	83.3%	100% *n* = 5	16.7% *n* = 6
VESP	40	0.542	65.0%	85.6% *n* = 30	55.5% *n* = 36

Table 5—Mayfield nest success estimates for control, dixie harrow, and mowed plots in the Sage Hen Pasture in the Gunnison Basin, Colorado, 2006 and 2007. BRSP = Brewer's Sparrow, VESP = Vesper Sparrow, and GTTO = Green-tailed Towhee.

Species	Control	Dixie Harrow	Mowed	Kruskal-Wallis
All Species (plots pooled) *N* = 119	0.80[a]	0.79	0.70	
All species (plots unpooled) *N* = 12	0.73	0.81	0.65	$p = 0.672$
Range of Values	0.39 – 1.0	0.54 – 1.0	0.61 – 0.71	
Standard Error	0.136	0.114	0.027	
CV[b]	37.3%	28.3%	8.5%	
Plot 1	C1 = 0.89 (*n* = 14)	D1 = 1.0 (*n* = 8)	M1 = 0.61 (*n* = 15)	
Plot 2	C2 = 1.0 (*n* = 4)	D2 = 0.54 (*n* = 10)	M2 = 0.61 (*n* = 7)	
Plot 3	C3 = 0.39 (*n* = 7)	D3 = 0.70 (*n* = 16)	M3 = 0.71 (*n* = 11)	
Plot 4	C4 = 0.64 (*n* = 14)	D4 = 1.0 (*n* = 2)	M4 = 0.70 (*n* = 12)	
Sample Size	39	36	45	
Mayfield Nest Success for Three Most Abundant Species				
BRSP	0.791 (*n* = 22)	0.916 (*n* = 16)	0.740 (*n* = 16)	$p = 0.529$
VESP	0.703 (*n* = 10)	0.445 (*n* = 9)	0.487 (*n* = 17)	$p = 0.753$
GTTO	0.504 (*n* = 3)	1.00 (*n* = 6)	1.00 (*n* = 3)	n.a.

[a]Bold numbers representing the Mayfield nest success estimates for all species combined were calculated by pooling all four replicates within each treatment (*N* = 119), the non-bold numbers represent the means of the four treatments (*N* = 12).
[b]CV is the co-efficient of variation calculated as the standard deviation divided by the mean multiplied by 100.

Management and Research Implications

Relatively little information is available regarding responses of sagebrush birds to restoration and management efforts in the sagebrush steppe ecosystem. Most studies measuring bird response to alterations of sagebrush were associated with sagebrush treatments intending to "improve" sagebrush for livestock foraging (Braun and others 1976). In general, the result of these large scale burns, spraying operations, or mechanical projects was a decline in shrub dependent bird species. For example, Brewer's sparrows declined 54 percent the year following heavy application 2,4-D spraying on a 16 ha (40 ac) plot in Montana (Best 1972) and five years post-treatment, after shrubs died, Brewer's sparrows were almost completely absent from the study site (Pyrah and Jorgenson 1974). Similarly, Brewer's sparrows on a 32 ha (80 ac) plot declined 67 percent one year following spraying and 99 percent two years post spraying in Wyoming (Schroeder and Sturges 1975). Sage sparrows, Brewer's sparrows, and sage thrashers are "decreasers" following large scale sagebrush treatments, with thrashers and probably sage sparrows decreasing more significantly due to their specialization on large sagebrush (thrashers) and large stands of sagebrush (sage sparrows) (Castrale 1982).

In contrast, smaller sagebrush removal projects and prescribed restoration alterations do not necessarily have short-term negative impacts. For example, after a moderate-sized, incomplete burn in Idaho, researchers did not document a decline by sage sparrows or sage thrashers, and while Brewer's sparrows declined two years after the burn, their populations fluctuated and increased four years post-burn (Peterson and Best 1987). Further, when 16 ha (40 ac) sagebrush plots were sprayed with 2,4-D in 30 m wide strips or where herbicide application resulted in sagebrush kill less than 50 percent, no change in number of Brewer's sparrow and vesper sparrow pairs was documented (Best 1972). Heavily manipulated sagebrush sites (mechanical removal of 100, 75, 50, 25 and 0 percent of sagebrush canopy cover in mosaic pattern) at small scale (4.5 ha) did not correlate with a major change in sage sparrow or Brewer's sparrow territory location or size or population density (Wiens and others 1986).

The types of treatments mentioned above mimic the scale and patterns of mechanical treatments that the BLM Gunnison Field Office prescribed for our study. The principle guidelines included small areas, approximately 30 percent of landscape treated, with treatments done in sinuous pattern. The key to successful treatment design is maintaining adequate shrub cover for shrub nesting sagebrush obligates. Further, our study plots were rested from livestock grazing for two years post-treatment. Rest from grazing may have been an important factor in increasing grass cover and concealing nests of ground nesting birds (vesper sparrows). As grazing is resumed, further study could elucidate its effects on nest success of sagebrush obligate birds.

Small scale treatments did not negatively affect sagebrush birds, but are these treatments beneficial to a group of birds that are among the fastest declining birds in North America (Paige and Ritter 1999)? Whereas sagebrush canopy cover declined in our study plots after mechanical treatments, grass cover and forb cover increased (Adam Payton, BLM, personal communication) perhaps creating positive habitat values including cover for ground nesting species (vesper sparrows) and food resources for all the birds. Further, despite reduction in sagebrush cover, at least one vesper sparrow and one sage thrasher nested within the uprooted sagebrush in dixie harrow plots. Increase in forbs within dixie harrow plots was attributed to pre-existing seed sources and not plants seeded after the treatment (Adam Payton, BLM, personal communication). This forb response may have been associated with the soil disturbance allowing for more efficient seed germination. An increase in forb cover and diversity likely would enhance insect abundance and habitat quality for nesting adults and broods. More information is needed to assess the positive impacts of treatments on sagebrush birds.

Long term research is required to determine the effective response of birds to treatments in the sagebrush. Evidence from other studies suggests that breeding birds may return to sites they had occupied the previous season (site fidelity) prior to implementation of treatments even though habitat may have declined dramatically as a result of the treatment (Wiens and others 1986). Therefore, a time lag in bird response to habitat changes may occur and this time lag can lengthen if offspring imprint on specific nesting sites. In some cases, anthropogenic alterations of habitat or distribution of predators, nest parasites, or competitors may create habitat traps, where birds continue to select habitat based on structure of vegetation, but preferred nest sites result in lowered nest success. For example, sage sparrows chose nest sites where they had lower nesting success as a result of human mediated redistribution of snakes (Misenhelter and Rotenberry 2000).

Obtaining adequate data to estimate nest success requires that the study plots are large enough to harbor statistically reasonable sample sizes of nesting birds. In our study, plot size was 6 ha (15 ac). The number of nests per plot ranged from 0 to 10 within a season and most plots had 0 to 2 nests of each species. Spatial scale of treatments was marginally adequate for Brewer's sparrows and possibly vesper sparrows, but too small to measure a population level response by most species (Wiens and others 1986). Future studies should be implemented at larger geographical scales, but maintain the ratio of one third or less treated landscape and avoid large blocks of treated sagebrush within areas.

Predation was the major cause of nest failure (71 to 77 percent of nests) in our study and in numerous other sagebrush bird nesting studies (Dobbs and others 1998; Jones and Cornely 2002; Martin and Carlson 1998; Reynolds and others 1999; Rotenberry and others 1999). Predation rates in our study were lower than experienced in several other studies (Dobbs and others 1998; Jones and Cornely 2002; Reynolds 1981; Reynolds and others 1999; Rotenberry and others 1999). Primary predators are not large and medium sized mammals, and probably not avian predators such as corvids and shrikes, but mostly rodents. In this study we were able to directly implicate least chipmunks using video, but much of our evidence relies on indirect sign at the nest which is a problematic method for determining nest predators (Lariviere 1999). More research using remote infrared camera surveillance of real nests is required to determine the relative effect of a variety of predators.

In addition, despite the widespread documentation of predation as the key mortality agent in sagebrush songbirds, it is important to understand predation as a consequence of habitat degradation and alteration. Further, predation is not uniform across time or space within the sagebrush ecosystem and may be influenced greatly by precipitation, episodic predator densities (for example, ground squirrels; Rotenberry and Wiens 1989), and avian diseases, among other complicating factors.

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Table 6—Mean + SD nest success for artificial nests in relation to mechanical treatments in the sagebrush ecosystem in the Gunnison Basin, Colorado 2006 to 2007. Across rows represent treatment comparisons, whereas down columns represent artificial nest type comparisons. At bottom of table the Mayfield nest success estimates are repeated for comparison with artificial nests.

Nest Type	Control	Dixie Harrow	Mowed	Kruskal-Wallis
2006 Ground Nests	42.5 ± 20.6%	45.0 ± 30.0%	25.0 ± 28.9%	$p = 0.384$
2006 Shrub Nests	57.5 ± 27.5%	67.5 ± 18.9%	55.0 ± 37.0%	$p = 0.792$
2007 Shrub Nests	37.5 ± 20.6%	42.5 ± 23.6%	62.5 ± 35.9%	$p = 0.282$
2007 Old Brewer's Sparrow Nests	60.0 ± 28.3%	na	na	
Kruskal-Wallis	$p = 0.489$	$p = 0.244$	$p = 0.155$	
Mayfield Nest Success	73 ± 13.6%	81 ± 11.4%	65 ± 2.7%	$p = 0.672$

REFERENCES

Andrews, R., Righter, R. 1992. Colorado Birds. Denver Museum of Nature and Science. 442 p.
Best, L.B. 1972. First-year effects of sagebrush control on two sparrows. Journal of Wildlife Management 36(2):534-544.
Braun, C., Baker, E., Maurice, F., Eng, R.L., Gashwiler, J.S., Schroeder, M.H. 1976. Conservation Committee report on effects of alteration of sagebrush communities on the associated avifauna. Wilson Bulletin 88(1):165-171.
Castrale, J.S. 1982. Effects of two sagebrush control methods on nongame birds. Journal of Wildlife Management 46(4):945-952.
Colorado Partners in Flight. 2000. Colorado Land Bird Conservation Plan. [Online]. Available: http://www.rmbo.org/pif/bcp/phy62/sage/grsg.htm [May 23, 2008].
Dahlgren, D.K., Renee, C., Messmer, T.A. 2006. Greater Sage-grouse response to sagebrush management in Utah. Wildlife Society Bulletin 34(4):975-985.
Dobkin, D.S., Sauder, J.D. 2004. Shrubsteppe landscapes in jeopardy. Distributions, abundances, and the uncertain future of birds and small mammals in the Intermountain West. High Desert Ecological Research Institute, Bend, OR. 194 p.
Dobbs, R.C., Martin, P.R., Martin, T.E. 1998. Green-tailed Towhee (*Pipilo chlorurus*). *In* The Birds of North America, No. 368 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA. 24 p.
Doyle, G. 2003. Survey of selected seeps and springs within the Bureau of Land Management's Gunnison Field Office Management Area (Gunnison and Sauguache Counties, CO). Colorado Natural Heritage Program, Fort Collins, CO. 143 pp.
Dunn, E.H. et al. 2005. High priority needs for range-wide monitoring of North American landbirds. Partners in Flight Technical Series No. 2. Partners in Flight website: http://partnersinflight.org/pubs/ts/02-MonitoringNeeds.pdf.
Hunter, W., Spears, R., Clayton F. 1975. Soil Survey of the Gunnison Area, Colorado: parts of Gunnison, Hindsdale and Saguache Counties. USDA Soil Conservation Service and Colorado Agricultural Experiment Station.
International Union for the Conservation of Nature (IUCN). 2007. IUCN Red List of Threatened Species. [Online]. http://www.iucnredlist.org [June 28, 2008].
Johnston, B.C., Huckaby, L., Hughes, T.J., Pecor, J. 2001. Ecological types of the Upper Gunnison Basin. Denver (CO): USDA Forest Service, Rocky Mountain Region.
Jones, S.L., Cornely, J.E. 2002. Vesper Sparrow (*Pooecetes gramineus*). *In* The Birds of North America, No. 624 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA.
Kapadia, A.S., Chan, W., Moye, L. 2005. Mathematical statistics with applications. Chapman Hall/CRC, Boca Raton, FL. 617 p.
Knick, S.T., Dobkin, D.S., Rotenberry, J.T., Schroeder, M.A., Vander H., Mathew, W., van Riper III, C. 2003. Teetering on the edge or too late? Conservation and research issues for avifauna of sagebrush habitats. Condor 105: 611-634.
Krueger, H.O. 1981. Breeding adaptations of the Vesper Sparrow (*Poocetes gramineus*) in a fire-altered ecosystem. M.S. Thesis, Central Michigan University, Mount Pleasant, MI.
Lariviere, S. 1999. Reasons why predators cannot be inferred from nest remains. Condor 101:718-721.
Lowther, P.E., Kroodsma, D.E., Farley, G.H. 2000. Rock Wren (*Salpinctes obsoletus*). *In* The Birds of North America, No. 486 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA. 20 p.
Mac, M.J., Opler, P.A., Haecker, E.P., Doran, P.D. 1998. Status and trends of the nation's biological resources. Vol. 2. USDI, US Geological Survey, Reston, VA.

Martin, J.W., Carlson, B.A. 1998. Sage Sparrow (*Amphispiza belli*). *In* The Birds of North America, No. 326 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA. 20 p.

Mayfield, H.F. 1961. Nesting success calculated from exposure. Wilson Bulletin 73:255-261.

Mayfield, H.F. 1975. Suggestions for calculating nest success. Wilson Bulletin 86(4):456-466.

Misenhelter, M.D., Rotenberry, J.T. 2000. Choices and consequences of habitat occupancy and nest site selection in sage sparrows. Ecology 81(10):2892-2901.

Noss, R.F., LaRoe III, E.T., Scott, J.M. 1995. Endangered Ecosystems of the United States: A preliminary assessment of loss and degradation. USDI National Biological Service. Biological report 28. Washington, D.C. 58 p.

Paige, C., Ritter, S.A. 1999. Birds in a sagebrush sea: managing sagebrush habitats for bird communities. Partners in Flight Western Working Group, Boise, ID. 47 p.

Patterson, M.P., Best, L.B. 1996. Bird abundance and nesting success in Iowa CRP fields: the importance of vegetation structure and composition. American Midland Naturalist 135:153-176.

Peterson, K.L., Best, L.B. 1987. Effects of prescribed burning on nongame birds in a sagebrush community. Wildlife Society Bulletin 15:317-329.

Pietz, P.J., Danfors, D.A. 2000. Identifying predators and fates of grassland passerine nests using miniature video cameras. Journal of Wildlife Management 64(1):71-87.

Pyrah, D., Jorgenson, H.E. 1974. Ecology of sagebrush control. Montana Fish and Game Department. Job Report, Federal Aid Project W-105-R-9.

Ralph, C.J., Geupel, G.R., Pyle, P., Martin, T.E., DeSante, D.F. 1993. Handbook of Field Methods for Monitoring Landbirds. Gen. Tech. Rep. PSW-GTR-144. Albany, CA: Pacific Southwest Research Station, Forest Service, USDA 41 p.

Reynolds, T.D. 1979. The impact of loggerhead shrikes on nesting birds in a sagebrush environment. Auk 96:798-800.

Reynolds, T.D. 1981. Nesting of the sage thrasher, and Brewer's sparrow in southeastern Idaho. Condor 83:61-64.

Reynolds, T.D., Rich, T.D. 1978. Reproductive ecology of the sage thrasher (*Oreoscoptes montanus*) on the Snake River Plain in south-central Idaho. Auk 95:580-582.

Reynolds, T.D., Rich, T.D., Stephens, D.A. 1999. Sage Thrasher (*Oreoscoptes montanus*). *In* The Birds of North America, No. 463 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA. 24 p.

Rogers, C.M., Taitt, M.J., Smith, J.N.M., Jongeian, G. 1997. Nest predation and cowbird parasitism create a demographic sink in wetland-breeding song sparrows. Condor 99:622-633.

Rotenberry, J.T., Wiens, J.A. 1989. Reproductive biology of shrubsteppe passerine birds: geographical and temporal variation in clutch size, brood size, and fledging success. Condor 91(1): 1-13.

Rotenberry, J.T., Patten, M.A., Preston, K.L. 1999. Brewer's Sparrow (*Spizella brewerii*). *In* The Birds of North America, No. 390 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA. 24 p.

Sada, D.W., Williams, J.E., Silvy, J.C., Halford, A., Ramakka J., Summers, P., Lewis, L. 2001. Riparian area management: A guide to managing restoring, and conserving springs in the western US. Technical Reference 1737-17. Bureau of Land Management, Denver, CO. BLM/ST/ST-01/001+1737. 70 p.

Schroeder, M.H., Sturges, D.L. 1975. The effect on Brewer's sparrow of spraying big sagebrush. Journal of Range Management 28:294-297.

Sedgwick, J.A. 2004. Habitat restoration for Gunnison and Greater sage-grouse – a literature review. USDI Bureau of Land Management, Gunnison Field Office. 65 p.

Shaffer, T.L. 2004. A unified approach to analyzing nest success. Auk 121(2):526-540.

Thrift, M., Magee, P.A. 2005. The effects of mowing on small mammal communities in arid sagebrush-steppe within Gunnison Basin. Thornton Final Research Report, Western State College of Colorado, Gunnison 13 p.

Wiens, J.A., Rotenberry, J.T., Van Horne, B. 1986. A lesson in the limitations of field experiments: shrubsteppe birds and habitat alteration. Ecology 67(2):365-376.

Winter, M., Hawks, S.E., Shaffer, J.A., Johnson, D.H. 2003. Guidelines for finding nests of passerine birds in tallgrass prairie. The Prairie Naturalist 35(3): 197-211.