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Progress Report

UPLAND GAME BIRD ECOLOGY

Study I: Greater Sage-grouse (*Centrocercus urophasianus*) Habitat and Population Trends in Southern Idaho

July 1, 2007 to June 30, 2008

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SUBPROJECT:		**STUDY NAME:**	Greater Sage-grouse Habitat and Population Trends in Southern Idaho
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PERIOD COVERED: July 1, 2007 to June 30, 2008

GREATER SAGE-GROUSE HABITAT AND POPULATION TRENDS IN SOUTHERN IDAHO

Abstract

Greater sage-grouse (*Centrocercus urophasianus*) are an important game bird for Idaho as well as the Intermountain West. Proper management of this species relies on our understanding of their habitat use and on our abilities to accurately estimate their population levels. Data analysis is continuing on the four-year nesting habitat project reported in Job 1. A new population project was started involving lek counts (Job 2) and inter-lek movements (Job 3). The pilot project has ended and a graduate study will continue through 2009.

JOB 1. GREATER SAGE-GROUSE NEST HABITAT IN SOUTHERN IDAHO

Abstract

We are investigating nest habitat characteristics for greater sage-grouse in Idaho. We measured vegetation on 212 sage-grouse nests and 138 random plots on 15 study areas in southern Idaho during 2002-2005. Data analyses for 2003-2005 are presented in this report. Principal component analysis was used to reduce the set of correlated variables ($n = 91$) to independent components. Three components described 51% of the variance and included shrub height (31% of variance), horizontal cover (11%), and shrub density (9%). Nests were associated with taller and less dense shrubs than available at random. Multivariate comparison of means showed nests had less bare rock, greater horizontal cover, and taller live grass and shrubs than at random plots. No differences could be detected either between successful and unsuccessful nests or among two age classes of hens (yearlings, adults) when combined with nest fate. Further analysis will include comparisons at the plant species level.

Recommendations

1. Analyze data and provide completion report.

2. Publish results in peer reviewed journal.

Introduction

Greater sage-grouse populations have declined throughout the Intermountain West (Connelly and Braun 1997, Connelly et al. 2004), and their distribution is greatly influenced by the occurrence of shrub-steppe habitat types, especially those dominated by sagebrush (Patterson 1952, Connelly and Braun 1997). Habitat quality is an important factor influencing nest success, which ultimately affects recruitment and population levels. Nests are more likely to hatch when sites are under sagebrush (Connelly et al. 1991), have higher canopy coverage and density of sagebrush than the surrounding area (Wallestad and Pyrah 1974), and have greater percent cover of residual grass >18 cm tall within 1 m of the nest (Gregg et al. 1994).

To increase greater sage-grouse productivity through habitat management, the Idaho Department of Fish and Game Commission approved the Idaho Greater Sage-grouse Management Plan (IDFG 1997), later signed by the Bureau of Land Management (BLM). One management objective was to "Manage nesting and early brood habitat to provide 15-25% sagebrush canopy coverage and about seven inches or more of grass and forb understory during the May nesting period" (IDFG 1997:12). Natural resource agencies have difficulty (pers. comm. Paul Makela, BLM wildlife biologist) applying the seven-inch (18 cm) herbaceous height guideline to habitat types dominated by understory species with small stature (e.g., Sandberg's bluegrass [*Poa sandbergii*]). Measuring grass height is time consuming and is an added workload (pers. comm. Paul Makela). Also, it is unknown how the seven-inch grass height relates to livestock utilization levels (i.e., light or slight versus moderate or heavy use). Utilization sampling is a common practice for range management personnel and utilization contours are developed for many grazing allotments. These estimates have not been related to greater sage-grouse nest selection or nest success.

Nest initiation begins approximately 10 days after breeding (Autenrieth 1981). Egg laying requires 1.3 days/egg laid with an average of seven eggs/nest (Patterson 1952), and incubation lasts 26 days (Pyrah 1954). Plant structure surrounding the nest, especially grasses and forbs, changes rapidly during the month between nest selection and hatching. Nest sites are typically measured after the hen leaves to avoid abandonment or attracting predators resulting from observer influence. Measuring nest site vegetation this late may not reflect the habitat condition the hen was responding to at nest initiation and may not allow us to completely understand reasons for unsuccessful nests. The landscape around the nest changes from dormant residual grasses and forbs produced during the previous year, to lush and succulent vegetation as the growing season progresses. Factors that influence nest-site selection are unknown but could involve dormant vegetal structure at the time of nest selection or potential cover at hatch. Succulent forbs are nutritionally important for pre-laying hens (Barnett and Crawford 1994) and may influence nest-site selection. Managing habitat for potential cover is difficult due to variable precipitation patterns. Residual cover is dependent on the previous year's precipitation and grazing practices, and its structure may be negatively impacted by snow depth.

Past research on greater sage-grouse breeding habitat has focused on shrub structure (Wallestad and Pyrah 1974) and general understory cover (Klebenow 1969, Connelly et al. 1991, Gregg et al. 1994), overlooking the possible importance of species diversity and variance of plant structure. Comparing differences in variance estimates allows for testing the homogeneity of habitat (Ratti et al. 1984). Spatial heterogeneity may be more important than nest concealment in reducing nest depredation (Bowman and Harris 1980). Also, past research projects have focused on single study sites dominated by one or two habitat types. Greater sage-grouse are known to nest in several habitat types throughout Idaho.

No research has been conducted to relate plant structure, range utilization, grazing systems, or habitat type to greater sage-grouse productivity or nest-site selection. This information would assist land management agencies to properly manage rangelands to benefit declining greater sage-grouse populations (Schroeder et al. 1999).

Objective

Determine vegetation and range management parameters associated with successful and unsuccessful greater sage-grouse nests throughout southern Idaho.

Study Areas

This research is being conducted on 15 study sites, of which 2-4/year have ongoing greater sage-grouse telemetry projects (Figure 1). The study areas are distributed throughout southern Idaho ranging in elevation from 1,600-2,400 m in a variety of shrub-steppe habitat types and range conditions. At least 12 habitat types (Hironaka et al. 1983) are present on the study areas and each area has at least one habitat type. The study areas are on public and private land and are grazed in accordance with federal leases administered by BLM or U.S. Forest Service.

Methods

Successful and unsuccessful greater sage-grouse nest sites were obtained from radio-marked hens being monitored as part of other ongoing studies. Each nest was classified according to a specific habitat type. Habitat measurements were taken from the sites after hens ceased nesting efforts.

Vegetation sampling was conducted similar to Wakkinen (1990), Gregg et al. (1994), and Musil et al. (1994). Measurements were taken along four 10 m transects placed at right angles radiating from the center of the nest. Droop height of the closest shrub and grass for each species was measured within 1 m of the transect at 1, 3, and 5 m from the center of the nest for each transect. Droop height is defined as the tallest naturally-growing portion of the plant (Connelly et al. 2000). Droop height of residual (previous season growth) and live (current season growth) leaf, and height of tallest flower stalk (tallest of residual or live) for each grass species was measured separately. The number of flower stalks was also counted. Effective height is measured by placing a meter stick behind the grass or shrub and estimating the tallest height most concealing the increments on the stick. Effective height is the height of plant structure that effectively provides horizontal concealment cover. Plants with few flower stalks have effective heights measured at the top of the densest portion of residual or live leaves, or branches, below the flower stalks. Plants with numerous flower stalks provide effective cover from these structures above residual and live structure.

A Jones (1968) cover board was used to measure horizontal cover within the nest bowl. Horizontal cover outside of the nest bowl was measured with a Robel et al. (1970) pole. The pole was placed at 1, 3, and 5 m from the nest along the transects and read 20 cm above the ground immediately outside of the nest shrub or at the center of a random plot (Figure 2). The view of the pole from this position mimics the eye level of a greater sage-grouse hen incubating a nest. If the pole was imbedded within the nest shrub at 1 m, then the pole was considered 100% covered. At least one-half of the 2.54 cm tall segment (48 segments/pole) of the pole had to be obscured by vegetation to be counted as covered. Shrub canopy cover (Canfield 1941) and shrub density was measured along 10 m transects. Gaps in the canopy >5 cm were excluded (Connelly et al. 2003*b*). Shrub density was determined by counting the number of plants of each shrub species touching or within 0.5 m on both sides of the transects. Understory cover for each forb and grass species was measured with a 40 x 50 cm modified Daubenmire (1959) frame at 1, 3, and 5 m from the nest on each of the four transects. Cover canopies were modified from Daubenmire (1959) to include more sensitivity for lower values. These percent cover classes were: 1 (0-1%), 2 (2-5%), 3 (6-25%), 4 (26-50%), 5 (51-75%), and 6 (76-100%). Slope and aspect were measured using a clinometer and compass, respectively.

Measurements of grass height by species were taken at one plot 30-50 m from incubating radio-marked hens in 2003-2005 to determine growth phenology. Measurements were made within one week of initiation of incubation. The same sampling scheme for grass height measurements at nest sites was conducted at these “near nest” plots. Individual grass species were marked with stick pins so the exact plant could be measured at the end of incubation. Near nest plots were located at the same elevation and aspect as the nest to ensure similar growth patterns and also in similar shrub density and height by ocular estimation. Random plots, independent from nest sites, were generated using ArcView Spatial Analyst (ESRI Redlands CA 92373) software and measured during the hatching period. The same measurements made on nests were made at the random plots.

Principal component analysis (McGarigal et al. 2000) was conducted to reduce the set of correlated variables to independent components for comparison between nests and random plots. No random plots were measured in 2002. Varimax rotation was used to facilitate interpretation of the variables within the components (O’Rourke et al. 2005). Meaningful factor loadings was set at ±0.40. Variables significantly loading on >1 component were removed from the analysis and the analysis re-run. Means were calculated for variables and principal components and compared using multivariate analysis of variance (MANOVA, O’Rourke et al. 2005) using Wilk’s lambda to measure association for overall effects and Tukey’s Studentized Range for multiple comparisons at the 0.05 level of significance.

Results

During 2002-2005, 212 greater sage-grouse nests were measured in 15 study areas (Figure 1) in southern Idaho. Summary of sample sizes are provided in Table 1. No random plots were measured in 2002, therefore, only data for 2003-2005 were analyzed for this report for comparison of nest sites with what was available at random. Ninety-one vegetation variables were measured at nest and random plots (Table 2). Missing values often occurred for grazed grass heights, seedling densities, height of residual grass, number of grass flowers, and height of grass flowers. Including these variables in the analysis resulted in removal of 53% of the observations due to missing data, so they were removed to increase sample size. Missing values in any variable causes the entire plot to be dropped from the multivariate analysis. In the final principal component analysis, 10 nest observations and 10 random plots were deleted (7% total) due to missing values.

Random plots were positioned at the location of the random coordinates and often did not include shrubs at the center of the plot, as normally occurs at nest sites. Rather than introduce bias by centering the random plot on the nearest shrub, variables immediately over the center plot or within 1 m such as VRT, HOR, TRUNKS, HTNESTLV, canopy cover and density of shrubs at 0-1 m, and Robel pole measurements at 1 m were removed from comparisons between random plots and nest sites. These variables will be included in subsequent analysis among nests.

Two variables, RBLLOW3 and RBLGRD5, were identified as complex variables because of significant loading on two components so were removed from the analysis, but 56 were retained. Ten principal components met the minimum Eigenvalue of 1.0 and described 83% of the variance in the data. A majority (51%) of variance was described by the first three principal components (Table 3). Shrub height was associated with component I (Prin I), horizontal cover (measured with the Robel pole) with component II (Prin II), and shrub density with component III (Prin III).

Nest sites were associated with significantly taller shrubs ($P = 0.0007$) and less shrub density ($P = 0.0481$) than available at random (Figure 3), but horizontal cover was not significantly different ($P = 0.1176$). There was no difference between either successful and unsuccessful nests or with random plots for horizontal cover ($P = 0.2001$) or shrub density ($P = 0.1219$), but both nest fates were in habitat with greater ($P = 0.0031$) shrub height than at random (Figure 4). Shrub height for adult nests were significantly greater ($P = 0.0038$) than at random, but multiple comparisons with yearling nests were not different for all three principle components ($P > 0.05$), though it appeared adults had greater horizontal cover than yearlings (Figure 5). Only shrub height for unsuccessful nests of adults were different ($P = 0.0209$) from random plots when age and fate were compared (Figure 6). Comparing plots among years (Figure 7), Prin I and Prin III showed significant differences protecting multiple comparisons ($P < 0.0001$) but was not significant ($P = 0.05$) for Prin II, horizontal cover. Year 2005 had taller shrubs used by grouse and at random than the previous two years but was similar within the same year for all years. Random plots in 2005 were similar to 2003 nests (Prin I). For Prin III, shrub density, all plots within the same year were similar but was significantly lower in 2005 for both nests and random plots than for the previous years (Figure 7).

Grouping study areas by two categories of moisture regimes (xeric, mesic), two categories of shrub growth form (short = *Artemisia arbuscula* and *A. nova*, tall = *A. tridentata* spp.), and one category for domination by a single species (three-tip sagebrush *Artemisia tripartita*), the first three principal components showed a gradient from xeric/short to mesic (Figure 8). Prin I and III tested significantly different for centroids within the components with the GLM procedure ($P < 0.0001$) so were protected for multiple comparisons, but Prin II was not protected ($P = 0.1311$). All the xeric short and tall study areas had less shrub heights than three-tip and mesic sites.

Within xeric sites, tall nest sites were similar to short nests but were significantly different from xeric short/tall random plots. Mesic nests/random plots had significantly taller shrubs than all the other categories. Three-tip sites had shorter shrubs than mesic sites but taller than xeric sites. For Prin III, shrub density, all sites were similar between nests and random plots within the same category. Three-tip random plots were the least dense of all the plots.

Multivariate comparisons between nest and random plot means were compared for 58 (Table 4). RBLLOW3 and RBLGRD5 were retained for MANOVA means comparisons. Rock cover was greater at random ($P < 0.04$) than at nest sites at all distances from the center. Horizontal cover (RBL) for all levels at 3-5 m was greater for nest sites than at random ($P < 0.001$). Live grass height (HTLVGR) was greater at nests than random ($P < 0.001$) at all distances but effective height of grass was only significant when averaged across the entire plot (EFGRTT, $P = 0.0194$). Only height of shrubs (HTSHTT) averaged across all distances from center was significantly taller than at random ($P = 0.0366$). Nests had greater canopy cover of shrubs 1-3 m from center (CCSH13, $P = 0.0415$) than occurred at random. Total canopy cover of shrubs (CCSHTT, $P = 0.0009$) and total canopy cover of sagebrush (CCSAGETT, $P = 0.0020$) were greater at nests than at random, but these variables include the segment 0-1 m from the center of the plot. No multiple comparisons could be made either between adult and yearling nests (Wilk's Lambda = 0.55, $F = 1.15$, $P = 0.2739$) or among age classes combined with nest fates (Wilk's Lambda = 0.21, $F = 0.93$, $P = 0.6962$).

Discussion

Greater sage-grouse hens selected nest sites with different structural characteristics than what was available at random in Idaho during 2003-2005. Nests occurred on sites with taller shrubs but at lower density within 5 m of the nest. Nest sites also had taller live grass, more horizontal cover, and less bare rock than available at random. Similarly, Sveum et al. (1998) found shrub height was greater at nests than at random but contrary to our findings, Aldridge and Brigham (2002), in a silver sagebrush (*Artemisia cana*) habitat, had greater shrub density at nests than at random and could not detect a difference in shrub height. Wallestad and Pyrah (1974) found higher density of sagebrush at successful nests than at unsuccessful, but we could not detect any differences between nest fates. We had not separated the characteristics at the plant species level. We also could not detect vegetation differences between adult nests and yearling nests.

Wakkinen (1990) found taller grass at nest sites than at random but he measured the tallest portion of the plant where we separated grass height among several structures (residual, live, effective, and flower height) and found taller effective and live grass heights at nests than at random at multiple distances from the center. Maximum height for grass, regardless of which structure measured, has been separated at the species level but has not yet been analyzed for our data.

Greater sage-grouse are likely selecting nest sites for concealment from predators, both aerial and terrestrial. Hens require concealment while exiting from and returning to the nest during incubation breaks to avoid bringing attention to the nest as well as themselves. Our study is the first to measure horizontal cover from the perspective of the nesting hen. Our measurements did not distinguish what plant species were providing the horizontal cover, but it is probably the result of interception with both shrubs and grass. Greater sage-grouse hens are likely selecting sites with adequate views of approaching predators (Gotmark et al. 1995). The cover at nests, in our study, is provided by taller and fewer (less dense) shrubs than at random. Taller shrubs consequently produce more canopy cover, but less density provides more of a view further from the nest. Too much horizontal cover from too dense of shrubs would not allow the incubating hen an adequate response time to reduce her risk of mortality or to distract predators from finding her nest. Not enough cover would expose her as well as the nest during incubation breaks. Any practices that reduce horizontal cover minimize potential use of the site by nesting greater sage-grouse. Patterns of habitat use are a mechanism derived by the evolution of the species (Rotenberry 1981), and sage-grouse are not likely to adapt quickly enough to changes in vegetation during short time scales. Therefore, it is important to retain habitat characteristics that have been shown to be used by greater sage-grouse. Of course, use does not necessarily correlate with fitness at a landscape scale (Aldridge and Boyce 2007).

JOB 2. GREATER SAGE-GROUSE LEK ATTENDANCE RATES IN SOUTHERN IDAHO

Recommendations

1. Collect data through summer of 2009.

2. Analyze data and complete dissertation.

3. Publish results in peer-reviewed journal.

Introduction

Recent trends based on population monitoring indicate that populations of greater sage-grouse are generally declining throughout their range (Connelly and Braun 1997, Connelly et al. 2004). Schroeder et al. (2004) estimated that the range of sage-grouse has shrunk to approximately 56% of the pre-settlement distribution. Braun (1998) stated that according to available data, the number of male sage-grouse counted on breeding grounds each spring decreased from the 1950s through the 1990s throughout their range. While these indices are somewhat crude due to the nature of historical data, they are cause for alarm and justify more intense investigation.

The mating strategy of sage-grouse offers a convenient opportunity to observe and count individuals that congregate on breeding grounds (Patterson 1952, Jenni and Hartzler 1978, Connelly et al. 2003*b*). Each spring, males assemble and display on leks, and females visit the leks to select a male for breeding (Höglund and Alatalo 1995). Due to the conspicuousness of displaying males and the lack of cover that is typical of leks, these congregations are relatively easy to locate (Schroeder et al. 1999). Moreover, lek sites are usually traditional and persist for long periods of time (Dalke et al. 1963).

Lek routes currently provide the best index to breeding population levels throughout much of the species' range (Connelly et al. 2000). The current method for conducting a lek route includes locating all or some portion of the leks of a breeding population visually from low-flying aircraft or audibly from the ground, identifying groups of leks for developing lek routes, then revisiting each lek within a route at least four times throughout the spring to count the number of males present (Connelly et al. 2003*b*). Trends are estimated from these data by calculating the greatest number of males counted on a single visit across all leks within a route, for multiple years.

Because lek counts and lek routes may not be representative of the entire population of interest, alone they simply provide an index to breeding population levels and fall under what Anderson (2001) calls "convenience sampling." Although these congregations of breeding sage-grouse offer easy counting of individuals, leks may not be random subsets of the population. Yearling males and adult males may not be attracted to the breeding grounds in proportion to their actual ratio, and females only spend a fraction of the time on leks that males do (Dalke et al. 1963, Jenni and Hartzler 1978, Emmons and Braun 1984, Walsh et al. 2004). Furthermore, not all birds attending a lek during a lek route census are necessarily going to be observed and included in the number reported. Size, behavior, and location within the lek may all affect the sightability of the attending birds by an observer. Any population estimates resulting from a lek route would likely be biased for a particular sex or age class, depending on the time of the counts. Moreover, using counts from a lek route to estimate numbers of male sage-grouse is of little use as no valid technique exists to assess precision of such estimates (Anderson 2001).

There are concerns with using a lek route even as an index. Using uncorrected counts as an index may be unreliable because counts are contingent upon the following assumptions: 1) the sample is proportional to the population; 2) the proportion remains constant among years when trends are estimated; 3) the proportion remains constant among sites where relative abundance is to be compared; and 4) the detection probability is the same for all observers (Anderson 2001, White 2005). Despite stringent guidelines for conducting lek routes (Connelly et al. 2003*b*), these assumptions may not be realistic. Nichols (1992) stated that detection probabilities vary over time and space due to factors that are beyond our control. Further, if these assumptions are not verified, there is a risk of reporting highly biased results (White 2005).

Objectives

The objectives of this project include determining: 1) how the probability of attending a lek differs among adult male, yearling male, and female sage-grouse; 2) how and what biological factors affect these probabilities; and 3) what variables affect the sightability of birds attending a lek; in order to 4) develop a method to obtain unbiased estimates of abundance for each segment of a population from lek count data. Secondary objectives of this study are to estimate survival of nests, chicks, juveniles, and adult birds; determine the sex ratio during the breeding season; and estimate the harvest rate of the study population.

Study Area

Our research is being conducted on Brown's Bench in Twin Falls County in south-central Idaho, and this area extends into Elko County in north-central Nevada. Brown's Bench is bordered to the east by Salmon Falls Creek Reservoir and to the west by an area of rolling hills locally known as Monument Springs. This area receives approximately 24 cm of precipitation annually and ranges in elevation from 1,524 m to 2,300 m. The major cover types include low sagebrush

(*Artemisia arbuscula*) /black sagebrush (*A. nova*) /grass, Wyoming sagebrush (*A. tridentate* ssp. *wyomingensis*)/grass, mountain sagebrush (*A. tridentate* ssp. *vaseyana*)/grass, mountain shrub, and crested wheatgrass seedings (*Agropyron cristatum*). Other, less-dominant cover types include aspen woodland (*Populus tremulodies*), mountain mahogany woodland (*Cercocarpus montanus*), and wet meadow/riparian (Hironaka et al. 1983, Klott et al. 1993). Livestock grazing is the most common land use for the entire study area. The BLM manages most of the land with privately-owned ranches comprising the rest.

We used nine leks in 2007 located on Brown's Bench south of the Three Creek road and north of the Idaho/Nevada border (Figure 9). In 2008, we included an additional five leks located north of the Three Creek Road, east of Cedar Creek, and west of Salmon Falls Creek. A preliminary study of sage-grouse in this area conducted in 2005-2006 indicated that the population was non-migratory. Nevertheless, data collected in 2007 indicate that some of the birds comprising the winter population of our study area move large distances throughout the year (over 30 km) and are likely migratory (Connelly et al. 2000).

Methods

Pilot Study

Trapping and Marking. In 2005 and 2006, male sage-grouse were captured using spotlighting (Wakkinen et al. 1992, Connelly et al. 2003*b*) in the vicinity of the leks during early to mid-March. These males were resident in the area and had been displaying irregularly on sunny days since February. Twenty-three females (22 adults and one yearling) had been captured in earlier studies during previous years.

Attendance Probability and Sightability Estimation

Lek counts by three observers, with one observer counting displaying males and attending females according to the protocol by Connelly et al. (2003*b*), commenced on 25 March and were repeated approximately weekly with the seventh count occurring on 3 May 2005. Simultaneously, two observers located radio-marked grouse using dual-element, null-peak yagi antenna systems mounted on pickup trucks. This allowed each radio-marked grouse within radio range of the lek to be identified as to whether or not it was recorded by the first observer during the lek count.

Survival

We will use the known-fate model in Program MARK with the following covariates to estimate survival: year, sex, age, and season. Assumptions for survival estimates from radio telemetry include: the marked sample is randomly selected from the population; marked animals are independent; marking does not influence survival; and when fate is unknown (censored), known survival time is assumed to be independent of the animal's actual fate.

We will use Akaike's Information Criterion (AIC) for model selection, and all parameter estimates will be generated using model averaging based on AIC weights (Burnham and Anderson 1998, Murray 2006).

Field Study

Trapping and Marking. Sage-grouse are being captured using spotlighting (Wakkinen et al. 1992, Connelly et al. 2003*b*) during winter. We attempt to capture and fit birds with radio transmitters relatively early in the winter to minimize their potential association with a particular lek as the mark-resight method we will use to estimate detection probabilities relies on the assumption that samples (marked individuals) are randomly selected. A random sample will also aid in the search for new leks using radio telemetry, where selecting a sample of individuals that may have strong ties to a known lek will not likely lead to the discovery of new leks. All captured birds are classified by gender and age using wing characteristics (Dalke et al. 1963, Beck et al. 1975), and females are weighed.

In 2007, we began trapping on 18 January and continued through 15 March, at which time 32 male and 28 female sage-grouse had been captured. In 2008, trapping occurred between 30 January and 15 March, during which 44 male and 17 female sage-grouse were captured. All captured birds were fitted with 16.5 g necklace style radio transmitters (Advanced Telemetry Systems, Isanti, Minnesota) and received a numbered aluminum leg band. In 2007, birds also received three 14 mm, colored flat-band, wrap-around style leg bands (A. C. Hughes, Middlesex, United Kingdom) in a unique combination.

Attendance Probability and Sightability Estimation

For five days just before beginning lek routes (approximately 15-20 Mar), we spent the early morning hours searching for previously unrecorded lek locations. We visited all suspected breeding habitat within the study area and listened for sounds of strutting males as per Connelly et al. (2003*b*) and located radioed males. Maximizing the number of leks in our routes should increase our resightings (sample size), which will likely improve the precision of parameter estimates (Pollock et al. 1990).

Lek routes were conducted between 20 March and 16 May in 2007, and between 17 March and 21 May in 2008. Leks were counted from 0.5 hours before to one hour after sunrise when weather conditions were clear to partly cloudy and there was little to no wind (Connelly et al. 2003*b*). In this manner, it was possible to visit two to three leks per day, allowing 15 minutes at each lek and approximately 15 minutes to travel between leks. We included all leks in the vicinity currently included in the Idaho Department of Fish and Game standard lek route, as well as any additional ones we discovered. Presently, we have a total of 14 leks in our route, which we grouped into twos or threes based on their proximity to each other. All leks within a group were visited on the same day. A resighting occasion is defined by all leks within our study area being visited exactly once, and we completed a total of eight resighting occasions in 2007 and nine in 2008.

Lek routes were conducted by two researchers, each equipped with a telemetry receiver and spotting scope. Both individuals approached each lek at approximately a 90-degree arc from each other, being extremely cautious not to flush birds. Upon arriving at a predetermined position that allowed good visibility of the entire lek, the primary observer counted total number of male and female sage-grouse attending according to the protocol by Connelly et al. (2003*b*). Both researchers then scanned through the list of frequencies of radioed birds using hand-held three-element, null-peak yagi antenna systems, noting signals strong enough and in the general direction that would indicate positive lek attendance. We used predefined compass bearings to delineate the "edge" of the lek relative to each observation point for all leks. Items recorded included date, weather conditions, starting time, observer location, and observer's name for each count, and number and frequency of radioed birds determined to be on the lek during a lek count. If direction and signal strength from both positions indicated the bird was likely on the lek, the bird was assumed to be attending. Researchers then moved to the next lek, repeating the previous steps.

After two years of pilot study, we did not feel confident with the assumption that all birds attending a lek were seen by the lek route observer, and more importantly, that radioed-marked birds with signals detected on the lek were absolutely included in the count. As a result, we felt it necessary to add a detection probability or "sightability" component to our overall study.

For each day we conducted lek routes, additional observers made observations at one or two leks from a stationary blind. We positioned blinds on three leks in 2007 and four in 2008; these leks represented the range of sizes of leks and cover types for this study area. We positioned blinds within 20 m of the edge of the leks within sagebrush to minimize potential effects the introduced structure may have on the birds' behavior. We set up blinds no less than one week from the day of the first lek route to allow birds adequate time to adjust to the structure. On the day of the lek count, a single observer entered the blind two hours before sunrise to minimize flushing birds. When visibility was sufficient to see birds on the lek, but no later than 0.5 hours before sunrise, each observer conducted a count of adult males, yearling males, and females visiting the lek. After each count, the observer then scanned the frequencies with a receiver and a small hand-held two-element antenna for radioed birds on the lek. We recorded the following data: observer's name, date, general weather conditions, time of each count, number of each segment of the population visually counted, number of displaying males, and number and frequency of radios heard. The observer repeated counts and frequency scans every 15 minutes. The observer continued collecting data from the blind until all or most of the birds flushed from the lek.

Using mark-resight techniques, we will use the Recaptures Only model in Program MARK to estimate the probability of attending a lek for sage-grouse from a relatively discrete breeding population. Program MARK allows the modeling of detection probabilities with group-specific, time-specific, and individual-specific covariates, which can greatly improve the precision of the estimates (White 2005). The data requirements for this model include the detection histories for each marked (radioed) bird, which is simply a record of detected or not detected for each bird during each lek route (resighting occasion). The covariates we plan to use in the model include: sex, age, date, time of day, size of lek, moon phase, weather, and year.

We will use AIC for model selection and all parameter estimates will be generated using model averaging based on AIC weights (Burnham and Anderson 1998). We will use the generalized mark-resight population size estimation method described by Bowden and Kuffeld (1995) to estimate abundance and the corresponding variance for all segments of the population.

We will determine the sightability bias of sage-grouse that attend leks and use multivariate regression to evaluate effects of biologically relevant variables on the sightability of male and female sage-grouse from a lek route census. We will also develop models of visibility bias similar to those used for helicopter surveys of ungulates (Samuel et al. 1987, Bodie et al. 1995). We will use counts conducted from blinds located at the edge of leks to compare counts conducted during lek routes under the assumption that counts from the blind will include 100% of attending grouse. The variables we plan to use in the sightability model are: total number of males attending, number of yearling males attending, density and height of cover, percentage of males displaying, number of females attending, time of day relative to sunrise, weather, distance to center of lek, and size (area) of lek.

Survival

In addition to an unbiased estimate of abundance and population trend, understanding which components of the population affect the current trend is crucial for proper management of a species. These various vital rates are typically grouped into two categories: recruitment and survival. Factors such as weather and time have been shown to cause variation in survival and recruitment (Zablan et al. 2003, Fields et al. 2006, Moynahan et al. 2006). Understanding the effects of these factors can improve demographic estimates and may also lead to improved management strategies.

Nest Survival. For precocial species, nest survival is the probability that $\geq$1 egg hatches from a given nest, and daily nest survival rate is defined as the probability that a nest will survive a 24-hour period (Dinsmore et al. 2002). These metrics are key components of avian demographics and are used to drive and evaluate management strategies (Jehle et al. 2004, Stanley 2004).

Females with radio transmitters are located daily from the beginning of April to the end of June, or until nesting efforts cease. We continue to monitor hens with failed nests in an effort to detect secondary nest attempts. Once hens are noted in the same location on three consecutive days, we attempt to get a visual confirmation of nesting without flushing the bird. Nests are then monitored daily from a single location approximately 30 m from the site to minimize disturbance (Schroeder 1997). If the female was not located on the nest, we approach the nest to determine fate. Fate, number of chicks hatched, or cause of failure are determined from shell/egg remnants and other cues at the nest (Wallestad and Pyrah 1974, Martin and Guepel 1993).

We plan to use the nest survival model in program MARK (White and Burnham 1999) to estimate daily survival and determine which biologically relevant factors affect variability of nest survival. The nest survival model in program MARK expands on the daily nest survival model described by Bart and Robson (1982), allowing the use of individual, group-specific, and time-specific covariates (Dinsmore et al. 2002). This method does not require the restrictive assumptions such as constant survival or that failure occurred at the midpoint of an interval, as do models such as Mayfield's estimator (Jehle et al. 2004).

The assumptions of this model are: (1) nests are correctly aged when first discovered, (2) nest fates are determined accurately, (3) nest monitoring does not affect survival, (4) nest fates are independent, and (5) daily nest survival rates are homogeneous.

The minimum data required for the nest survival model include: the day the nest was found, the last day the nest was checked alive, the last day the nest was checked, and the fate of the nest. We will also estimate the day incubation began from monitoring of daily hen activity so we can include nest age as a covariate. Other covariates that will be included are: year, nest age, date of nest initiation, hen age, condition of hen at time of capture (hen weight), average temperature, and daily precipitation.

We will use AIC for model selection and all parameter estimates will be generated using model averaging based on AIC weights (Burnham and Anderson 1998).

Chick Survival. We will estimate chick survival if sample sizes in a given year are adequate (>10 successful nesting hens). On the morning after a hatch, the brood hen will be located using radio telemetry just before dawn, when chicks are assumed to still be brooding. All chicks will be captured and placed into a bag and kept warm until released. For each chick, we will measure mass, collect a feather for classifying gender in the lab (Griffiths et al. 1998), and insert a Passive Integrated Transponder (PIT) tag subcutaneously, just below the nape. At 4, 8, and 12 weeks after average hatch date, we will attempt subsequent mark-capture occasions of chicks. Locations of hens with broods will be used to identify general brooding areas for the population. Transects will be traversed with truck or ATV through the predefined area and we will use spotlighting techniques to locate hens with chicks or chicks alone. Dave Dahlgren (personal communication.) used a trained pointing dog to successfully locate hens with broods as well as lone chicks. We will attempt to use this method on a minimum of two days during each occasion to locate chicks. All individuals captured will be scanned for PIT tags. Those without tags will be given one, and we will record weight, sex (feather of chicks), and location of capture for all chicks. Age of newly captured chicks will be estimated from a table of average weights generated from birds of known age and sex from our data and the published literature. Recapture occasions will be conducted for 10 consecutive nights. If inclement weather or full moon prevents capture, occasions will continue when conditions improve until 10 nights have been reached. During the week-12 capture occasion, all chicks captured will receive adult radio transmitters instead of PIT tags. After 10 days of capturing chicks, locations of radioed hens will be used to assist in capturing chicks for the purpose of equipping a total of 25 chicks with radios. Chicks located in this manner will not be included in the mark-recapture analysis for survival estimation.

We will use mark-recapture methods to estimate survival from hatch to 12 weeks old and use the general Cormack-Jolly-Seber model in Program MARK to generate estimates of survival. The data requirements for this method are the capture histories for each marked chick for all mark-recapture occasions. As we do not anticipate a large dataset, covariates will be limited to sex, age, and weather.

We will use AIC for model selection and all parameter estimates will be generated using model averaging based on AIC weights (Burnham and Anderson 1998).

Juvenile and Adult Survival. We will attempt to locate all radioed birds with radio telemetry at a minimum of once per week throughout the year. UTM coordinates of each bird will be recorded within 50-100 m using a hand-held GPS unit to minimize disturbance. The transmitters used will be equipped with a mortality sensor. We will collect all deceased birds and attempt to determine source of mortality from the remains.

We will use the known-fate model in Program MARK with the following covariates to estimate survival: year, sex, age, and season. Assumptions for survival estimates from radio telemetry include: the marked sample is randomly selected from the population; marked animals are independent; marking does not influence survival; and when fate is unknown (censored), known survival time is assumed to be independent of the animal's actual fate.

We will use AIC for model selection and all parameter estimates will be generated using model averaging based on AIC weights (Burnham and Anderson 1998, Murray 2006).

Sex Ratio

Because hens only visit leks once or twice to choose a mate and copulate, we will not likely be able to detect enough radioed hens on leks to estimate their attendance probability or their population size. We will, however, be able to estimate hen population size from the estimated male population size if we can determine the sex ratio of the population.

We will estimate the sex ratio of the population of sage-grouse using two techniques. First, we will count males and females flushed during winter surveys. The major assumption for this technique is that field personnel can correctly recognize the sex of sage-grouse.

From areas known to be used by sage-grouse in winter, we will randomly select areas to survey from foot or vehicle. When birds flush, we will note the number of each sex and the area they flew to. Once we have sufficiently sampled an area, we will move to a new area, being careful not to re-sample the same birds during a single sampling occasion. We will repeat this procedure at least four times with at least a week separating each occasion.

Second, we will collect sage-grouse droppings from areas commonly used by sage-grouse for foraging or roosting. The droppings will then be analyzed in the lab to determine sex (Griffiths et al. 1998). The major assumptions of this method are that both male and female sage-grouse deposit droppings at the same rate, and that we can correctly identify the sex of sage-grouse from their droppings with DNA analysis. We will search areas known to be used by sage-grouse as winter forage and roost sites for freshly-deposited droppings. We will search these areas by foot after a fresh snow to collect only the freshest droppings and to ensure they have been preserved (frozen) for analysis. Each dropping will be sealed in bag and labeled with the date and location it was found. Samples will then be placed in a cooler and transported to a freezer until analyzed in the lab.

Harvest

Within the Brown's Bench study area, there is currently a week-long hunting season each fall with a daily bag limit of one bird and a possession limit of two birds. There is strong evidence that hunting mortality is additive to winter mortality for sage-grouse (Ellison 1991, Johnson and Braun 1999, Connelly et al. 2000, Connelly et al. 2003*a*), so understanding mortality due to harvest is crucial for proper management of the species.

We will use hunter returns of leg-banded and PIT-tagged birds to estimate harvest rate. Primary access to the study site is limited to a single gravel road, along which we will establish a hunter check station on both the opening and closing weekend of the hunting season. We will ask hunters not to remove the skin from shot birds until after stopping at the check station via posted signs at the entrance to the area and at nearby camping grounds. All birds reported will be classified to gender and aged and scanned for PIT tags.

Results

Pilot Study

Attendance Probability and Sightability Estimation

2005 Field Season. Adult males attended leks most frequently (96%) and were counted on the leks most frequently (84% of time present within vicinity of lek; Table 5), yearling males less frequently (74% attendance and 69% detection when attending), and females rarely (15% attendance and 8% detection). Combined adult and yearling males attended during 88% of counts and were counted (observed on the lek) 79% of the time that they were present within the vicinity of a lek. Because our ultimate goal is to estimate the actual number of sage-grouse present in the entire vicinity sampled by the lek route, the most meaningful measure is the probability of detecting birds within the population. These rates are somewhat lower than attendance rates for males (68%, *SE* = 4.16%; Table 6) and extremely low for females (1.27%, *SE* = 0.90%). The same radio-marked males were seen repeatedly at leks over the course of the seven weekly counts, but radio-marked females were only seen a single time at any lek. The maximum count for combined radio-marked and unmarked males on any of the seven surveys was 156 birds (combined adults and yearlings). Based on the 68% (*SE* = 4.2%) probability of detecting radio-marked males, this outcome implies that there were a total of 233 (95% CI = 263-365) males attending the leks on Brown's Bench during the breeding season in 2005.

2006 Field Season. Lek attendance data for 2006 have not been completely analyzed. However, it appears that peak male counts occurred much earlier in 2006 compared to 2005 (Figure 10). Moreover, the highest count of yearling males in 2006 was only four birds. Furthermore, in 2006 yearlings had a higher probability of attending leks than adults.

Survival

Survival data from 2005 and 2006 have not yet been analyzed.

Field Study

Attendance Probability and Sightability Estimation

Of the 33 male sage-grouse trapped in 2007 or surviving from previous years, 17 were captured before 1 March of the year trapped ("early"), while 16 were captured after 1 March ("late"). Four of the "early" grouse left the study area during or before the breeding season, and five died, while only one of the "late" grouse left the study area and none died during the breeding season.

Of the 44 males captured in 2008, 29 were used for the attendance probability analysis. Seven of 18 captured before 1 March (early) were omitted from the analysis; three slipped their collars, three died, and one left the study area. Eight of 26 captured between 1 and 15 March (late) were omitted; six died, one died or slipped its collar, and one died or left the study area. Five birds surviving from 2007 with live transmitters were also included for a total sample size of 34 (30 adults and four yearlings).

In 2007, we conducted a total of nine complete lek routes on the nine leks in our study area. Additionally, we collected data from blinds on three of the leks for a total of 21 blind-mornings during our lek routes. We detected a total of 91 resightings of 16 adult males, 14 resightings of three yearling males, and a total of eight resightings of seven females on our study leks. The probability of detecting a marked bird on a lek in our study during the nine-week duration in 2007 was 0.63 (*SD* = 0.23, *n* = 17) for adult males, 0.52 (*SD* = 0.46, *n* = 3) for yearling males, and 0.09 (*SD* = 0.08, *n* = 14) for females. The attendance probability for "early" males was 0.59 (*SD* = 0.34, *n* = 7), and for "late" captured males was 0.63 (*SD* = 0.22, *n* = 12).

In 2008, we conducted a total of nine complete lek routes on 14 leks and collected attendance data from blinds on four of the leks for a total of 31 blind-mornings. We detected a total of 23 resightings of four yearling males and 206 resightings of 30 adult males. The probability of detecting a marked bird on our study area during the nine-week study in 2008 was 0.76 (*SD* = 0.23, *n* = 30) for adult males and 0.64 (*SD* = 0.29, *n* = 4) for yearling males. The attendance probability for "early" males in 2008 was 0.64 (*SD* = 0.28, *n* = 14) and for "late" males was 0.82 (*SD* = 0.17, *n* = 20).

Peak male counts for 2008 followed a trend similar to that of 2006 and 2007 (Figure 10) with male sage-grouse peak counts occurring relatively early in the season. Counts in 2005 followed a pattern considered normal for sage-grouse with numbers of males peaking in late April.

To date, we have modeled the 2006 and 2007 data for attendance probability. The bootstrap goodness-of-fit test in program Mark showed our global model was a good fit to the data with only slight overdispersion (c-hat = 1.23). The top model chosen by AIC model selection procedures included the variables of year and a quadratic time trend (Table. 7). Two other models resulted in Δ AIC values less than 2, indicating that they were equally parsimonious. These models included age and a quadratic time trend (Δ AIC of 0.877), and a quadratic time trend alone (AIC of 1.88).

A graphical representation of the predicted attendance probabilities from the models averaged based on AIC weights shows a general increase in attendance probability up to the fourth or fifth occasion, followed by a decrease until the final occasion (Figure 11). Both the 2007 adults and 2007 yearlings peaked in predicted attendance earlier, and achieved a greater probability than the 2006 birds. In 2006, yearlings had a higher probability of attending leks than adults, while in 2007, the opposite was predicted by the top models. Despite a low average coefficient of variation of 15.7%, the confidence limits for these estimates were rather large (Figure 12).

During our lek routes, we detected on average 90.88% (*SD* = 22.99) of the total birds counted from the adjacent blind in 2007 and 87.69% (*SD* = 24.38) in 2008.

Nest Success

We were able to monitor the daily movements of 17 females throughout the nesting season in 2007. We detected a total of 15 nests initiated by these hens, which included a second nest attempt from a single adult. Only two of the 15 nests (13.3%) successfully hatched. In 2008, we monitored 14 hens through the nesting season. We detected a total of 11 nests initiated, which again included a second nest attempt from a single adult hen. Only three of the 11 nests (27.3%) successfully hatched in 2008.

Discussion

Pilot Study

The radio-tagged sample of 20 males provided valuable estimates of attendance and detection probabilities for males in the population as well as forming the basis for evaluating less-intensive approaches to obtaining unbiased estimates. The remarkably good performance of the proposed extensive technique based on conducting standardized lek counts in which ancillary data, such as time of day that a count begins as well as moon phase and cloud cover, implies that modeling proportion of the maximum number of birds counted could dramatically improve the value, precision, and accuracy of standardized lek counts.

Field Study

The purpose for capturing birds earlier in the winter was to try to get a truly independent sample with the hypothesis that birds captured around leks closer to the breeding season are more likely to have territories on the given lek and therefore will have a higher probability of attending the lek than a male randomly selected from the population. Based on limited data from 2007, capturing birds earlier in the winter did not appear to have much of an effect on the probability that birds attended leks (*P* = 0.59 for early captured birds versus *P* = 0.63 for later captured birds). In 2008, however, there did seem to be an affect (*P* = 0.64 for early captured birds versus *P* = 0.82 for later captured birds), suggesting that birds captured earlier in the winter may better represent the population regarding lek attendance. Capturing birds in September or October should result in a sample that is independent of leks, providing a baseline to compare attendance probabilities of birds captured in winter and allow for a more accurate test of the hypothesis. Unfortunately, this would only be a useful approach for a non-migratory population. In migratory populations, grouse captured during late summer or early fall could disperse to several different breeding populations, making it difficult to obtain an adequate sample size for the study area of interest.

The three variables of time, age, and year were all important in explaining the variation in the probability of male sage-grouse attending leks for the 2006 and 2007 data. Lek attendance ranged from 25-77% and 13.5-74% for adult and yearlings, respectively. However, the dataset included resightings from a total of only six yearling birds. While these data points were enough for age to be a significant predictor in our model, the parameter estimates should not be given too much attention until we can increase our sample size over the next two years.

Attendance probability peaked on the fifth occasion in 2006, and on the fourth occasion in 2007. The exact dates of these peaks were 18 April 2006, and 9-12 April 2007. Additional years in this study would likely result in a wider range of peak attendance; however, from this study it appears that lek route efforts concentrated over the month of April would result in greater proportion of the population being counted on our study area.

In addition to the delay in peak attendance between 2006 and 2007, general attendance in 2006 was lower than in 2007. These results could be due to a true annual effect; however, it could also be due to the additional two leks included in the Brown's Bench 2007 lek route. If marked birds attended these two leks, or any other active lek not included in the route, the resulting estimated attendance probability would be biased low.

The results from our blind counts in 2007 and 2008 indicate that on average, lek route counts include about 91% and 88%, respectively, of the total birds present on the leks. Further analysis of these data should reveal which factors affect the precision with which an observer counts sage-grouse during a lek route, and the accuracy he or she has with identifying the age of birds on a lek.

Lek attendance patterns over the last three years (2005-2007) suggest production was poor in 2006, 2007, and 2008 with few yearling males recruited to the breeding population. We do not know whether or not population trajectory might affect sage-grouse lek attendance patterns. Nevertheless, relatively few yearlings in the population may result in less variation in lek attendance rates if yearlings attend less regularly than adults.

JOB 3. INTER-LEK MOVEMENTS OF GREATER SAGE-GROUSE IN SOUTHERN IDAHO

Recommendations

1. Collect data through summer of 2009.

2. Analyze data and complete dissertation.

3. Publish results in peer-reviewed journal.

Introduction

Adult male greater sage-grouse are highly territorial on leks and most research suggests that these birds have relatively high lek attendance rates (Dalke et al. 1963, Jenni and Hartzler 1978, Emmons and Braun 1984). In contrast, available evidence suggests that yearling males show less fidelity to a given lek and may attend two or more leks during a breeding season (Emmons and Braun 1984, Schroeder and Robb 2004). Moreover, conflicting data have been published on lek attendance patterns. Emmons and Braun (1984) observed that mean lek attendance was 86% for yearling males and 92% for adult males. They also indicated that 90% of radio-marked yearling male sage-grouse and 94% of radio-marked adult male sage-grouse attended leks during the period of high male counts. Although the data reported by Emmons and Braun (1984) are similar to that reported by other researchers (Dalke et al. 1963, Jenni and Hartzler 1978), Walsh et al. (2004) reported that adult male sage-grouse had an average daily attendance rate of 42% while the daily attendance rate for yearlings was 19%. They also indicated that on 58% of days in which seven radio-marked adult males were observed, they did not apparently attend a lek. Both studies were conducted in northern Colorado in breeding habitats that ranged from 2,200 to 2,964 m. It is not clear why these apparent attendance rates are so different, but the variation could be due to differences in monitoring, analytical techniques, or disturbance regimes. Clearly, attendance rates can affect the accuracy of lek counts, and understanding mechanisms affecting attendance and interlek movements will allow development of a better monitoring system than the one currently used. Thus, we are attempting to quantify interlek movements of different age and gender groups of greater sage-grouse as part of a larger study dealing with sage-grouse lek attendance patterns.

Study Area

Our research is being conducted on Brown's Bench, in Twin Falls County in south-central Idaho and this area extends into Elko County in north-central Nevada. Brown's Bench is bordered to the east by Salmon Falls Creek Reservoir and to the west by an area of rolling hills locally known as Monument Springs. This area receives approximately 24 cm of precipitation annually and ranges in elevation from 1,524 m to 2,300 m. The major cover types include low sagebrush / black sagebrush / grass, Wyoming sagebrush / grass, mountain sagebrush / grass, mountain shrub, and crested wheatgrass seedings. Other, less dominant cover types include aspen woodland, mountain mahogany woodland, and wet meadow/riparian (Hironaka et al. 1983, Klott et al. 1993). Livestock grazing is the most common land use for the entire study area. The BLM manages most of the land with privately-owned ranches comprising the rest.

The nine leks currently used in this study are located on Brown's Bench south of the Three Creek road and north of the Idaho/Nevada border (Figure 9). A preliminary study of sage-grouse in this area conducted in 2005-2006 indicated that the population was non-migratory. Nevertheless, data collected in 2007 indicate that some of the birds comprising the winter population of our study area move large distances throughout the year (over 30 km) and may be migratory (Connelly et al. 2000).

Methods

Trapping and Marking

Sage-grouse are being captured using spotlighting (Wakkinen et al. 1992, Connelly et al. 2003*b*) during winter. We attempt to capture and fit birds with radio transmitters relatively early in the winter to minimize their potential association with a particular lek as the mark-resight method we will use to estimate detection probabilities relies on the assumption that samples (marked individuals) are randomly selected. A random sample will also aid in the search for new leks using radio telemetry, where selecting a sample of individuals that may have strong ties to a known lek will not likely lead to the discovery of new leks. All captured birds are classified by gender and age using wing characteristics (Dalke et al. 1963, Beck et al. 1975), and females are weighed.

In 2007, we began trapping on 18 January and continued through 15 March, at which time 32 male and 28 female sage-grouse had been captured and fitted with 16.5 g necklace-style radio transmitters (Advanced Telemetry Systems, Isanti, Minnesota). In addition to the radio, all captured birds received a numbered aluminum leg band, along with three 14 mm, colored flat-band, wrap-around style leg bands (A. C. Hughes, Middlesex, United Kingdom) in a unique combination.

Results and Discussion

We documented inter-lek movements by male sage-grouse in both years of the pilot study and both years of our formal field work. During spring 2007, we monitored 17 sage-grouse that were captured before 1 March of the year trapped (“early”), and 16 grouse that were captured after 1 March (“late”). Four of the “early” grouse left the study area during or before the breeding season and five died, while only one of the “late” grouse left the study area and none died during the breeding season. In 2008, we monitored 18 sage-grouse that were captured before 1 March of the year trapped (“early”), and 26 grouse that were captured after 1 March (“late”). One of the 18 “early” grouse left the study area while six died or slipped their radio-collars. Similarly, of the 26 “late” grouse, one left the study area while seven died or slipped their radio-collars. Five birds surviving from 2007 with live transmitters were also included for a total sample size of 34 (30 adults and four yearlings). Birds leaving the area were likely part of the Brown’s Bench winter population that includes grouse from adjacent breeding populations. Thus these birds likely attended other leks but we do not include them in our analysis of inter-lek movements. Preliminary data indicate that grouse from the Shoshone Basin (east of our study area) and northern Nevada (south of our study area) winter on Brown’s Bench. Our sampling strategy was to capture a sample of sage-grouse in late winter on sites where wintering concentrations occur. Unfortunately, there appears to be substantial mixing of demes on the Brown’s Bench area during winter making this approach more difficult and perhaps requiring radio-marking excessive numbers of males and females to produce the desired sample size of radio-marked males and females on our lek-routes. Perhaps a combined strategy in which birds radio-marked on wintering areas were augmented by additional captures near leks would be useful to assess the fraction of birds in the population that are available to be sampled near leks while still marking sufficient birds to obtain precise mark-resight and sightability models of abundance. We do not know whether or not population trajectory might affect sage-grouse lek attendance patterns. Nevertheless, relatively few yearlings in the population may result in fewer inter-lek movements.

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Table 1. Vegetation sampling of greater sage-grouse nests, Idaho, 2002-2005.

Year	Nest success (%)	Vegetation samples (*n*)		
		Nests	Near Nests	Random
2002	48	56		
2003	34	62	40	55
2004	49	46	35	45
2005	48	48	21	38
Total	45	212	96	138

Table 2. Vegetation variables measured at greater sage-grouse nests and random plots, Idaho, 2003-2005.

Mnemonic	Variable description
CCGRSPPNU	Number of grass species encountered for canopy cover measurements
CCGR[a]	Canopy cover of grass
CCGRTT[b]	Total canopy cover of grass
CCFBSPPNU	Number of forb species encountered for canopy cover measurements
CCFB[a]	Canopy cover of forbs
CCFBTT[b]	Total canopy cover of forbs
CCRO[a]	Canopy cover of bare rock
CCROTT[b]	Total canopy cover of bare rock
RBL[a]	Robel pole cover
RBLLOW[a]	Robel pole cover for 0-18 cm above ground
RBLMED[a]	Robel pole cover for 18-61 cm above ground
RBLHIGH[a]	Robel pole cover for 61-122 cm above ground
RBLGRD[a]	Robel pole cover for 0-61 cm above ground
RBLTT[b]	Total Robel pole cover
HTGRSPPNU	Number of grass species encountered for height measurements
HTDDGR[a]	Height of dead (residual) grass
HTLVGR[a]	Height of live (green and growing) grass
HTFWGR[a]	Height of flower of grass
NUFWGR[a]	Number of flower stalks of grass
EFGR[a]	Effective grass height
HTDDGRTT[b]	Total dead grass height
HTLVGRTT[b]	Total live grass height
HTFWGRTT[b]	Total height of grass flowers
NUFWGRTT[b]	Total number of grass flowers
EFGRTT[b]	Total effective grass height
HTSHSPPNU	Number of shrub species encountered for height measurements
HTSH[a]	Height of live shrub
HTFWSH[a]	Height of shrub flowers
NUFWSH[a]	Number of shrub flowers
HTFWSHTT[b]	Total height of shrub flowers
NUFWSHTT[b]	Number of shrub flowers
EFSHTT[b]	Total effective shrub height
CCSHSPPNU	Number of shrub species encountered for canopy cover measurements
CCSH01	Canopy cover of shrubs from center of plot to 1 m
CCSH13	Canopy cover of shrubs from 1-3 m from center of plot
CCSH35	Canopy cover of shrubs from 3-5 m from center of plot
CCSH510	Canopy cover of shrubs from 5-10 m from center of plot
CCSH110	Canopy cover of shrubs from 1-10 m from center of plot
CCSHTT	Total canopy cover of shrubs
CCSAGETT	Total canopy cover of sagebrush species
DENSHSPPNU	Number of shrub species encountered for density measurements
DENSH01	Density of shrubs from center of plot to 1 m

Table 2. Continued.

Mnemonic	Variable description
DENSH13	Density of shrubs from 1-3 m from center of plot
DENSH35	Density of shrubs from 3-5 m from center of plot
DENSH510	Density of shrubs from 5-10 m from center of plot
DENSH110	Density of shrubs from 1-10 m from center of plot
DENSHTT	Total density of shrubs
DENSAGETT	Total density of sagebrush species
HTNESTLV	Height of live plant immediately over nest or center of plot
TRUNKS	Number of shrub trunks in contact with nest bowl or plot center
SLOPE	Degree of slope across center of plot
ASPECT	360 degree direction of downward slope
VRT	Vertical cover over center of nest or plot
HOR	Horizontal cover of center of nest or plot 1 m from center
VRTHORTT	Total vertical and horizontal cover

[a] Variable includes three separate values, one for each distance from center of plot at 1, 3, and 5 m (e.g., CCGR1 = canopy cover of grass at 1 m from center of plot).

[b] Variable is average for entire plot for all distances from center of plot.

[c] Canopy cover, Robel pole, vertical and horizontal cover = %, height = cm, density = #/m^2, slope = degrees, aspect = 360º azimuth.

Table 3. Correlations of habitat variables significantly loading on the first three principal components for greater sage-grouse nest habitat in Idaho, 2003-2005.

	Principal Component		
Variable	I	II	III
HTSH1	0.84	0.14	-0.15
EFSH1	0.86	0.02	-0.15
HTSH3	0.80	0.34	-0.17
EFSH3	0.86	0.13	-0.16
HTSH5	0.78	0.30	-0.19
EFSH5	0.84	0.09	-0.17
HTSHTT	0.87	0.27	-0.17
EFSHTT	0.90	0.05	-0.18
RBL3	0.13	0.91	-0.08
RBLMED3	0.13	0.89	-0.12
RBLHIGH3	0.14	0.83	-0.04
RBLGRD3	0.11	0.88	-0.11
RBL5	0.21	0.89	-0.18
RBLLOW5	0.01	0.44	-0.17
RBLMED5	0.18	0.79	-0.21
RBLHIGH5	0.22	0.87	-0.13
DENSH13	-0.31	-0.21	0.72
DENSH35	-0.15	-0.11	0.94
DENSH510	-0.20	-0.14	0.92
DENSH110	-0.22	-0.15	0.93
DENSHTT	-0.20	-0.13	0.94
DENSAGETT	-0.15	-0.15	0.89
% of total variance	31	11	9
Cumulative % of variance	31	42	51

Table 4. Vegetation characteristics at greater sage-grouse nest sites and available at random, Idaho, 2003-2005.

	Nests (n = 146)		Random (n = 128)		
Variable[a]	Mean	SE	Mean	SE	P[b]
CCGRSPPNU	3.8	0.10	3.4	0.12	0.0739
CCGR1	22.7	1.24	19.6	1.27	0.0820
CCGR3	20.7	1.13	19.5	1.18	0.4519
CCGR5	21.7	1.18	19.1	1.22	0.1360
CCGRTT	21.7	1.09	19.4	1.15	0.1488
CCFBSPPNU	8.2	0.38	7.5	0.46	0.2254
CCFB1	11.6	1.03	11.1	1.05	0.7556
CCFB3	11.9	1.01	10.9	1.13	0.5060
CCFB5	12.6	1.11	10.8	0.98	0.2472
CCFBTT	12.0	0.96	10.9	0.99	0.4399
CCRO1	7.2	0.96	14.6	1.66	<0.0001
CCRO3	10.2	1.30	14.6	1.62	0.0327
CCRO5	10.9	1.37	15.6	1.68	0.0337
CCROTT	9.4	1.16	14.9	1.58	0.0050
RBL3	53.4	2.12	39.9	2.04	<0.0001
RBLLOW3	93.9	0.94	86.5	1.62	<0.0001
RBLMED3	63.5	2.36	50.6	2.86	0.0006
RBLHIGH3	34.4	2.68	18.7	2.06	<0.0001
RBLGRD3	72.4	1.84	61.1	2.36	0.0002
RBL5	65.6	1.97	53.3	2.34	<0.0001
RBLLOW5	98.4	0.42	94.1	1.17	0.0003
RBLMED5	78.9	1.95	65.4	2.84	<0.0001
RBLHIGH5	46.6	2.77	32.7	2.74	0.0005
RBLGRD5	84.6	1.46	73.8	2.23	<0.0001
HTGRSPPNU	4.2	0.12	4.1	0.14	0.4165
HTLVG1	17.4	0.57	14.0	0.52	<0.0001
EFGR1	8.8	0.46	7.5	0.46	0.0506
HTLVGR3	16.9	0.54	14.1	0.47	0.0002
EFGR3	8.6	0.42	7.8	0.43	0.2005
HTLVGR5	16.6	0.55	14.2	0.45	0.0009
EFGR5	8.5	0.41	7.8	0.45	0.2686
HTLVGRTT	17.0	0.53	14.1	0.45	<0.0001
EFGRTT	9.9	0.74	7.8	0.43	0.0194
HTSH1	43.5	1.73	38.0	2.31	0.0526
EFSH1	36.9	1.94	32.4	2.43	0.1392
HTSH3	39.8	1.36	36.8	1.86	0.1897
EFSH3	32.6	1.47	30.5	1.96	0.3931
HTSH5	40.1	1.49	36.8	1.89	0.1691
EFSH5	31.9	1.55	30.7	2.00	0.6574
HTSHTT	42.0	1.41	37.2	1.87	0.0366
EFSHTT	33.0	1.53	31.2	2.00	0.4539

Table 4. Continued.

Variable[a]	Nests (n = 146)		Random (n = 128)		
	Mean	SE	Mean	SE	P[b]
CCSHPPNU	3.7	0.12	3.5	0.12	0.2738
CCSH13	23.7	1.27	20.1	1.24	0.0415
CCSH35	23.5	1.28	21.8	1.27	0.3557
CCSH510	21.9	1.07	20.3	1.13	0.3119
CCSHTT	25.7	1.06	20.6	1.09	0.0009
CCSH110	22.6	1.06	20.6	1.10	0.1784
CCSAGETT	17.1	0.73	13.7	0.78	0.0020
DENSHSPPNU	4.1	0.14	3.9	0.14	0.4297
DENSH13	2.8	0.15	3.2	0.22	0.1437
DENSH35	3.2	0.28	3.3	0.22	0.6539
DENSH510	2.9	0.19	3.0	0.17	0.7123
DENSH110	2.9	0.19	3.1	0.19	0.5180
DENSHTT	3.0	0.20	3.1	0.19	0.7023
DENSAGETT	2.0	0.18	2.1	0.16	0.5951
SLOPE	5.0	0.48	4.2	0.44	0.3110
ASPECT	170.1	8.88	158.2	9.08	0.3531

[a] See Table 2 for descriptions of variables.
[b] Multiple comparisons protected by results of MANOVA; Wilk's Lambda = 0.403, $F = 5.50$, $P < 0.0001$.

Table 5. Radio-marked male and female greater sage-grouse captured and relocated in vicinity of leks on Brown's Bench, Idaho, which were observed during seven standard lek counts conducted from 25 March to 3 May 2005.

Demographic information	Adult males	Yearling males	Total males	Hens
Radio-tagged individuals	12	8	20	23
Radio-weeks available during lek counts	79	47	126	157
Radio-weeks available on/near leks	76	35	111	24
Number seen during lek counts	62	24	86	2
Overall attendance rate	96.2%	74.5%	88.1%	15.3%
Probability of detecting attending birds	83.8%	68.6%	78.9%	8.3%
Probability of detecting birds in population (SE)	78.5%	51.1%	68.2% (4.16%)	1.27% (0.90%)
Counts of all birds (w/ and w/o radios) at leks:				
Maximum	152	7	156	8
Mean	148.4	3.8	152.2	3.43
Projected number of birds in population:				
From maximum count			233	628
From average count			196	1,646

Table 6. Maximum number of male and female greater sage-grouse counted during three scans of birds present at five leks during seven weekly surveys of Brown's Bench Lek Route, Idaho, from 25 March to 3 May 2005.

	Maximum males counted in three scans						
Leks	Mar 25	Mar 30	Apr 1	Apr 5	Apr 15	Apr 26	May 3
TWOSEC	1	32	52	52	47	56	34
WALTS	7	3	4	23	24	29	18
SADDLE	40	18	31	42	46	50	41
LUCUS	4	0	5	9	5	8	8
TROUGH	16	0	3	8	13	13	14
Total males	68	53	95	134	135	156	115
	Maximum females counted in three scans						
Leks	Mar 25	Mar 30	Apr 1	Apr 5	Apr 15	Apr 26	May 3
TWOSEC	0	0	0	1	0	0	0
WALTS	2	0	0	1	0	0	1
SADDLE	3	1	1	0	1	4	0
LUCUS	1	0	0	0	0	0	0
TROUGH	2	0	0	0	2	1	3
Total females	8	1	1	2	3	5	4

Table 7. Top 10 models selected by AIC for predicting attendance probabilities of male sage-grouse on leks in 2006 and 2007.

Attendance probability model	AIC	Delta AIC	AIC weights	Model likelihood	Number of parameters
year.t^2	368.901	0	0.391	1.000	7
age.t^2	369.779	0.877	0.252	0.645	7
t^2	370.779	1.878	0.153	0.391	4
age+t^2	372.801	3.899	0.056	0.142	5
year+t^2	372.862	3.960	0.054	0.138	5
age.year.t^2	373.174	4.273	0.046	0.118	11
age+year+t^2	374.872	5.971	0.020	0.051	6
time	375.550	6.649	0.014	0.036	10
age+time	377.680	8.778	0.005	0.012	11
year+time	377.743	8.841	0.005	0.012	11

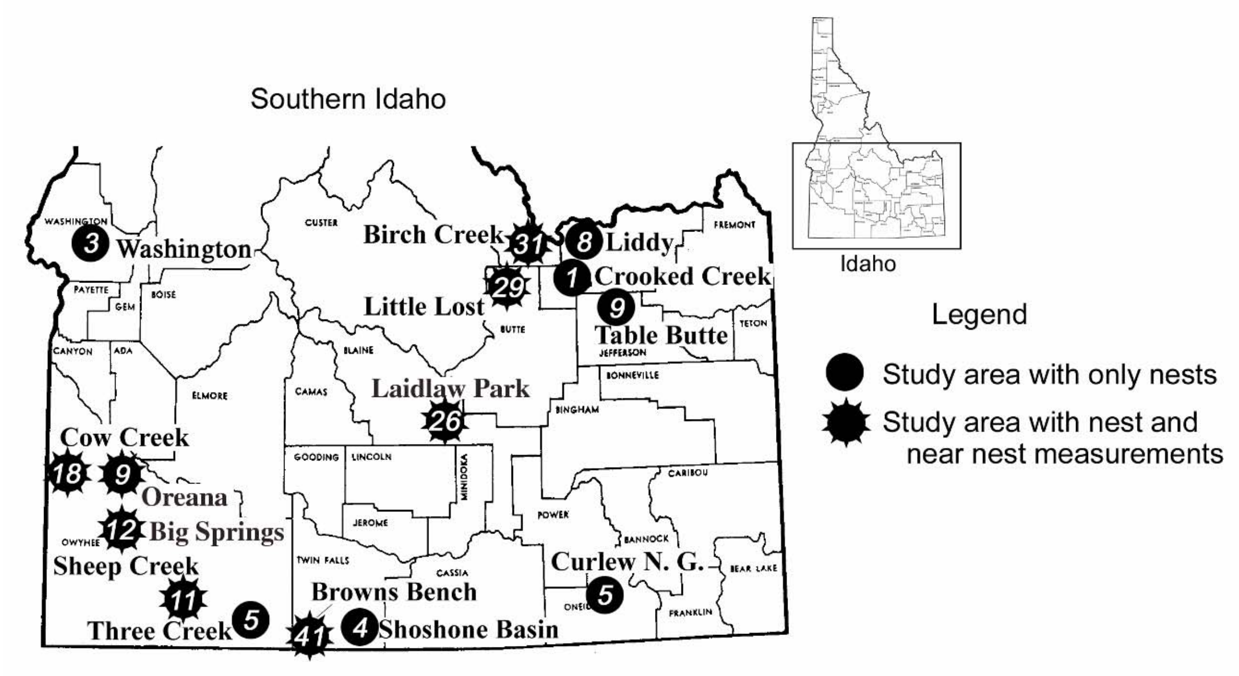

Figure 1. Study areas in southern Idaho for greater sage-grouse nesting habitat, 2002-2005. Numbers within markers are sample sizes for nests.

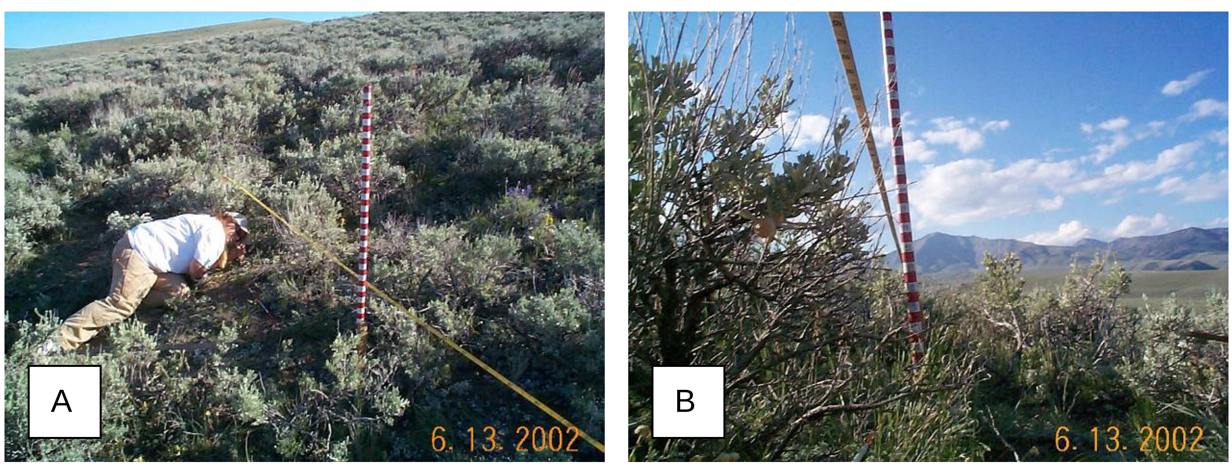

Figure 2. Measurement of horizontal cover at a greater sage-grouse nest site, Idaho. Photo A: observer is reading the Robel pole from immediately outside the nest bowl from eye level 20 cm above ground. Pole is at the 3 m distance from center of nest. Photo B: view of Robel pole measured in Photo A.

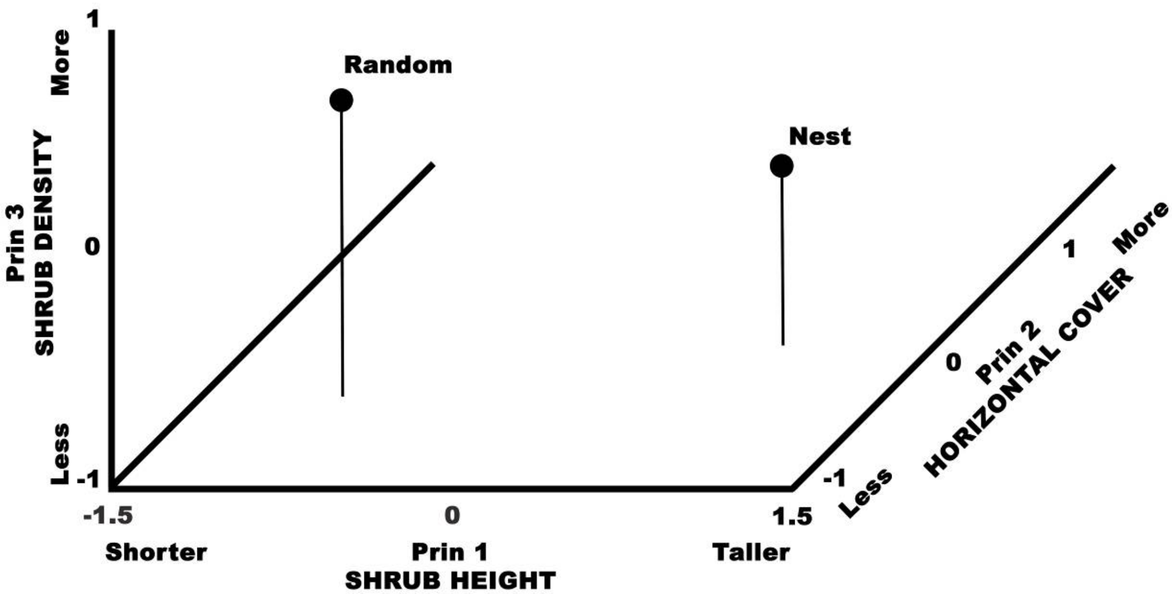

Figure 3. Habitat relationship for first three principal components between greater sage-grouse nest sites and random plots, Idaho, 2003-2005.

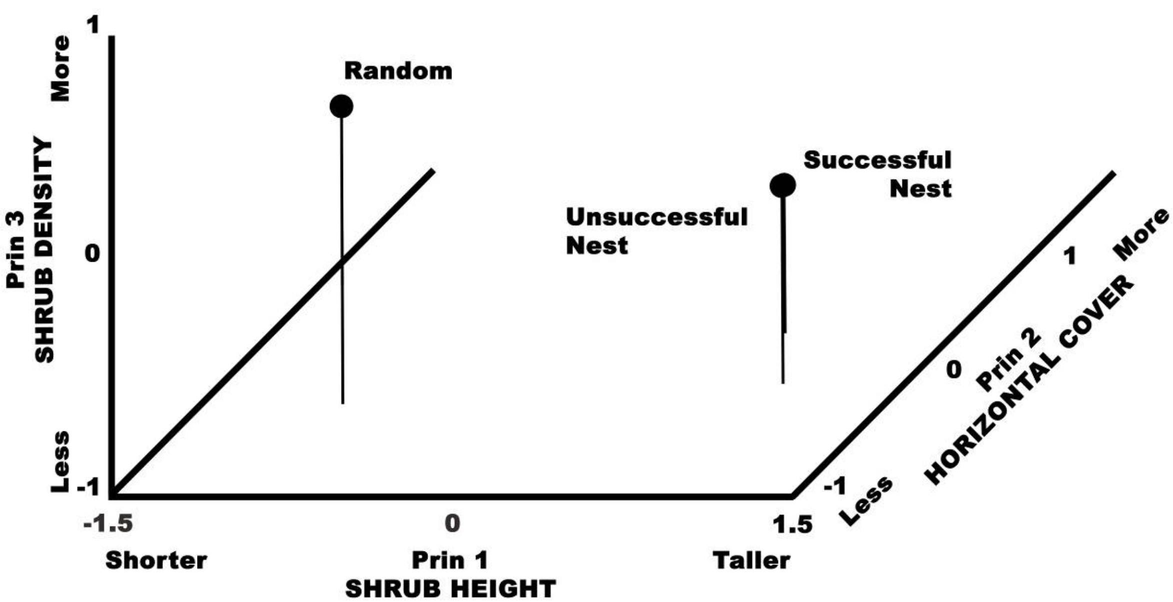

Figure 4. Habitat relationship for first three principal components among successful and unsuccessful greater sage-grouse nests and random, Idaho, 2003-2005.

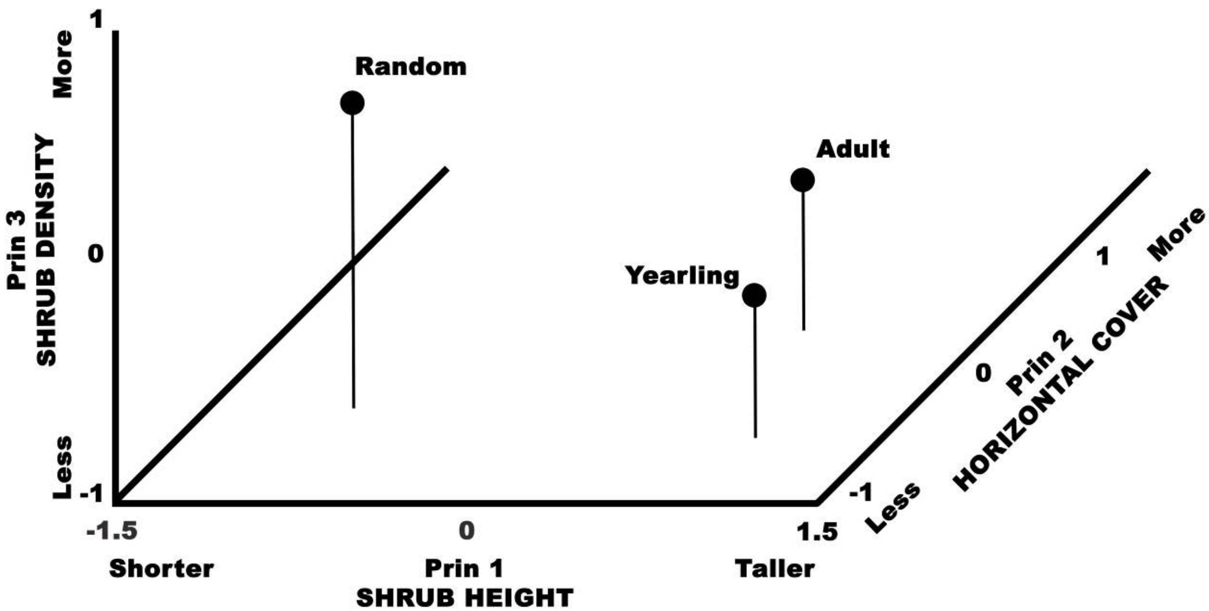

Figure 5 Habitat relationship for first three principal components among age of nesting greater sage-grouse and random plots, Idaho, 2003-2005.

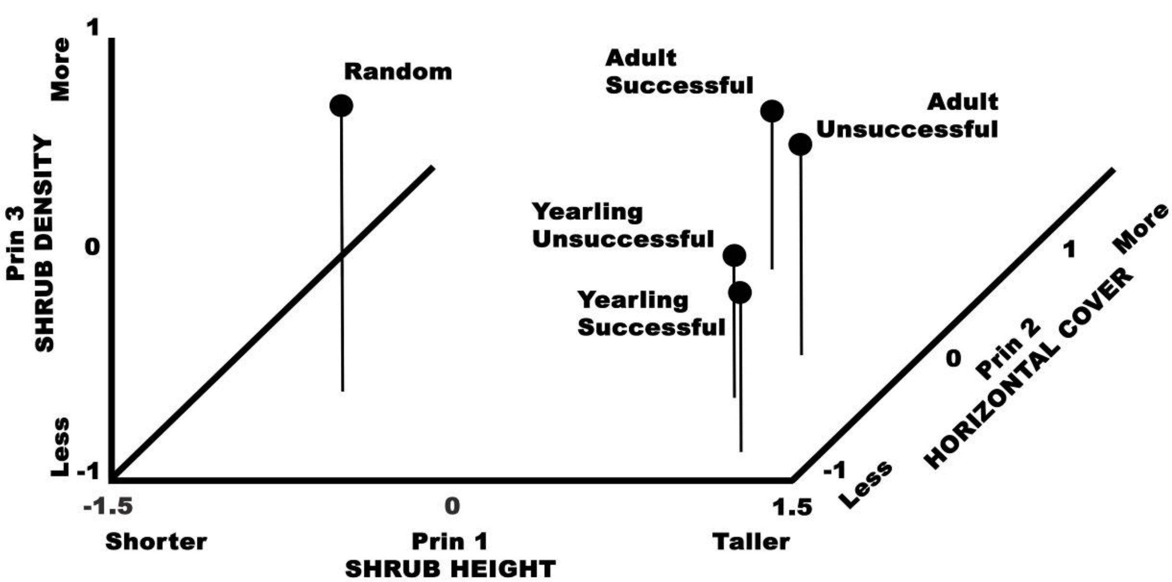

Figure 6. Habitat relationship for first three principal components among nest fates for adult and yearling greater sage-grouse nests and random plots, Idaho, 2003-2005.

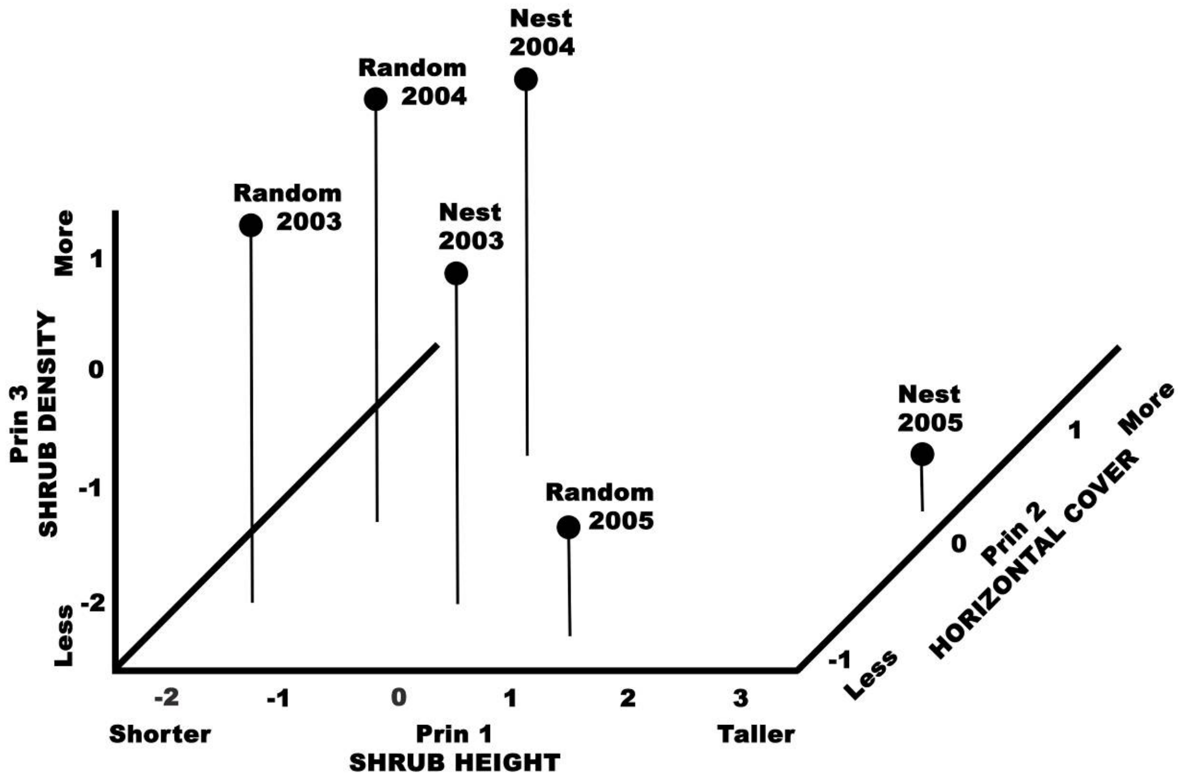

Figure 7. Habitat relationship for first three principal components among greater sage-grouse nest sites and random plots by year, Idaho, 2003-2005.

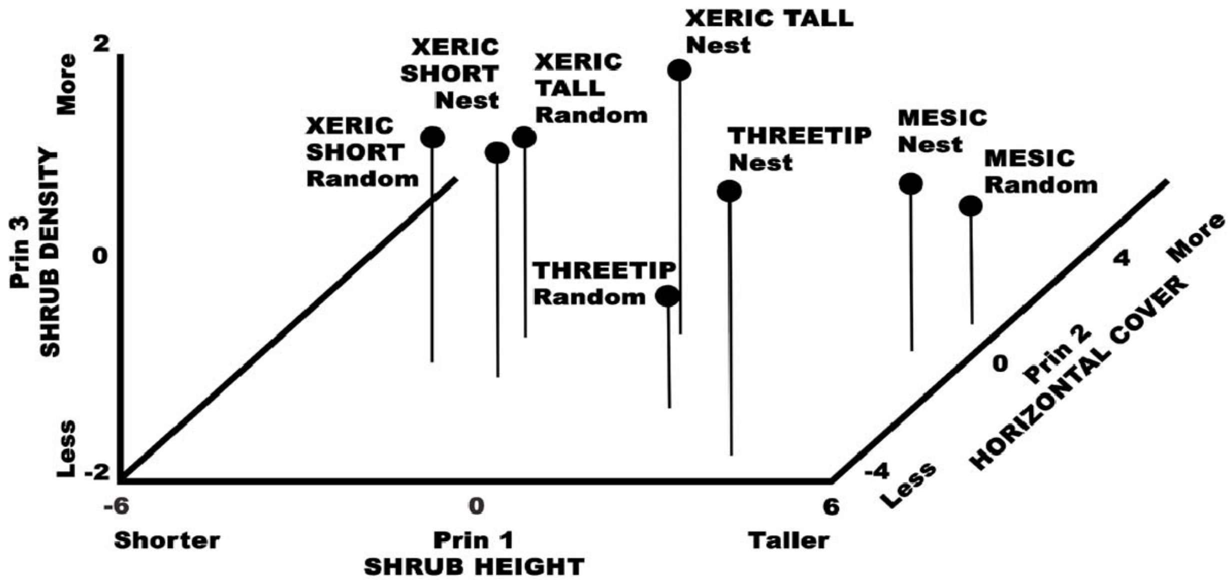

Figure 8. Habitat relationship among study area types based on moisture content and shrubs for greater sage-grouse nests and random plots on the first three principal components, Idaho, 2003-2005.

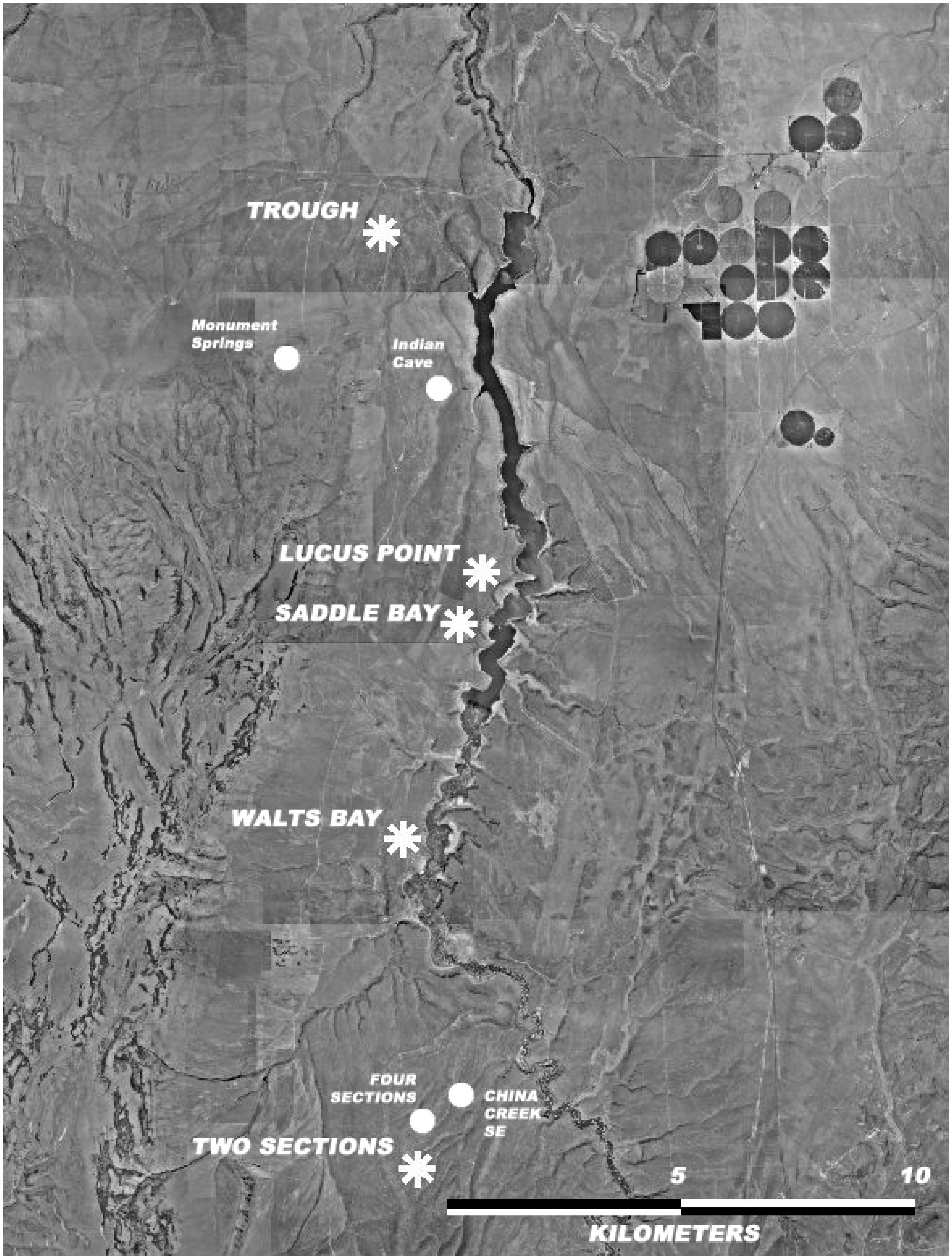

Figure 9. Brown's Bench study area with leks. Asterisks indicate leks used in lek count.

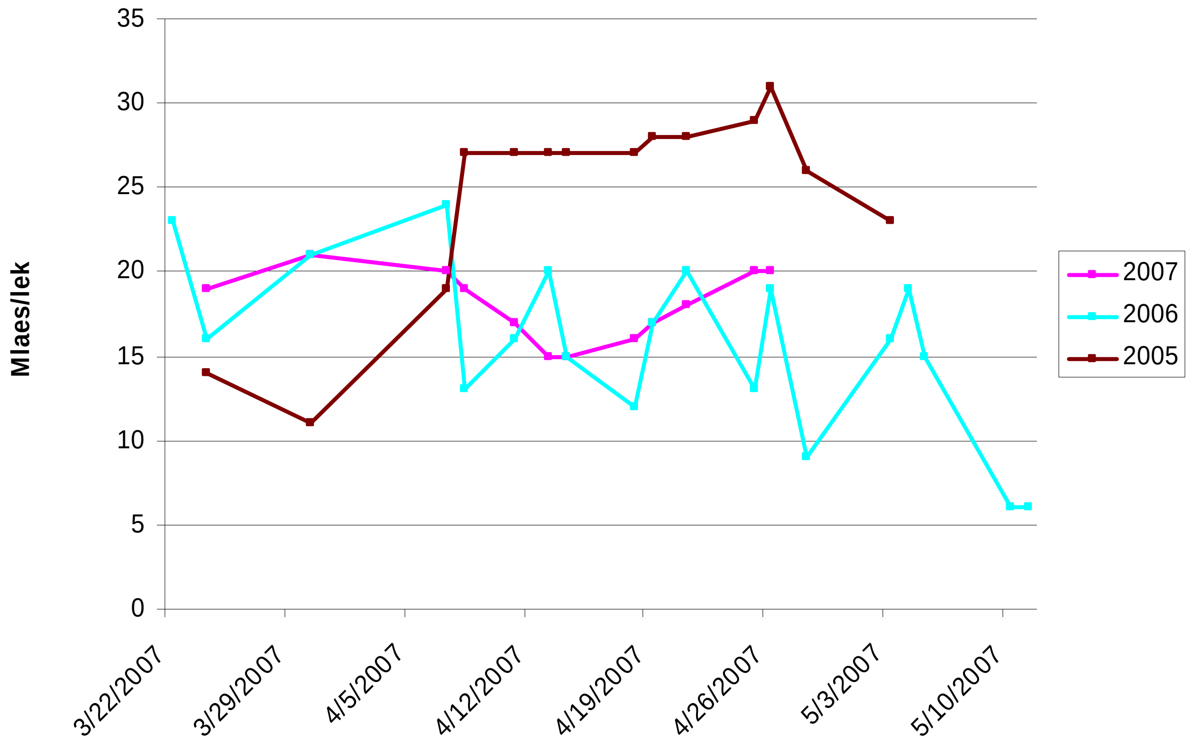

Figure10. Lek attendance patterns on Browns Bench for 2005 through 2007.

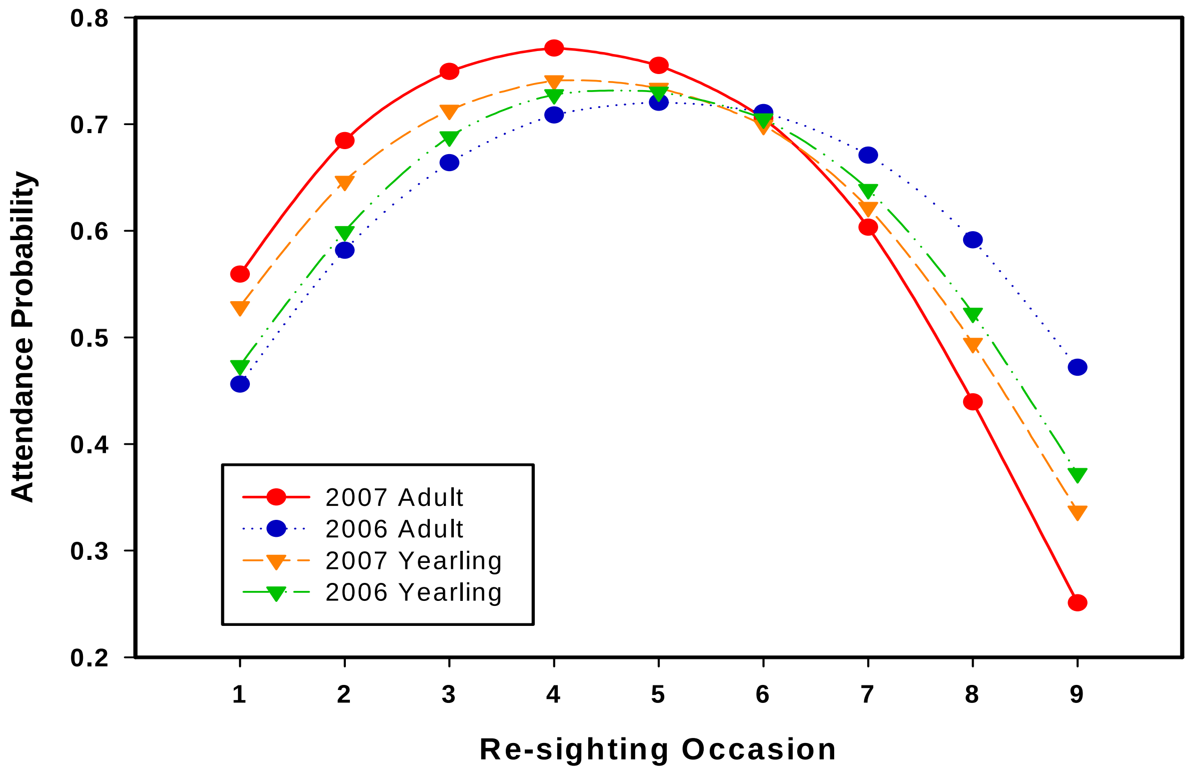

Figure 11. Predicted attendance probabilities from the models averaged based on AIC weights for adult and yearling sage-grouse in 2006 and 2007.

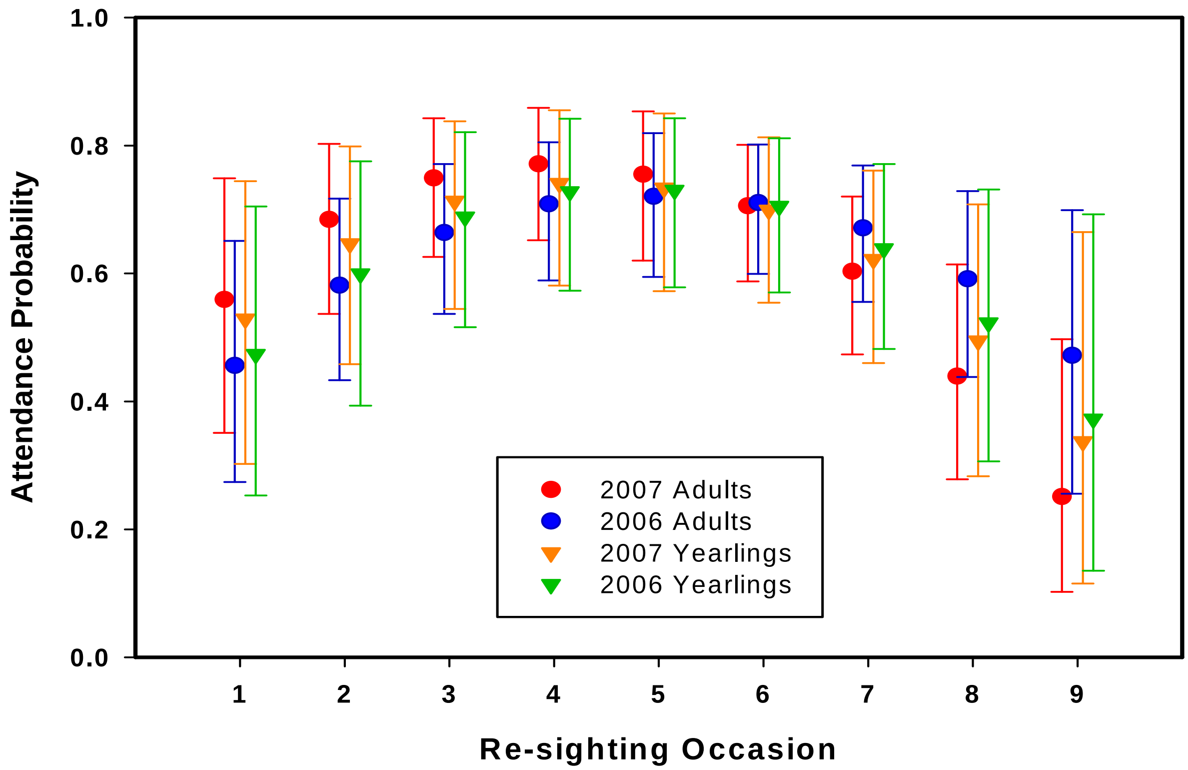

Figure 12. Predicted attendance probabilities with 95% confidence bands from the models averaged based on AIC weights for adult and yearling sage-grouse in 2006 and 2007.

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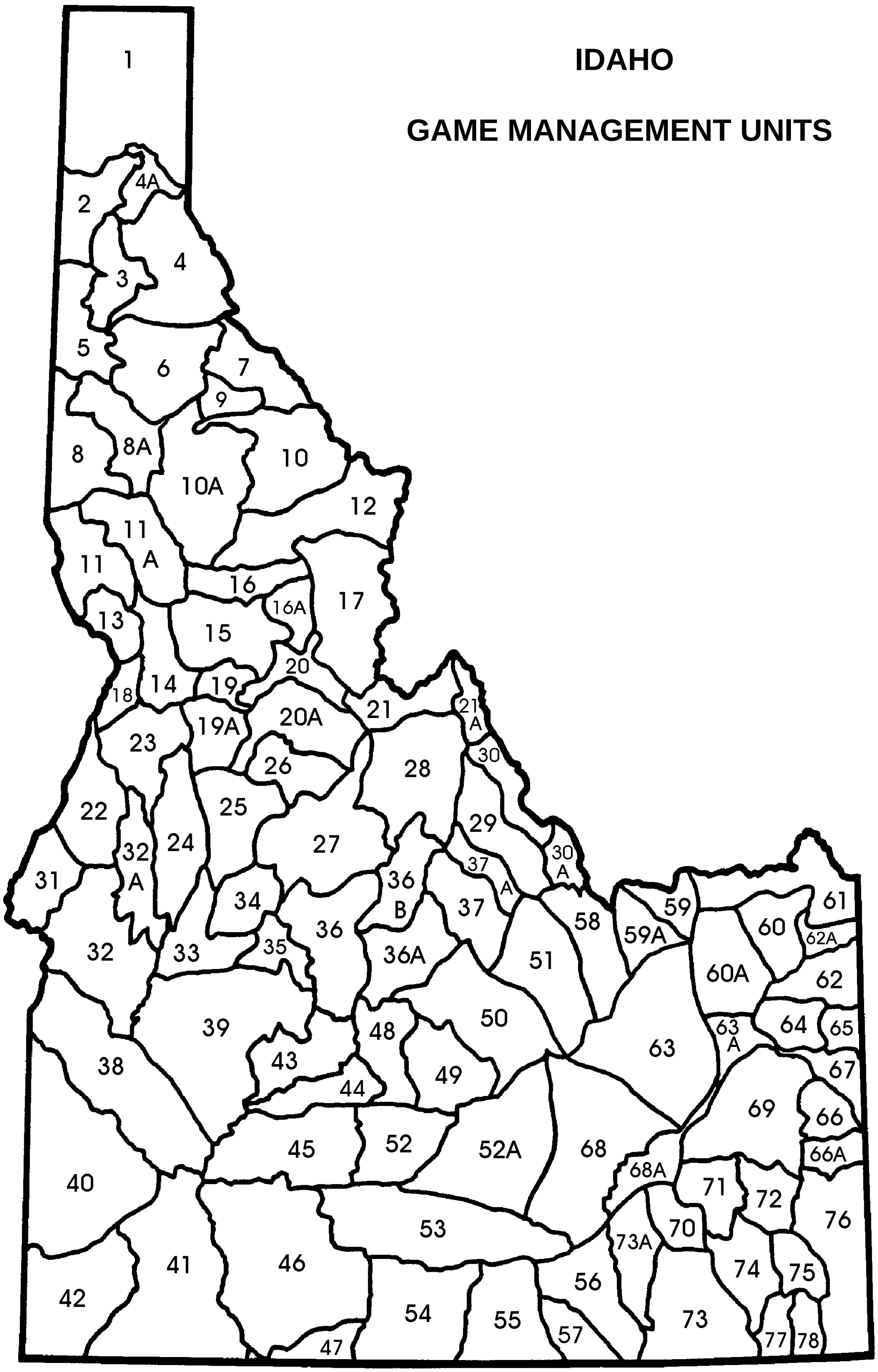
GAME MANAGEMENT UNITS



FEDERAL AID IN WILDLIFE RESTORATION

The Federal Aid in Wildlife Restoration Program consists of funds from a 10% to 11% manufacturer's excise tax collected from the sale of handguns, sporting rifles, shotguns, ammunition, and archery equipment. The Federal Aid program then allots the funds back to states through a formula based on each state's geographic area and the number of paid hunting license holders in the state. The Idaho Department of Fish and Game uses the funds to help restore, conserve, manage, and enhance wild birds and mammals for the public benefit. These funds are also used to educate hunters to develop the skills, knowledge, and attitudes necessary to be responsible, ethical hunters. Seventy-five percent of the funds for this project are from Federal Aid. The other 25% comes from license-generated funds.