2011-12-09

Seasonal Habitat Selection by Greater Sage Grouse in Strawberry Valley Utah

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Winter Habitat Selection and Nesting Ecology of Greater Sage Grouse

in Strawberry Valley, Utah

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A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of

Master of Science

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December 2011

ABSTRACT

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In Strawberry Valley, Utah

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This study examined winter habitat use and nesting ecology of greater sage grouse (*Centrocercus urophasianus)* in Strawberry Valley (SV), Utah located in the north-central part of the state. We monitored sage grouse with the aid of radio telemetry throughout the year, but specifically used information from the winter and nesting periods for this study. Our study provided evidence that sage grouse show fidelity to nesting areas in subsequent years regardless of nest success. We found only 57% of our nests located within the 3 km distance from an active lek typically used to delineate critical nesting habitat. We suggest a more conservative distance of 10 km for our study area. Whenever possible, we urge consideration of nest-area fidelity in conservation planning across the range of greater sage grouse. We also evaluated winter-habitat selection at multiple spatial scales. Sage grouse in our study area selected gradual slopes with high amounts of sagebrush exposed above the snow. We produced a map that identified suitable winter habitat for sage grouse in our study area. This map highlighted core areas that should be conserved and will provide a basis for management decisions affecting Strawberry Valley, Utah.

Keywords: *Centrocercus urophasianus*, lek, nest success, fidelity, lek-to-nest distance, nest spacing habitat map, sagebrush, scale, winter, Random Forests.

ACKNOWLEDEMENTS

I thank my advisor Dr. Randy Larsen for his help on this project. He has provided numerous editorial comments for this document. He has always supported me in every way possible. I have spent countless hours talking with him about this project as well as other interesting topics. He has motivated me to be a great researcher, recognize the “big picture”, and to always do my best. He has made working towards my M.S. educational and fun.

I also thank the other graduate committee members on my committee including Dr. Frank Howe and Dr. Steve Petersen who provided help and support with preparation of this document and in other facets of my education. I also thank Dr. Rick Baxter for all of his help out in the field as well as with all of the work that goes on behind the scenes of a great research project. He has provided editorial comments for this document as well as suggestions to improve the numerous government reports and grant proposals I drafted. I would also like to thank all of those who have helped me out in the field and with data entry—specifically Jared Baxter, Josh Kaze, Jared Oyster, Cooper MaCourtney, and David Smedley.

My family and friends have provided faith, love, and support during my work towards this master’s degree. I am very grateful for my wife Krista who has who has so patiently supported me during many days and nights away from home. She has been a help throughout this whole process and been a wonderful aid in everything I do. I thank the Utah Reclamation, Mitigation, and Conservation Commission (URMCC) for very generous financial support of this project. Finally, I thank the Utah Division of Wildlife Resources (UDWR) for their support with funding and equipment for this project.

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CHAPTER 1

NEST-AREA FIDELITY BY GREATER SAGE GROUSE IN STRAWBERRY VALLEY, UTAH

ABSTRACT

Nest-area fidelity is common among many birds including those in the orders Anseriformes, Ciconiiformes, and Procellariiformes. Fidelity to nesting areas may serve to increase fitness and reduce risks associated with nesting in new habitats. Successful nesting attempts are often associated with a higher probability that nesting adults return in a consecutive year. Conversely, unsuccessful birds are often less likely to show fidelity in subsequent years providing support for the increased fitness hypothesis. Despite substantial natural history information from across their range, the prevalence of nest-area fidelity remains unclear for greater sage grouse (*Centrocercus urophasianus*). Due to this lack of fidelity data, 3km around the lek continues to be used by management agencies to identify and conserve quality nesting habitat. Our objectives were to 1) determine if individual female sage grouse showed fidelity to nesting locations in subsequent years, 2) test whether successful females were more likely to demonstrate fidelity than unsuccessful females, and 3) examine the distance between nest sites and active leks in Strawberry Valley, Utah. We observed 30 radio-marked females that attempted a nest in consecutive nesting seasons between 2000 and 2010. The mean distance between initial year's nests and subsequent year's nests ($\bar{x}$ = 1,459 m; SE = 84.9 m) was lower ($P < 0.01$) than mean distance from initial year's nests to random nests ($\bar{x}$ = 13,263 m; SE = 227.5 m) indicating sage grouse demonstrated nest-area fidelity. We found no support ($P > 0.05$) for the hypothesis that successful females (n = 17; $\bar{x}$ = 1,355 m; SE= 142.6 m) would be more

likely to nest closer to the previous nest location than unsuccessful females (n = 13; $\bar{x}$ = 1,595 m; SE = 214.9 m). Mean distance from all nests (n = 181) to nearest active lek was 4.3 km**.** We found only 57% of our nests located within the 3 km distance from an active lek usually used to delineate critical nesting habitat. We suggest a more conservative distance of 10 km for our study area and consideration of nest-area fidelity in conservation planning.

Introduction

Nest-area fidelity is common among many birds including those in the orders Anseriformes, Ciconiiformes, and Procellariiformes (Bried *et al* 2003, Cezilly *et al* 2000, Blums *et al.* 2002). Fidelity to nesting areas may increase fitness and reduce risks associated with nesting in new habitat (Bergerud and Gratson 1988). Increased fitness can result from reduced rates of nest predation, higher fledging rates, and increased survival of nesting adults in familiar, quality nesting habitat (Greenwood and Harvey 1982). Successful nesting attempts (defined as hatching one or more chicks) are often associated with a higher probability that the nesting adult returns in a subsequent year. Conversely, unsuccessful birds are often less likely to show fidelity in subsequent years. This general relationship has been demonstrated in a variety of different birds (Greenwood and Harvey 1982).

Despite substantial natural history information for many species, nest-area fidelity studies are lacking for species in the order Galliformes. This lack of information is particularly acute for species with a lek breeding system. Lekking species typically show fidelity to their breeding grounds (Berry & Eng 1985, Dunn & Braun1985, Fischer et al.1993), but little is known about fidelity to nesting areas. This lack of information may be attributed to the belief that the lek is the center of all nesting habitat and fidelity to the lek meant fidelity to nesting areas (Braun et al.

1977). Wakinen et al. (1992) challenged this paradigm with data suggesting that nests were distributed randomly with respect to leks for greater sage-grouse (*Centrocercus urophasianus* – hereafter referred to as sage grouse).

Sage grouse are a lekking species that occurr in western North America. They have experienced dramatic declines throughout much of their historic range over the past 50 years (Connelly and Braun 1997, Braun 1998). As a result of this decline and persistent threats to this species, the U.S. Fish and Wildlife Service determined that listing sage grouse as threatened or endangered under the 1973 Endangered Species Act was warranted, but precluded by higher priority items (U.S. Department of Interior 2010). While many interrelated factors have contributed to the decline and listing of sage grouse, reductions in habitat quantity and quality are largely responsible and one of the few factors that can be consistently managed (Connelly et al. 1991, Gregg et al. 1994, DeLong et al. 1995, Sveum et al. 1998 Crawford et al. 2004).

Sage-grouse are closely associated with sagebrush (*Artemisia* spp.) plant communities. They use sagebrush for food and cover throughout their life cycle (Patterson 1952, Braun et al. 1977, Braun 1987, Eng and Schladweiler 1972, Beck 1975, Beck 1977, Robertson 1991). Sage-grouse require a variety of sagebrush densities and heights for breeding, nesting, brood-rearing, and wintering habitat (Crawford et al. 2004). The quantity and quality of these sagebrush habitats has declined over the last fifty years (Braun et al. 1976, Braun 1997, Connelly and Braun 1997). Currently, large amounts of native range are either unsuitable or of marginal value to sage grouse. Proper management and conservation of remaining habitats is essential to ensure long-term conservation of sage grouse and prevent any further range-wide declines (Braun 1998).

Long-term conservation of sage grouse, however, is challenging because of the large space requirements of this species. Space-use estimates for individual sage grouse vary by season, but have been reported from 11 to 31 km^2 in winter (Wallestad 1975) and 3 to 7 km^2 during summer (Connelly and Markham 1983, Gates 1983). Although sage grouse utilize large home ranges, fidelity to certain areas including winter, summer and lekking areas has been documented (Dunn and Braun 1985, Rolstad and Wegge 1988, Berry 1985, Svedarsky 1988, Shroeder and Robb 2003). Strong site fidelity may become increasingly important for small populations in places where prime sage grouse habitat is fragmented. While range-wide management is ideal, focus on high-use areas critical for completion of important life history events (e.g. nesting, lekking, brood rearing) will provide the greatest benefits and reduce excessive management costs.

To guide conservation and management efforts, the Western States Sage Grouse Committee (Braun et al. 1977) and others (Connelly et al. 2000) established recommendations for vegetation manipulation in sage grouse habitat. The Western States Sage Grouse Committee specifically addressed protection of nesting habitat by assuming that the area within 3 km of a lek was important for nesting and should include dense stands of sagebrush. This guideline was based on research suggesting the majority (59-87%) of sage grouse nest within this distance of an active lek (Braun et al. 1977). This idea was challenged, however, by Wakinen et al. (1992) who reported that nests were distributed randomly with respect to leks and that grouse did not select habitats around leks for nesting.

Given this uncertainty and the current emphasis on habitat management, it is important that we understand more about nesting ecology and nest-area fidelity of sage grouse. Nest-area fidelity studies for sage grouse are lacking and proper management of sagebrush habitats for sage grouse would benefit from increased understanding of the relationship between nests and leks. Twelve years of telemetry-based research in Strawberry Valley, Utah afforded us an opportunity to examine nesting ecology of sage grouse in greater detail. Our specific objectives were to 1) determine if individual sage grouse showed nest-area fidelity in subsequent years, 2) test whether successful females were more likely to demonstrate fidelity than unsuccessful females, and 3) examine the spatial relationship between nests and location of active leks. We predicted that successful females would be more likely to show nest-area fidelity than unsuccessful females.

Study Area

We investigated nesting ecology and nest-area fidelity of sage grouse in Strawberry Valley, Utah (Figure 1) located in the north-central part of the state (coordinates near center of valley NAD 83 Zone 12T; UTM 0492078/4445216). Strawberry Valley is approximately 24 km long and 9 km wide. It is characterized by mountain ridges and high mountain meadows, with elevations ranging from 2,250 to 2,600 m. The valley experiences cool dry summers and cold wet winters. Average annual precipitation was 79 cm (NRCS 2000). Strawberry Reservoir is the most dominant feature of the valley, covering 6,950 ha of historically occupied riparian and sagebrush steppe habitat. Over 9,000 ha of sagebrush habitat currently exists within SV. This habitat was characterized as montane sagebrush steppe, with mountain big sagebrush (*Artemesia tridentata vaseyana*) and silver sagebrush (*A. cana*) predominant shrubs A more detailed description of our study area is available in Baxter et al. (2008) or Bunnell et al. (2000).

Methods

We captured grouse during spring (late March and April) and fall (September – November) by netting them from pickup trucks and all-terrain vehicles during 1998–2010. We began 2 h after sunset (2100 to 0200 hours) implementing a modified spotlight method (Wakkinen et al. 1992). We fitted each captured female with a 22 g necklace-style radio transmitter (Advanced Telemetry Systems, Inc., Isanti, MN; 19-hr duty cycle, 45 pulses/min, with mortality after 8 hr and max battery life of 30 months) prior to release at the capture location. We tracked radio-marked sage grouse weekly from the ground with a 4-element Yagi antenna and either a TR2 (Telonics Inc., Mesa, AZ) or R-1000 radio receiver (Communication Specialists Inc., Orange, CA). In addition to monitoring from the ground, we periodically used a fixed-wing aircraft to locate radio-marked birds ($\bar{x}$ = 8 flights per year).

We identified nest locations by homing radio-marked birds until we made visual confirmation. We recorded all coordinate locations in UTM NAD 83 using a Garmin global positioning systems (GPS). We then determined nest fate after a female completed her nesting attempt by examining egg membrane condition and/or visual documentation of a female with brood. We assumed that if an egg membrane separated from the shell, a chick had hatched successfully (Klebenow 1969). We considered a nesting attempt successful when ≥ 1of the eggs hatched.

To evaluate the spatial relationship between nests and active leks, we measured the distance between all nests and the closest active lek with ArcGIS (version 9.3, ESRI, Redlands, CA). We identified active leks using historical information coupled with both ground and helicopter surveys. To avoid problems with pseudo replication, we only used distances between the first nest and nearest active lek from the birds for which we had subsequent year nesting data (Magaña et al. 2011).

To test the hypothesis that successful females would demonstrate greater nest-area fidelity, we calculated the distance between an initial nesting attempt in one year and the subsequent nesting attempt in the following year for all grouse that nested in sequential years. We then used a 95% kernel density estimate around all known nests and generated a polygon within which we created random nesting locations. Finally, we measured the distance between each initial year's nest and the closest random nest for comparison.

We divided our data into successful, unsuccessful, and random groups. Initial evaluation suggested that distances were not normally distributed and variance not equal between groups. Consequently, we used a Kruskal Wallis non-parametric test to determine if differences existed between groups (Whitlock and Schluter 2009). Following a significant result with this analysis, we used the non-parameteric rank sum test (Whitlock and Schluter 2009) for pairwise comparisons (successful initial year's nest to subsequent year's nest, unsuccessful initial year's nest to subsequent year's nest, and initial year's nest to random nest). We used the Bonferroni correction to adjust P-values for these multiple tests (Dunn 1961). We used version 2.7 of program R to conduct all statistical analyses (R Development Core Team 2009).

Results

We documented 181 nests over the 12 year study period (1998-2010). Of these, 30 constituted a subsequent year's nesting attempt. Distance between all initial year nests and subsequent-year nests averaged 1,459 m (range 57 to 9,560 m). After removing three outliers (distance > 5,000 m), mean distance dropped to 882 m (range 57 to 1,916 m). Mean distance from initial year's nest to closest random nest was 13,263 m (range 614 to 26,047 m). Mean distance between initial year's nests and subsequent year's nests was lower ($P < 0.01$) than mean distance from initial year's nests to random nests (Figure 2) indicating nest-area fidelity. We found no support, however, for our hypothesis that successful females would demonstrate higher nest-area fidelity than unsuccessful females as mean distances between initial and subsequent year's nests were not different (*P* > 0.9). Successful females (n = 17) averaged 1,355 m with a median of 367 m, (range 57 to 5,066 m) compared to unsuccessful females (n = 13) with mean distance = 1,595 m and a median of 345 m (range 78 to 9,560 m). Mean distance between all nests (n = 181) and nearest active lek was 4.3 km with a median of 2.6 km (range .11 to 14 km). We found only 57% of our nests located within 3 km of the nearest active lek. A plot of each nest's distance to the nearest active lek showed two distinct break points as 64% of nests occurred within 4 km and 95% within 10 km (Figure 3).

Discussion

Sage grouse in Strawberry Valley demonstrated fidelity to nesting areas in subsequent years. Mean distance between the initial year's nest and subsequent year's nest was small (882 m after removal of 3 outliers) compared to both seasonal and annual space-use patterns of this species which can be as large as 31 km^2 (Wallestad 1975, Connelly and Markham 1983, Gates 1983, Robertson 1991, Leonard et al. 2000). Fisher et al. (1993) argued that strength of fidelity should be measured by the distance between consecutive nests relative to the size of a species' annual range. Using this argument, our data suggest sage grouse in our area showed strong fidelity to nesting areas.

We found no support for our hypothesis that successful females would be more likely to return to the same nesting area than unsuccessful females. Although successful hens did have a smaller average distance between consecutive nests (successful females = 1,355 m, unsuccessful females = 1,595 m) confidence intervals showed large overlap and formal tests for a difference were not significant. Fisher et al. (1993) believed that nest fate did not influence the distance moved between consecutive nests; instead, they suggested that nest selection reflected a strategy to avoid previous nests, regardless of their fate, and areas predators may be more likely to search.

By moving subsequent year nests 500-1000m sage grouse may balance risk from predators focusing on immediate areas around previous nests and benefits of nesting in quality habitat. Predators of willow ptarmigan (*Lagopus lagopus*) nests, for example, concentrated searches in areas where they previously found nests (O'Reilly and Hannon 1989), which would support the argument of Fisher et al. (1993) if this behavior persisted. While fidelity appears evident, something other than nest success influenced sage-grouse nest-area fidelity in Strawberry Valley.

Another hypothesis for selection of nesting areas in successive years suggests that both habitat type and habitat disturbance influence choice. Storaas and Wegge's (1987) study on nesting Capercaillie (*Tetrao urogallus*) found that four out of five successful females, and eight out of 14 unsuccessful birds changed habitat types in consecutive years. Similarly, Connelly et al. (1991) argued that sage grouse may minimize risks of nesting in unsuitable areas by showing some flexibility for selection of nesting habitat. Fidelity to an area with quality nesting habitat without returning to the exact nesting location may be a demonstration of limited flexibility. Nonetheless, continued research will be required in order to more fully understand the mechanisms behind nest-area fidelity.

For managers, knowledge of nest-area fidelity may be beneficial in identification and conservation of critical nesting areas. We recognize that this information requires multiple years of reliable telemetry data and that such information may not always be available. In these areas, it may benefit sage grouse to increase the commonly used 3 km buffer around leks to protect nesting habitat. In our study only 57% of all nests were located within this buffer. These results are similar to Wakkinen et al. (1992) who reported only 55% of nests within 3 km of active leks. They argued that sage grouse do not select nest sites based on distances from leks and that leks were not part of an actual "breeding complex" that included surrounding nesting areas. This result coupled with our results suggests a more conservative approach is warranted because only 57% of our nests would have received protection using the common 3 km guideline. For our study area, a distance of 4 km encompassed 64 percent of nests whereas a distance of 10 km covered 95 %. While a 3 km buffer around leks would have encompassed more than half of our nests, given the current status of sage grouse, we suggest a conservative approach with larger distances around active leks in order to help conserve sage grouse populations.

Management Implications

Our lek-to-nest distance data challenged the commonly accepted practice of designating the area 3 km within an active lek as critical nesting habitat (Braun et al. 1977). Where appropriate data is available, we suggest that nest-area fidelity be used to define which areas merit protection and management. Identification of these areas may help limit unnecessary disturbances during critical nesting periods and ensure proper nesting habitat guidelines are met. In areas where fidelity data are not available, an increased buffer size (up to 10 km) should be considered. Increasing the buffer size will ensure protection of a higher percentage of sage grouse nests.

LITERATURE CITED

Baxter, R.J., J.T. Flinders, and D.L. Mitchell. 2008. Survival, movements, and reproduction of translocated greater sage-grouse in Strawberry Valley, Utah. Journal of Wildlife Management 72:179-186.

Beck, T.D.I. 1975. Attributes of a wintering population of sage grouse, North Park, Colorado. Thesis, Colorado State University, Fort Collins, Colorado, USA.

Beck, T.D.I. 1977. Sage grouse flock characteristics and habitat selection in winter. Journal of Wildlife Management 41:18-26.

Bergerud, A.T. and M.W. Gratson. 1988. *Adaptive strategies and population ecology of northern grouse*, . University of Minnesota Press, Minneapolis, Minnesota, USA.

Berry, J.D. and R.L. Eng. 1985. Interseasonal movements and fidelity to seasonal use areas by female sage grouse. Journal of Wildlife Management 49:237- 240.

Blums, P., J.D. Nichols, and J.E. Hines. 2002. Sources of variation in survival and breeding site fidelity in three species of European ducks. Journal of Animal Ecology 71:438–450.

BRAUN, C. E. 1998. Sage grouse declines in western North America: what are the problems? Proceedings of the Western Association of State Fish and Wildlife Agencies 78: 139-156

Braun, C.E., T. Britt, and R.O. Wallstead. 1977. Guidelines for maintenance of sage grouse habitats. Wildlife Society Bulletin 5:99-106.

Braun, C.E., M.F. Baker, R.L Eng, J.W. Gashwiler, and M.H. Schroeder. 1976. Conservation committee report on effects of alteration of sagebrush communities on the associated avifauna. Wilson Bulletin 88:165-177.

Braun, C.E. 1987. Current issues in sage grouse management. Proceedings of the Western Association of State Fish and Wildlife Agencies 67:134-144.

Braun, C.E. 1998. Sage grouse declines in western North America: what are the problems?

Proceedings of the Western Association of State Fish and Wildlife Agencies 78:139–156.

Bried, J., D. Pontier, and P. Jouventin. 2003. Mate fidelity in monogamous birds: a re-examination of the Procellariiformes. Animal Behavior. 65:235–246.

Bunnell, K.D., J.T. Flinders, D.L. Mitchell, and J.H. Warder. 2004. Occupied and unoccupied sage grouse habitat in Strawberry Valley, Utah. Journal of Range Management 57:524–531.

Connelly, J. W. and O. D. Markham. 1983. Movements and radionuclide concentrations of sage grouse in southeastern Idaho. Journal of Wildlife Management 47:169-177.

Connelly, J.W., W.L Wakkinen, A.D. Apa, and K.P. Reese. 1991. Sage grouse use of nest sites in southeastern Idaho. Journal of Wildlife Management 55:521-524.

Connelly, J.W. and C.E. Braun. 1997. Long-term changes in sage grouse (*Centrocercus urophasianus*) populations in western North America. Wildlife. Biology 3:229–234.

Connelly, J.W., M.A. Schroeder, A.R. Sands, and C.E. Braun. 2000. Guidelines to manage sage grouse populations and their habitats. Wildlife Society Bulletin 28:967-985.

Cezilly, F., F. Dubois, and M. Pagel. 2000. Is mate fidelity related to site fidelity? A comparative analysis in Ciconiiforms. Animal Behavior. 59:1143–1152.

Crawford, J.A., R.A. Olson, N.E. West, J.C. Mosley, M.A. Schroeder, T.D. Whitson, R.F. Miller, M.A. Gregg, and C.S. Boyd. 2004. Synthesis paper: ecology and management of sage-grouse and sage-grouse habitat. Journal of Range Management 57:2-19.

Delong, A.K., J.A. Crawford, and D.C. Delong Jr. 1995. Relationships between vegetational structure and predation of artificial sage grouse nests. Journal of Wildlife Management 59:88-92.

Dunn, O.J. 1961. Multiple comparisons among means. Journal of the American Statistical

Association. 56:52-64.

Dunn, P.O. and C.E. Braun. 1985. Natal dispersal and lek fidelity of sage grouse. Auk 102:621-627.

Fischer, R.A., A.D. Apa, W.L. Wakkinen, K.P. Reese, and J.W. Connelly. 1993. Nesting-area fidelity of sage grouse in southeastern Idaho. Condor 95:1038-1041.

Eng, R.L. and P. Schladweiler. 1972. Sage grouse winter movements and habitat use in central Montana. Journal of Wildlife Management 36:141-146.

Gates R.J. 1983. Sage grouse, lagomorph, and pronghorn use of a sagebrush grassland burn site on the Idaho National Engineering Laboratory. Thesis, Montana State University, Bozeman, Montana, USA.

Greenwood, P.J. and P.H. Harvey. 1982. The natal and breeding dispersal of birds. Annual Review of Ecology, Evolution, and Systematics. 13:1-21**.**

Gregg, M.A., J.A. Crawford, M.S. Drut, and A.K. Delong. 1994. Vegetational cover and predation of sage grouse nests in Oregon. Journal of Wildlife Management 58:162-166.

Klebenow, D.A. 1969. Sage grouse nesting and brood habitat in Idaho. Journal of Wildlife Management 33:649-661.

Leonard, K.M., K.P. Reese, and J.W. Connelly. 2000. Distribution, movements, and habitats of sage grouse Centrocercus urophasianus on the Upper Snake River Plain of Idaho: changes from the 1950's to the 1990's. Wildlife Biology 6:265- 270.

Magaña, M., J.C. Alonso, J.A. Alonso, C.A. Martín, B. Martín, and P. Palacín. 2011. Great Bustard (Otis tarda) nest locations in relation to leks. Journal of Ornithology 152:541–548.

NRCS. 2000. http://www.wcc.nrcs.usda.gov, accessed September 14, 2011.

O'reilly, P. and S.J. Hannon. 1989. Predation of simulated willow ptarmigan nests: the influence of density and cover on spatial and temporal patterns of predation. Canadian Journal of Zoology 67:1263-1267.

Patterson, R.L. 1952. The sage grouse in Wyoming. Sage Books, Denver, Colorado, USA.

R Development Core Team (2009). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Robertson, M.D. 1991. Winter ecology of migratory sage grouse and associated effects of prescribed fire in southeastern Idaho. Thesis, University of Idaho, Moscow, Idaho, USA.

Rolstad J. and P. Wegge. 1988. Spacing and habitat use of Capercaillie during summer. Canadian Journal of Zoology 66:65-68.

Schroeder, M.A. and L.A. Robb. 2003. Fidelity of greater sage-grouse Centrocercus urophasianus to breeding areas in a fragmented landscape. Wildlife Biology 9:291-299.

Storaas, T. and P. Wegge. 1987. Nesting habitats and nest predation in sympatric populations of capercaillie and black grouse. Journal Wildlife Management 51:167-172.

Svedarsky, W.D. 1988. *Reproductive ecology of female greater prairie-chickens in Minnesota, Ecology of Northern Grouse* p. 473-577, University of Minnesota Press, Minneapolis, Minnesota, USA.

Sveum, C., M.W.D. Edge, and J.A. Crawford. 1998. Nesting habitat selection by sage grouse in south-central Washington. Journal of Range Management 51:265-269.

U.S. Department of the Interior, Fish and Wildlife Service. 2010. Endangered and threatened wildlife and plants; 12-month finding for petitions to list the greater sage-grouse as threatened or endangered; proposed rule. Federal Register 73.

Wakkinen, W.L., K.P. Reese, and J.W. Connelly. 1992. Sage Grouse nest locations in relation to leks. Journal of Wildlife Management 56:379-381.

Wallestad, R.O. 1975. Male sage grouse responses to sagebrush treatment. Journal of Wildlife Management 39:482-484.

Whitlock, M.C. and D. Schluter. 2009. *The Analysis of Biological Data*. Roberts and Company, Greenwood Village, Colorado, USA.

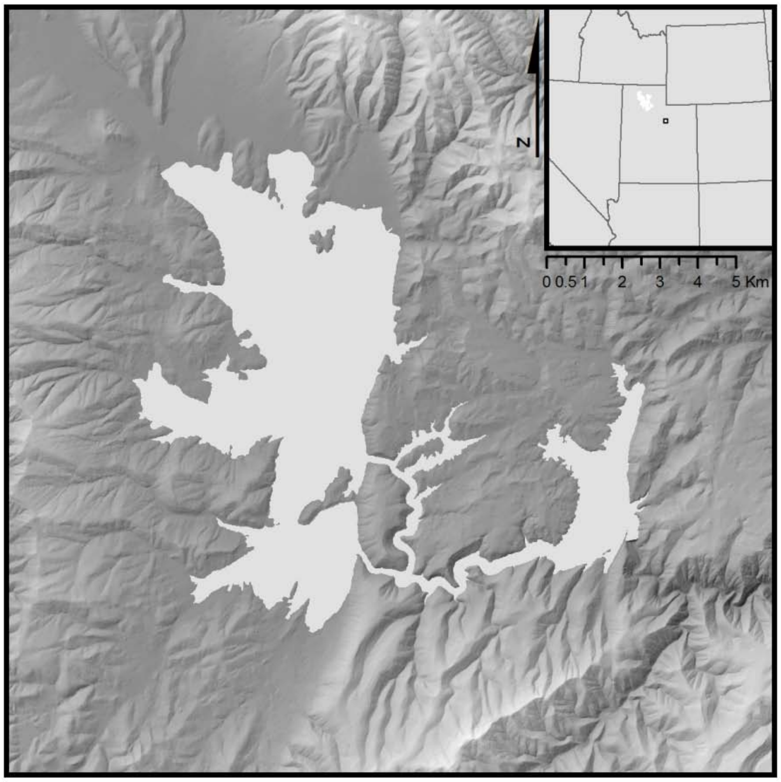

Figure 1. Strawberry Valley study area in north-central Utah where we identified greater sage grouse nests, 1998 – 2010.

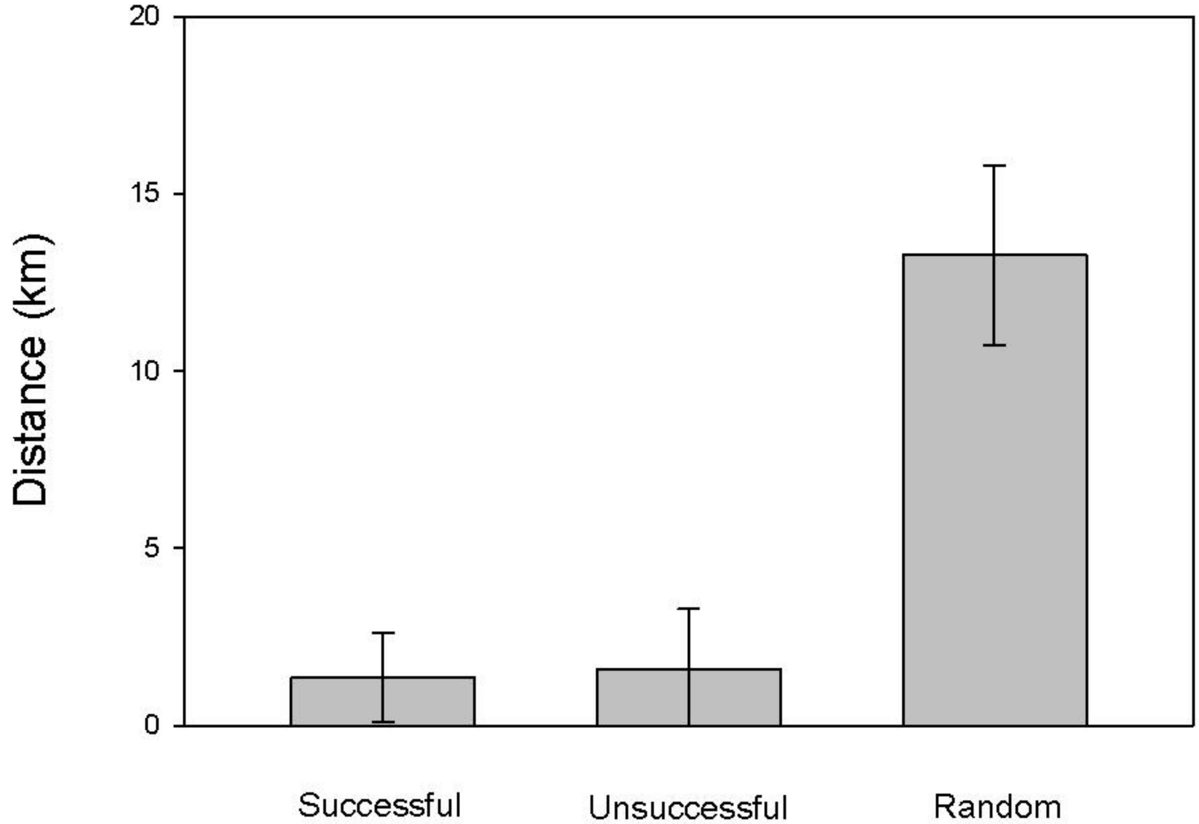

Figure 2. Mean distance (95% CIs) between initial-year nests and subsequent-year nests for successful and unsuccessful female sage grouse in Strawberry Valley, Utah (1998-2010) along with mean distance from these nests to random nest sites.

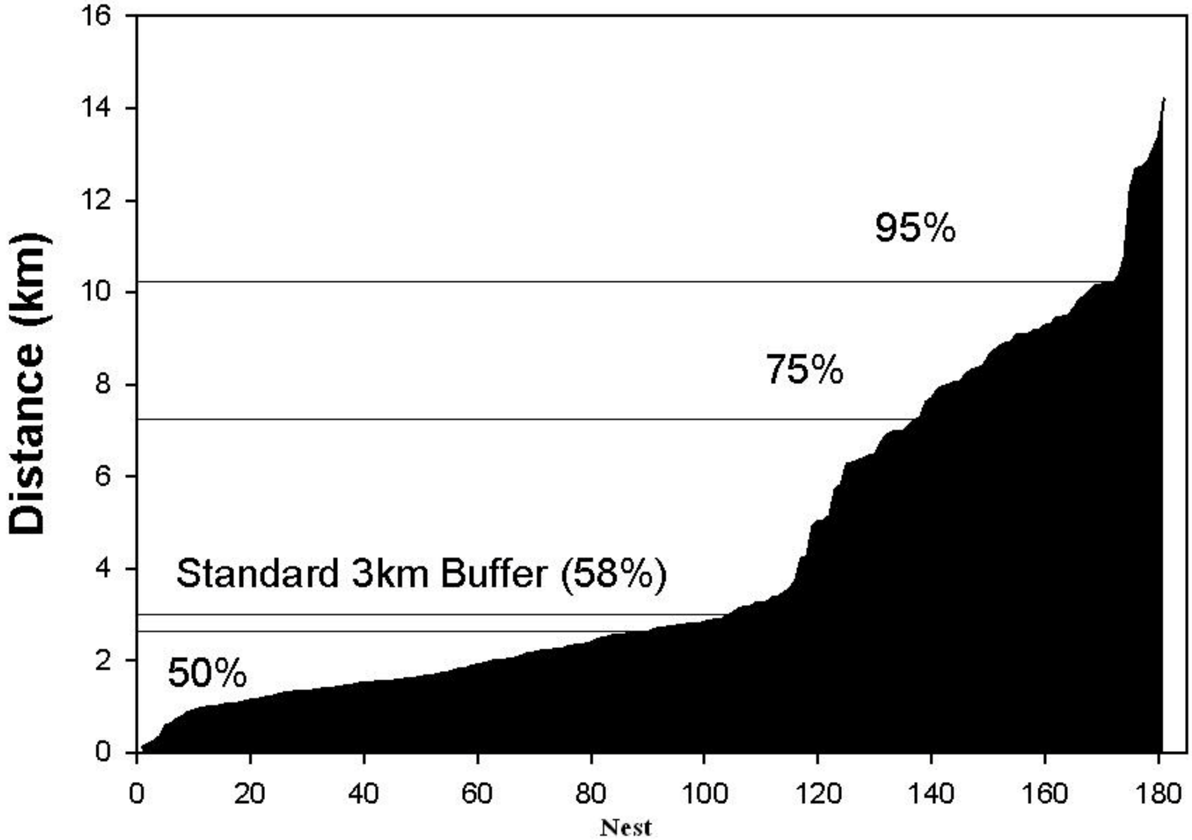

Figure 3. Histogram showing distances from greater sage grouse nests in Strawberry Valley, Utah to nearest active lek, 1998-2010.

CHAPTER 2
WINTER HABITAT SELECTION BY GREATER SAGE GROUSE IN CENTRAL UTAH: A MULTI-SCALED APPROACH

ABSTRACT

Greater sage grouse have responded to the loss, fragmentation, and degradation of sagebrush habitats with dramatic declines throughout much of their historic range. In response to this decline, numerous research studies have been conducted across the species range. Recently, the view that winter is a period of low mortality for sage grouse has been challenged with evidence that prolonged periods of low temperature combined with deep snow can negatively influence survival rates. This research has highlighted the need to understand more about winter habitat selection for populations exposed to deep snow and cold temperatures. Our objectives were to: 1) assess winter habitat selection by greater sage grouse at multiple spatial scales in a high-mountain valley of central Utah, 2) compare winter habitat selection before and after successful augmentation of this sage grouse population, and 3) develop a predictive habitat model that identifies winter habitat in our study area. We radio-marked and monitored greater sage grouse during winter months from 1998-2010 in Strawberry Valley, Utah. At use sites and random locations, we collected habitat information that included vegetative measurements and topographic data. We augmented this information with GIS-based metrics (aspect, curvature, elevation, ruggedness, slope, and solar radiation) calculated at scales of 50, 100, 250, 500, 1000, 1500, and 3000 m. To determine which variables successfully differentiated use and random sites, we used the statistical classifier Random Forests. Greater sage grouse in our study area selected winter habitats with more canopy cover, horizontal obscurity, and shrub height in areas with lower slopes, less snow, and southeast to west aspects. Using this information, we

produced a map that identified suitable winter habitat for sage grouse in our study area. This map highlighted core areas that should be conserved and will provide a basis for management decisions.

Introduction

Greater sage grouse (*Centrocercus urophasianus* – hereafter sage-grouse) have responded to the loss, fragmentation, and degradation of sagebrush habitats with dramatic declines throughout much of their historic range (Connelly and Braun 1997, Braun 1998). As a result of this decline, sage grouse were recently found warranted, but precluded by higher priority species, for listing as threatened or endangered under the 1973 Endangered Species Act (U.S. Department of Interior 2010). While many interrelated factors have contributed to the decline and listing of sage grouse, habitat composition and quality is one of the few that can be consistently managed (Connelly et al. 1991, Gregg et al. 1994, DeLong et al. 1995, Sveum et al. 1998 Crawford et al. 2004). Protection of important habitat, however, requires that it first be identified for populations at risk.

Numerous studies of habitat selection have been conducted across the range of sage grouse in recent years (Braun et al. 1977, Leonard et al. 2000, Bunnell et al. 2004, Doherty et al. 2010). Several studies, for example, have addressed seasonal habitat use with emphasis on nesting and brood-rearing habitat (Klebenow 1969, Connelly et al. 1991, Delong et al. 1995, and Sveum et al. 1998). Furthermore, nesting and brood-rearing habitat have been evaluated in relation to leks (Braun et al. 1977, Wakinen et al. 1992, Peck 2011). These studies have shown variation across populations with a common need for a variety of sagebrush (*Artemisia* spp.) plant community types (Crawford et al. 2004).

Evaluation of winter habitat has also received attention (Beck 1977, Crawford et al. 2004, Doherty et al. 2008, Homer 1993, Braun et al. 2005, Berry and Eng 1985). Winter habitat selection has been studied in Colorado (Beck 1977), Idaho (Connelly 1988), Montana (Eng and Schladweiler 1972), Oregon (Hanf et al. 1994, Crawford et al. 2004), Utah (Rasmussen and Griner 1938), and Wyoming (Berry and Eng 1985, Holloran 1999). These studies addressed habitat selection, habitat requirements, and the influence of habitat quality on grouse during the winter months. Understanding winter habitat selection has become more important given recent evidence that prolonged periods of low temperatures coupled with deep snow can negatively influence survival (Anthony and Willis 2009). Additionally, recent work by Doherty et al. (2010) suggests that scale may be an overlooked factor not fully evaluated in earlier work that could influence seasonal habitat selection.

In Strawberry Valley, Utah (SV), sage grouse have experienced a 95% decline in abundance over the last seventy years. Griner (1939) estimated between 3,000 and 4,000 grouse existed in SV in the late 1930s. By the late 1990s, similar estimates suggested no more than 150 grouse persisted (Bunnell 2000). This drastic decline precipitated a long-term research study to identify and mitigate limiting factors beginning in 1998. Initial research showed that nesting, brood-rearing, and even unoccupied summer habitats (Bunnell et al. 2004, Bunnell 2000, Baxter et al. 2008, and Baxter et al. 2009) met or exceeded published guidelines (Connelly et al. 2000). Preliminary information, however, suggested that certain components (e.g. canopy cover) of winter habitat were lacking (Bambrough 2002). Sage grouse in this area also demonstrated low fidelity to winter habitats as their distribution during winter months was largely a function of snow depth.

Further research suggested that grouse in Strawberry Valley had low genetic diversity consistent with a classic bottleneck (Oyler-McCance et al. 2005). In response to this information, the Utah Division of Wildlife Resources approved translocation of sage grouse (n=389) from four different Utah populations between 2003 and 2008. These source populations experienced different environmental conditions, plant community composition (i.e. black sagebrush *Artemisia nova* compared to Wyoming big sagebrush *Artemisia tridentata*), and amounts of habitat disturbance or fragmentation. Nonetheless, translocated sage grouse acclimated to new habitats in Strawberry Valley, reproduced, and experienced similar survival rates to resident sage grouse (Baxter et al. 2008). In the years following translocation, the sage grouse population in Strawberry Valley expanded and recent estimates suggest nearly 400 grouse currently exist (Peck, unpublished data).

Despite this expansion, however, persistent conservation challenges remain. Strawberry Valley, for example, is a popular recreation area during both the summer and winter periods. Winter recreation in particular has increased in recent decades. Furthermore, continued expansion of recreational homes and cabins is expected to increase habitat fragmentation and further pressure sage grouse. These factors, coupled with the recent findings of Anthony and Willis (2009) suggesting that extreme winter conditions can affect survival, highlight the need for improved understanding of winter habitat selection.

Our study was the first to use a long-term dataset to address winter habitat use by a small and later augmented sage grouse population where comparisons of habitat use between resident and translocated sage grouse were possible. Our specific objectives were to: 1) assess winter habitat selection by greater sage grouse at multiple spatial scales in SV, 2) compare winter habitat selection before and after successful population augmentation, and 3) develop a predictive model for winter habitat in our study area. These results will help inform conservation of sage grouse both in SV and throughout their range.

Study Area and Methods

Study Areas

SV is located in north–central Utah (NAD 83 Zone 12T; UTM 0492078/4445216). This area is characterized as montane sagebrush steppe with mountain big sagebrush (*Artemesia tridentata*) predominant and silver sagebrush (*A. cana*) occurring at lower abundance in wet meadows and riparian areas. SV is approximately 24 km long and 9 km wide with elevations ranging from 2250 to 2600 m. The valley experiences cool dry summers and cold wet winters. Average annual precipitation over recent decades was 58 cm (NRCS 2000). Strawberry Reservoir, completed in 1985, was the most dominant feature of the valley, covering 6,950 ha of the nearly 16,000 ha of historical sagebrush steppe habitat.

In addition to our study of resident sage grouse, we translocated sage grouse to SV from four stable (≥ 500 breeding birds) source populations identified by the Utah Division of Wildlife Resources. These efforts were intended to augment the local population and increase genetic diversity. Because of the isolation by distance-population genetic structure shown by sage grouse, we followed the suggestion of Oyler-McCance et al. (2005) and selected neighboring rather than distant populations as sources for translocation. These source locations included Deseret Land and Livestock, Diamond Mountain, Parker Mountain, and western Box Elder County.

Deseret Land and Livestock, a private cattle ranch located in northeastern Utah, was dominated by Wyoming big sagebrush. Elevations ranged from 1,920 m to 2,650 m with terrain consisting of flat rolling hills sloping eastward to Wyoming. Precipitation was highly variable but averaged nearly 50 cm. Diamond Mountain, a high mountain plateau located in eastern Utah, consisted of big sagebrush with a mixture of perennial grasses and forbs in the understory (Ralphs and Busby 1979). Elevations ranged from 2,230 m to 2,850 m. Average annual precipitation ranged between 51 cm and 61 cm depending on elevation (Ralphs and Busby 1979, Laycock and Conrad 1981). Parker Mountain in south-central Utah was characterized by black sagebrush on the ridges and slopes with big sagebrush, bitterbrush (*Purshia tridentata*), and rabbitbrush (*Chrysothamnus viscidiflorus)* in the drainages. Elevations ranged from 2,140 m to 3,000 m with rolling hills and plateaus sloping to the north and east. Parker Mountain experienced hot dry summers with most precipitation occurring in the autumn and winter. Vegetation in western Box Elder County, (north-western corner of Utah) consisted of black sagebrush and Wyoming big sagebrush. Elevations ranged from 1,500 m to 2,100 m. This area experienced warm dry summers with cold wet winters, and average annual precipitation of 45 cm.

Capture and Field Monitoring

Using pickup trucks and all-terrain vehicles, we netted sage grouse on and near leks in late spring (March/April). We captured resident sage grouse in SV between 2003–2009 and translocated grouse each year from 2003-2008. We conducted capture sessions from 2 h after sunset until 0200 hours using a modified spotlight method (Wakkinen et al. 1992). We fitted captured sage grouse with a 22-g necklace-style radio-transmitter (Advanced Telemetry Systems, Inc., Isanti, MN) prior to release at the point of capture (resident) or active lek (translocated). Additional details regarding the transport and release of translocated sage grouse are available in Baxter et al. (2008).

We tracked radio-marked sage grouse using a 4-element Yagi antenna and an R-1000 digital radio receiver (Communication Specialists Inc., Orange, CA) during winter months (December – March) of each year. We recorded spatial locations of observed grouse using a global positioning system (GPS). For each observation, we verified the location from a distance using Nikon® 9x42 binoculars. Then, after flushing identified grouse, we confirmed the exact location with tracks in the snow. Our efforts were aided by use of snowmobiles and snowshoes. When grouse were difficult to locate from the ground, we scheduled periodic flights in a fixed-wing aircraft to locate them ($\bar{x}$ = 8 flights per year).

At flush locations and paired-random points (Bunnell et al. 2004, Baxter et al. 2009), we collected fine-scale habitat data. These data included aspect (compass), distance to habitat edge, distance to rocks/cliffs, distance to nearest shrub, shrub height above the snow, and slope (clinometer). Our fine-scale measurements also included measurement of snow depth and classification of snow conditions. For snow condition, we used eight different descriptions: wet, powder, packed, patchy, sugar, unknown, crust, and none. We classified snow as wet when snow was melting or slushy. Powder was very dry and light—easily blown in the wind and not packable. Packed snow had been compacted throughout the entire depth. We classified snow as patchy when the area was not completely covered in snow. Snow was considered sugar when it resembled the consistency of white sugar. This snow category was not wet, but was too heavy to be considered powder. Crust was snow that had a hard crust layer with softer snow underneath. For this snow type, we measured the depth of the crust by pushing a tape measure into it until release into softer snow. We described the snow as mixed when multiple different snow types were present or snow could not accurately be described by a single description.

In addition to snow condition, we also recorded the presence of snowmobile tracks. Tracks were considered present if old or new tracks could be seen in the area where grouse were flushed. Snowmobile track density was classified as light, moderate, or high. Light consisted of one or two tracks passing through the area. Density of tracks was classified as moderate when 3 to 5 tracks were visible. High density included areas frequented by recreational vehicles where the number of visible tracks exceeded 5.

We estimated vegetative cover using the line-intercept method (Canfield 1941) along two perpendicular 50-m transects that intersected at the flush or random point. We also estimated shrub density following the T^2 formulation (Ludwig and Reynolds 1988). For shrubs included in this calculation (2 per location), we measured average shrub height and shrub crown area. We estimated shrub crown area by taking a measurement of shrub crown diameter along the longest axis in the crown and a second length perpendicular to the first. We then used these two measurements to calculate the area of an ellipse (Bunnell et al. 2004).

We estimated horizontal obscurity with a 1-m^2 cover board divided into 36 equal squares (Bunnell et al. 2004). We positioned this cover board at ground level 2.5, 5, and 10 m from the flush or random location in each of the four cardinal directions. To mimic sage grouse height, we read the board from a height of 36 cm. We considered a square obscured if any part of it covered by vegetation. We obtained a vertical obscurity measurement by placing an 18 × 18 cm cover board divided into 36 equal squares on the ground at the flush point. We then recorded the number of squares obscured when looking from directly above the cover board.

Because sage grouse select habitat at larger scales, (Carpenter et al. 2010, Doherty et al. 2010) we augmented micro-level analysis with GIS-based measurements calculated at progressively larger spatial scales. Using the spatial locations, we first buffered them with 50;

100; 250; 500; 1,000; 1,500; and 3,000 m radius circles using ArcGIS (version 9.3; ESRI, Redlands, CA). Within these circles, we then calculated the average slope, aspect, elevation, curvature, solar radiation, and ruggedness using tools available in ArcGIS 9.3 and the benthic terrain modeler (Wright et al. 2005). We also used ArcGIS to estimate the distance to nearest habitat edge, distance to nearest anthropogenic feature, distance to the reservoir boundary, and distance to nearest road. For roads, we considered two classes. Major roads were paved or frequently traveled gravel roads consistently driven throughout the year. Minor roads were two-tracks and other unimproved roads where seasonal use was low.

Because of the difference in how random locations were generated between small scale (paired random, collected on the ground) and larger scale GIS-based variables (true random), we conducted two separate analyses. The first analysis (fine scale) included a comparison of use sites with paired-random locations across the following variables: aspect, slope, distance to edge, snow condition, snow depth, crust depth, presence of snowmobile tracks, snowmobile track density, distance to rocks/cliffs, total sagebrush canopy cover, distance to nearest shrub, average shrub height, horizontal obscurity, average shrub crown area, sagebrush crown cover, and percent sagebrush in canopy. For the second analysis, we included the GIS-based aspect, curvature, elevation, ruggedness, slope, and solar radiation (Carpenter et al. 2010) at each of the progressively larger scales. We further included distance to anthropogenic structure; distance to major road, distance to minor road, and distance to reservoir boundary in this analysis. We then calculated a decay distance for each measurement. For all scales variables, we included decay variables because the response of birds to a given anthropogenic structure typically declines as the distance between them increases (see Nielsen et al. 2009 or Carpenter et al. 2010 for details).

Statistical Analysis

For statistical analysis, we divided our data into two groups, prior to translcoation (group A; 1998-2002) and after translocation (group B; 2003-2010). Group A included only locations from resident birds captured in SV collected before translocations began. Conversely, group B included locations from resident and translocated birds collected after the first bird was moved into SV. To determine variables that successfully differentiated use from random sites, we used the statistical classifier Random Forests which has demonstrated superior performance compared to other classifiers (Cutler 2007). Random Forests builds multiple classification trees producing measures of variable importance. Compared to other classifiers, Random Forests has high accuracy, the ability to model complex interactions, and produces an estimate of variable importance that is not affected by multicollinearity (Cutler 2007). Random Forests produces an out-of-bag (OOB) error rate (estimate of prediction accuracy) using approximately one-third of the data. We used the Random Forests package (R Development Core Team 2009) in program R (R Development Core Team 2009) to conduct all statistical analyses.

We considered variables demonstrating a mean decrease in accuracy of near 1.0 or greater to be important. Once identified, we used these variables in a linear model (logistic regression) that we then applied across the study area to create a "heat map" highlighting suitable winter habitat. We used logistic regression for this map because it allowed for estimation of a probability of winter use associated with each pixel in our study area. Following creation of the habitat map, we verified accuracy by using 60 observations of sage grouse collected during the winter of 2011. Because these locations were not used in identification of assessment, they represented an independent sample.

Results

Fine-scale Analyses

We collected fine-scale habitat information at 115 group A winter-use sites and 115 corresponding paired random sites. Average flock size at use sites was 9.2 birds (SE 0.10, range 1 to 50). Seven of 19 variables demonstrated importance with a mean decrease in accuracy of near 1.0 or better (Figure 2). The "out of bag" (OOB) estimate of error rate was 17.89%. Use sites were located closer to shrubs and rocks/cliffs than random locations. Sage grouse favored areas with greater amounts of horizontal obscurity and higher total average shrub crown area. Sage grouse also selected areas with a greater amount of sagebrush and increased canopy cover compared to paired random sites with taller shrubs (Figure 3). Snow condition at flush sites varied, but grouse were flushed at sites with packed and patchy snow more than anticipated based on availability (Figure 4).

We collected micro-site winter habitat variables at 165 use and 165 random sites from during the years of and following translocation (group B). Average flock size at these locations was 20.6 (SE 1.66, range 1 to 104). Five of the 19 variables produced mean decreases in accuracy of near 1.0 or better (Figure 2). The OOB estimate of error rate was 18.54% for this analysis. Winter-use sites were located closer to shrubs than paired random locations. Sage grouse also favored areas with greater amounts of horizontal obscurity, higher amounts of shrub canopy cover, and taller shrubs compared to paired random locations (Figure 5). When compared (115 winter use sites from group A compared to 165 use sites following initiation of translocations from group B) only 3 of the 19 variables produced mean decreases in accuracy of near 1.0 or better (Figure 2). Use sites contained higher amounts of sage brush, more sagebrush canopy cover, and taller shrubs prior to translocation than they did during and after translocation.

Macro-level analysis

We compared 115 group A flush points to 115 corresponding random sites using GIS-based measurements calculated from progressively larger scales. Seven variables demonstrated a mean decrease in accuracy near 1.0 (Figure 6). The OOB estimate of error rate was 17.75% for this analysis. Sage grouse selected areas with lower slopes and a more southerly, southeasterly aspect than random locations at the 1,000 m scale. Sage grouse also selected for lower slopes and elevations at larger scales (Figure 7).

We analyzed 568 locations following initial translocation (group B) and an equal number of random sites at progressively larger scales. Only 2 variables exhibited a mean decrease in accuracy value of near 1.0 (Figure 6). The OOB estimate of error rate was 14.46% for this analysis. The most important variable was aspect at the 1,000 m scale. Similar to results prior to translocation, sage grouse selected areas with a more west to south-eastern aspect than random locations. The second important variable was solar radiation at the same 1,000 m scale with use locations demonstrating higher average values (watt hours per square meter) than random locations (Figure 8). For the comparison of use sites before (n = 116) and after translocation (n = 568), none of the variables produced mean decreases in accuracy >*0*.75 (Figure 6). The OOB estimate of error rate was 15.04% for this analysis.

Using these identified variables, we produced a heat map highlighting suitable winter habitat in our area. This map highlighted large areas surrounding the reservoir and along the eastern portion of our study area as suitable winter habitat (Figure 9). Accuracy assessment for this map showed that 58 of 60 (97%) 2011 winter locations were located in predicted suitable winter habitat.

Discussion

We collected winter habitat data over a 12-year period. Comparable studies (Eng and Schladweiler 1972, Beck 1977, Hupp and Braun 1989, Homer et al. 1993, Doherty et al. 2008) were conducted between 1-3 years highlighting one of the unique aspects of our study. Our results are similar to Beck's (1977) findings where 88 percent of flocks contained less than 50 individuals. We found 92 percent of all observations occurred where flock size was < 50. We did document increased flock size following successful translocation (group B) consistent with an expanding population (Baxter et al. 2008).

Our winter habitat results were consistent between years prior to and following initiation of translocations despite the large number of birds moved into SV from other populations. Only four variables (distance to rocks, total average shrub crown area, total amount of sagebrush, and snow condition) had a mean decrease in accuracy value of one or better during the years prior to translocation (group A), but not following translocation (group B). In the years following translocation several extensive habitat improvement projects have been implemented allowing grouse a wider range of sagebrush habitats to select from. This change may be the reason a difference in amount of sagebrush and total average shrub crown area differed. Alternatively, snow condition and amount differences across years prior to and following initiation of translocations may have influenced selection.

Average snow depth at use sites prior to translocation (group A) was 21.3 cm compared to 31.7 cm in the years after initiation of translocations. If total snow fall would have been more consistent for the two periods, we suspect even further similarity would have been observed. This consistency suggests that habitat selection for sage grouse in Utah is more a function of availability than population specific genetic or behavioral differences. Similar results have been reported for migratory bird species from multiple populations that instinctually identify locations along migratory pathways where their feeding and flight morphologies are best suited to exploit habitat structure (Hutto 2000, Petit 2000, Simons et al. 2000, Tankersley and Orvis 2003). This finding is encouraging for others considering augmentation of declining populations.

Hupp and Braun's (1989) study in the Gunnison basin of Colorado suggested that snow depth may affect the slope and aspect at which sage grouse forage. Sage grouse in SV were located in areas with an average snow depth of 27.4 cm (SD 21 cm) and between 5-10% slope (mean 10.8; SD 8.91). In contrast Eng and Schladweiler (1972) and Beck (1977) reported greater sage grouse winter use occurred on flat areas < 5% slope. Both of these studies reported much less snowfall, however, with depths ranging between 3 and 25 cm. Sage grouse throughout SV were most commonly located on west to southeast facing slopes consistent with previous work suggesting grouse prefer to winter on southwest slopes (Beck 1977, Hupp and Braun 1989).

Our data showed that grouse in SV preferred areas with high amounts of shrub canopy cover (Figures 2 and 3). This finding was consistent with others from across the species range (Eng and Schladweiler 1972, Beck 1977, Hupp and Braun 1989, Homer et al. 1993). At a fine scale, winter habitat selection of sage grouse in SV was closely associated with sagebrush characteristics. Grouse were located closer to sagebrush and near larger amounts of sagebrush than random locations. Distance to the closest shrub, horizontal obscurity, total average shrub crown area, total amount of sagebrush, total shrub canopy cover, and total sagebrush canopy cover showed consistently large (near to or > 1.0) mean decreases in accuracy across years. These results were consistent with others and further highlight the importance of sagebrush to wintering sage-grouse (Eng and Schladweiler 1972, Beck 1977, Hupp and Braun 1989).

At broader scales, winter habitat selection of sage grouse in Strawberry Valley was closely associated with aspect, slope, and elevation. These broader scales (e.g. 1,000 to 3,000 m) provided the variables with the best ability to differentiate use from random locations. Aspect, slope, and elevation have a direct influence on the amount of snow accumulated over the winter and subsequent availability of forage. We hypothesize that sage grouse in SV selected these areas based on access to sagebrush for both cover and forage. Interestingly, distance to anthropogenic features failed to produce strong classification accuracy. This finding differs from Carpenter et al. (2010) who found avoidance of anthropogenic features. For sage grouse in SV, distance to a major road had the best predictive ability, but it only resulted in a mean decrease in accuracy of ≤ 0.75.

The predictive habitat map highlighted large areas around the reservoir and on the eastern portion of our study area suggesting that conservation of sagebrush habitats in these areas will ensure grouse have adequate winter habitat. Interestingly, this map highlighted suitable habitat rarely used by sage grouse in SV suggesting that continued population expansion is not limited by availability of winter habitat.

Management Implications

Results across scales suggest taller shrubs with some combination of southerly aspect, slope and elevation are preferred. Given the recent emphasis on habitat restoration projects to improve brood-rearing habitat through reductions in canopy of sagebrush and facilitation of understory growth, special attention should be given to preserving older sagebrush in well-used winter areas. While the promotion of understory forb growth is important to some populations limited by availability of brood-rearing habitat, the residual younger sagebrush plants could easily be covered by snow and become unavailable to grouse during winter. Preservation of suitable winter habitat is essential to proper sage grouse management. Our results reinforce the idea that sage grouse require a suite of habitat characteristics for use throughout their life cycle. We suggest the habitat map be used in planning of habitat restoration projects and in management of winter recreation in SV. The process we followed is applicable to other populations where location data is available.

LITERATURE CITED

Anthony, R.G. and M.J. Willis. 2009. Survival rates of female greater-sage grouse in autumn and winter in southeastern Oregon. Journal of Wildlife Management 73:538-545.

Bambrough, D.J. 2002. Greater sage grouse winter and male and female summer habitat selection in Strawberry Valley, Utah. Thesis, Brigham Young University. Provo, Utah, USA.

Baxter, R.J., J.T. Flinders, and D.L. Mitchell. 2008. Survival, movements, and reproduction of translocated greater sage-grouse in Strawberry Valley, Utah. Journal of Wildlife Management 72: 179-186.

Baxter, R.J., J.T. Flinders, D.G. Whiting and D.L. Mitchell. 2009. Factors affecting nest-site selection and nest success of translocated greater sage grouse. Wildlife Research 36:479–487.

Beck, T.D. I. and C.B. Braun. 1978. Weights of Colorado sage grouse. Condor 80:241–243.

Beck, T.D.I. 1977. Sage grouse flock characteristics and habitat selection in winter. Journal of Wildlife Management 41:18-26.

Berry, J.D. and R.L. Eng. 1985. Interseasonal movements and fidelity to seasonal use areas by female sage grouse. Journal of Wildlife Management 49:237-240.

BRAUN, C. E. 1998. Sage grouse declines in western North America: what are the problems? Proceedings of the Western Association of State Fish and Wildlife Agencies 78: 139-156

Braun, C.E., T. Britt, and R.O. Wallstead. 1977. Guidelines for maintenance of sage grouse habitats. Wildlife Society Bulletin 5:99-106.

Braun, C.E., J.W. Connelly, and M.A. Schroeder. 2005. Seasonal habitat requirements for sage-grouse: spring, summer, fall, and winter. Proceedings sage grouse habitat restoration symposium held June 4-7, 2001. Boise, ID. Proc.RMRS-P-38. Fort Collins, CO: US Department Of Agriculture, Forest Service, Rocky Mountain, Research Station. 38-42 pp.

Bunnell, K.D. 2000. Ecological factors limiting sage grouse recovery and expansion in Strawberry Valley, Utah. Thesis, Brigham Young University, Provo, Utah, USA.

Bunnell, K.D., J.T. Flinders, D.L. Mitchell, and J.H. Warder. 2004. Occupied and unoccupied sage grouse habitat in Strawberry Valley, Utah. Journal of Range Management 57: 524–531.

Canfield, R.H. 1941. Application of the line interception method in sampling range vegetation. Journal of Range Management 39:388–394.

Carpenter, J., C. Aldridge, M.S. Boyce. 2010. Sage-grouse habitat selection during winter in Alberta. Journal of Wildlife Management 74:1806–1814

Connelly, J.W., H.W. Browers, and R.J. Gates. 1988. Seasonal movements of sage grouse in southeastern Idaho. Journal of Wildlife Management 52: 116-122.

Connelly W.J., W.L. Wakkinen, A.D. Apa, and K.P. Reese. 1991. Sage grouse use of nest sites in southeastern Idaho. Journal of Wildlife Management 55:521-524

Connelly, J.W. and C.E. Braun. 1997. Long-term changes in sage grouse Centrocercus urophasianus populations in western North America. Wildlife Biology 3:229-234.

Connelly, J.W., M.A. Schroeder, A.R. Sands, and C.E. Braun. 2000. Guidelines to manage sage grouse populations and their habitats. Wildlife Society Bulletin 28:967-985.

Crawford, J.A., R.A. Olson, N.E. West, J.C. Mosley, M.A. Schroeder, T.D. Whitson, R.F. Miller, M.A. Gregg, and C.S. Boyd. 2004. Synthesis paper: ecology and management of sage-grouse and sage-grouse habitat. Journal of Range Management 57:2-19.

Cutler, D.R., T. C. Edwards Jr., K.H. Beard, A. Cutler, K.T. Hess, J. Gibson, and J.J. Lawler. 2007. Random forest for classification in ecology. Ecology 88:2783-2792.

Dahlgren, D., R. Chi, and T.A. Messmer. 2006. Greater sage grouse response to sagebrush management in Utah. The Wildlife Society Bulletin 34:975-985.

Delong, A.K., J.A. Crawford, and D.C. Delong Jr. 1995. Relationships between vegetational structure and predation of artificial sage grouse nests. Journal of Wildlife Management 59:88-92

Doherty, K.E., D. E. Naugle, B.L. Walker, and J.M. Graham. 2008. Greater sage-grouse winter habitat selection and energy development. Journal of Wildlife Management 72:187-195.

Doherty, K.E., D.E. Naugle, and B.L. Walker. 2010. Greater sage-grouse nesting habitat: The importance of managing at multiple scales. Journal of Wildlife Management 74:1544-1553.

Eng, R. L. and P. Schladweiler. 1972. Sage grouse winter movements and habitat use in central Montana. Journal of Wildlife Management 36:141-146.

Gregg, M.A., J.A. Crawford, M.S. Drut, and A.K. Delong. 1994. Vegetational cover and predation of sage grouse nests in Oregon. Journal of Wildlife Management 58:162-166.

Griner, L.A. 1939. A study of the sage grouse (Centrocercus urophasianus) with special reference to life history, habitat requirements, and numbers and distribution. Thesis Utah State Agricultural College, Logan, Utah, USA. 83pp.

Hanf, J.M., P.A. Schmidt and E.B. Groshens. 1994 Sage Grouse in the high desert of central Oregon: results of a study, 1988-1993. United States Department of Interior, Bureau of Land Management, Series P-SG@1, Prineville, Oregon, USAp. 58

Holloran, J. M. 1999. Sage grouse (*Centrocercus urophasianus*) seasonal habitat use near Casper, Wyoming. Thesis, University of Wyoming, Laramie, Wyoming, USA.p. 116

Homer, C.G., T.C. Edwards, R.D. Ramsey, and K.P.Price 1993. Use of remote sensing methods in modeling sage grouse winter habitat. Journal of Wildlife Management 57:78-84.

Hupp, J.W. and C.E. Braun. 1989. Topographic distribution of sage grouse foraging in winter. Journal of Wildlife Management 53:823-829.

Hutto, R.L. 2000. On the importance of en route periods to the conservation of migratory landbirds. Studies in Avian Biology 20:109–114.

Klebenow, D.A. 1969. Sage grouse nesting and brood habitat in Idaho. Journal of Wildlife Management 33:649-661.

Laycock, W.A. and P.A. Conrad. 1981. Responses to vegetation and cattle to various systems of grazing on seeded and native mountain rangelands in eastern Utah. Journal of Range Management 34:52–58.

Leonard, K.M., K.P. Reese, and J.W. Connelly. 2000. Distribution, movements, and habitats of sage grouse Centrocercus urophasianus on the Upper Snake River Plain of Idaho: changes from the 1950's to the 1990's. Wildlife Biology 6:265-270.

Ludwig J.A. and J.F. Reynolds. 1988. Statistical ecology: A primer on methods and computing. John Wiley and Sons Inc. New York, New York, USA 341 pp.

Manly, B.F.J., L.L. McDonald, D.L. Thomas, T.L. McDonald, and W.P. Erickson. 2002. Resource selection by animals: statistical design and analysis for field studies. Second edition. Kluwer Academic,Dordrecht, The Netherlands. 223 pp.

Nielsen, S.E., J. Cranston, and G.B. Stenhouse. 2009. Identification of priority areas for grizzly bear conservation and recovery in Alberta, Canada. Journal of Conservation Planning

5:38–60.

NRCS 2000. http://www.wcc.nrcs.usda.gov. Accessed September 14, 2011.

Oyler-McCance, S.J., S.E. Taylor, and T.W. Quinn. 2005. A multilocus population genetic survey of the greater sage-grouse across their range. Molecular Ecology 14:1293–1310.

Peck 2011. Winter Habitat Selection and Nesting Ecology of Greater Sage Grouse in Strawberry Valley Utah, Thesis, Brigham Young University, Provo, Utah, USA.

Petit, D.R. 2000. Habitat use by landbirds along nearctic–neotropical migration routes: implications for conservation of stopover habitats. Studies in Avian Biology 20:15–33.

R Development Core Team. 2009. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Ralphs, M.H. and F.E. Busby. 1979. Prescribed burning: vegetative change, forage production, cost, and returns on six demonstration burns in Utah. Journal of Range Management 32:267–270.

Simons, T.R., S.M. Pearson, and F.R. Moore. 2000. Application of spatial models to the stopover ecology of trans-gulf migrants. Studies in Avian Biology 20:15–33.

Stacey,P.B. and M.Taper. 1992. Environmental variation and the persistence of small populations. Ecological Applications 2:18-29.

Sveum, C.M.,W.D. Edge, and J..A Crawford. 1998. Nesting habitat selection by sage grouse in south-central Washington. Journal of Rangeland Management 51:265-269.

Tankersley Jr. R. and K. Orvis. 2003. Modeling the geography of migratory pathways and stopover habitats for neotropical migratory birds. Conservation Ecology **7**:7. [online] URL: http://www.consecol.org/vol7/iss1/art7/

US Department of the Interior, Fish and Wildlife Service. 2010. Endangered and threatened wildlife and plants; 12-month finding for petitions to list the greater sage-grouse as threatened or endangered; proposed rule. Federal Register 73.

Wakkinen, W.L., K.P. Reese, J.W. Connelly, and R.A. Fisher. 1992. An improved spotlighting technique for capturing sage grouse. Wildlife Society Bulletin 20:425–426.

Wakkinen, W.L., K.P. Reese, and J.W. Connelly. 1992. Sage grouse nest locations in relation to leks. Journal of Wildlife Management 56:379-381.

Wallestad, R.O. 1975. Male sage grouse responses to sagebrush treatment. Journal of Wildlife Management 39:482-484.

Wright, D.J., E.R. Lundblad, E.M. Larkin, and R.W. Rinehart. 2005. Benthic Terrain Modeler. Oregon St. University, Corvallis, Oregon, USA.

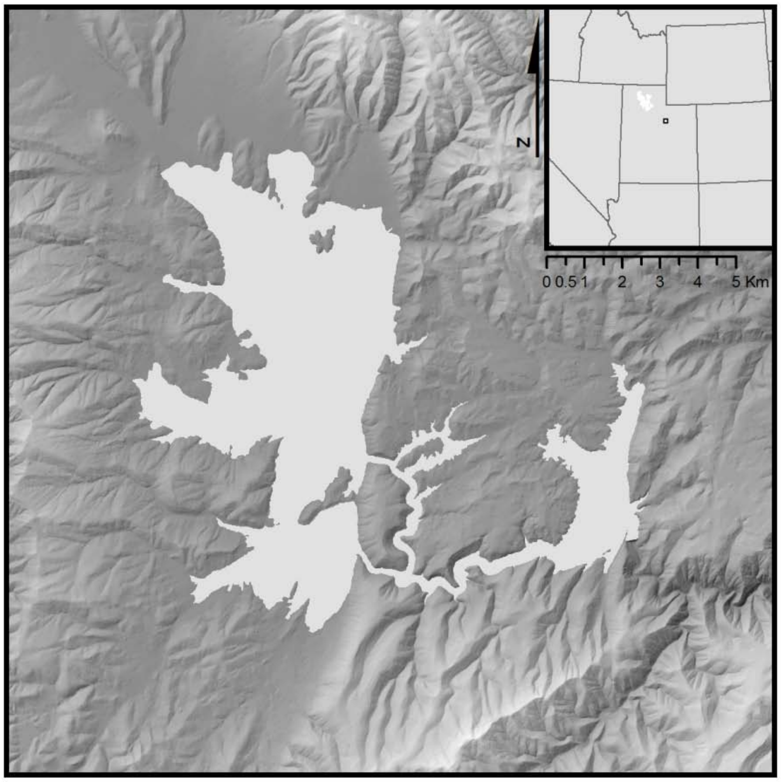

Figure 1 Study area map for Strawberry Valley, Utah where we assessed winter habitat selection by greater sage grouse (*Centrocercus urophasianus*), 1998-2010.

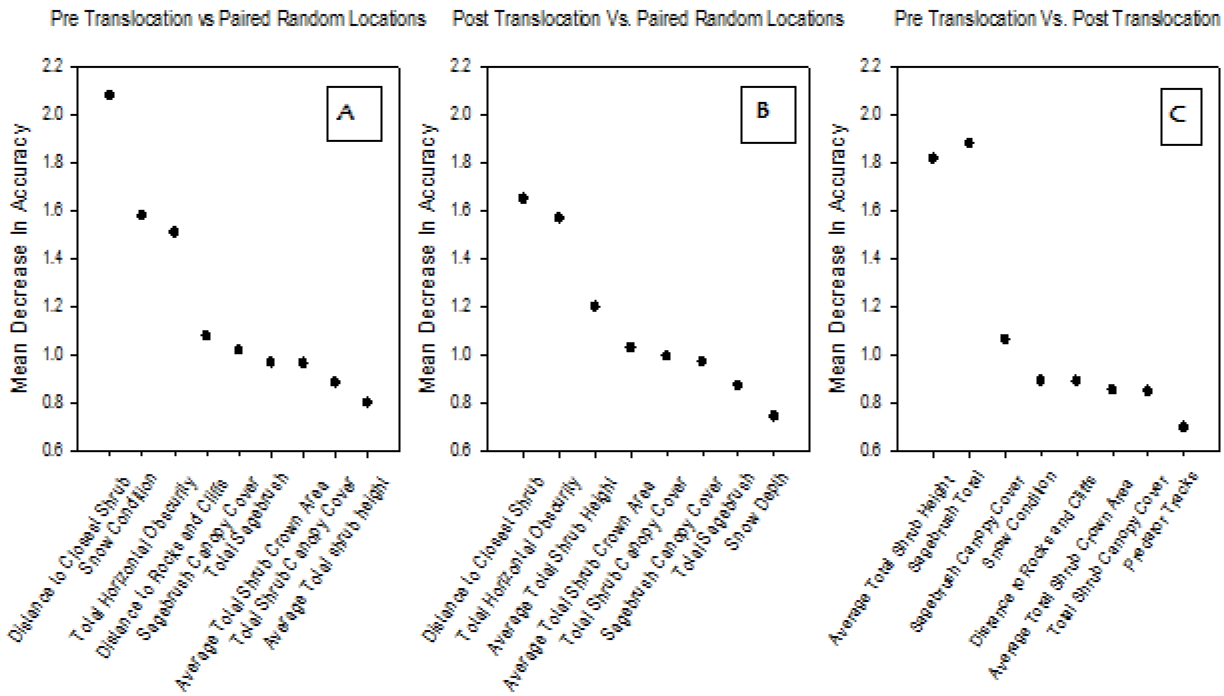

Figure 2. Micro-level variable importance plots generated using Random Forests to identify explanatory variables best able to differentiate between sage grouse winter-use sites and random locations in Strawberry Valley, Utah, 2003-2010. Mean decrease in accuracy for a variable is the normalized difference in classification accuracy between a model including each variable and one where observations are randomly permuted for the variable in question. Higher values indicate variables that are more important to the classification.

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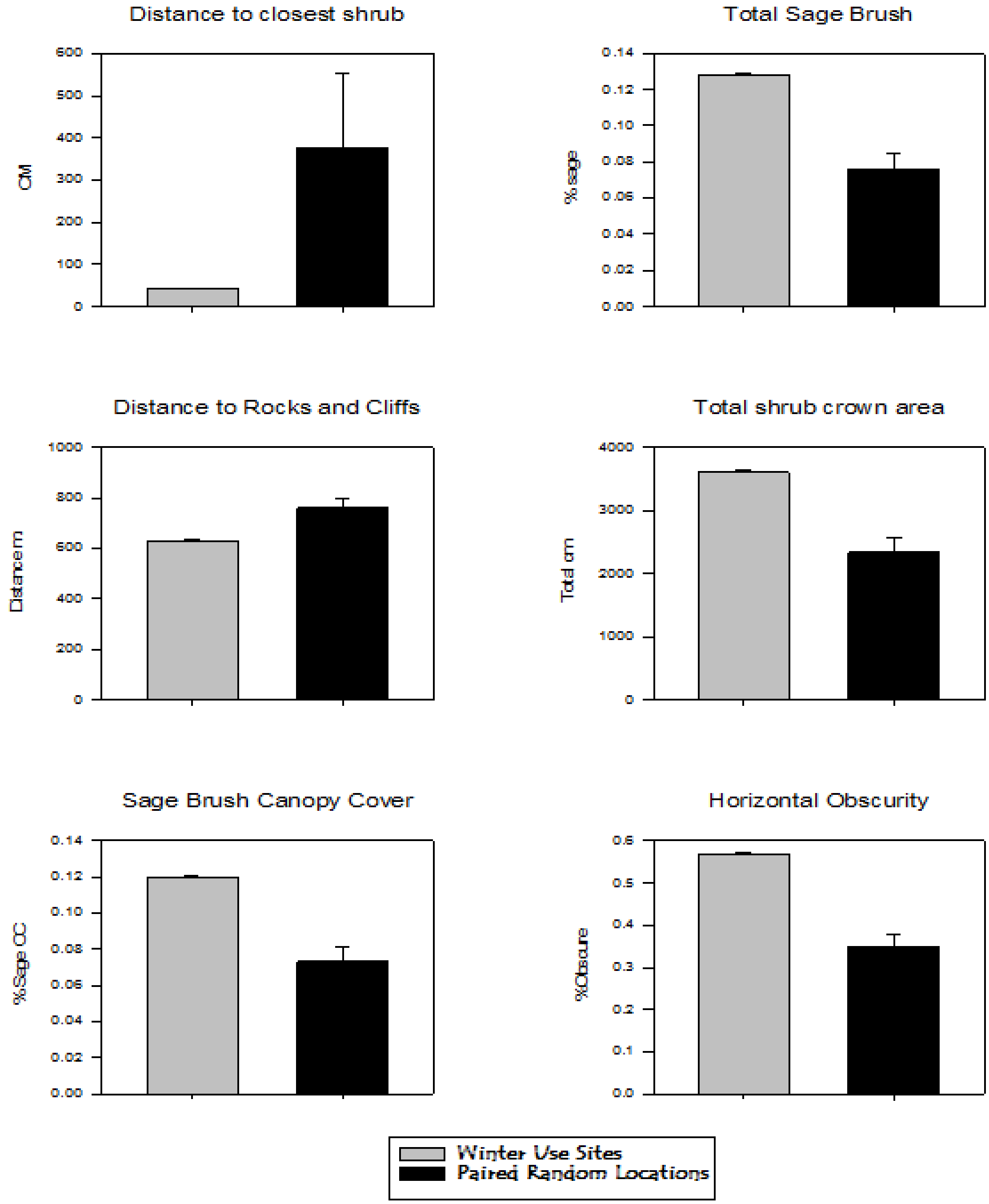

Figure 3. Mean (95% CIs) values for winter use and paired random locations identified as important (mean decrease in accuracy of ≥ 1) to greater sage grouse prior to translocation (group A) in Strawberry Valley, Utah 2003-2010.

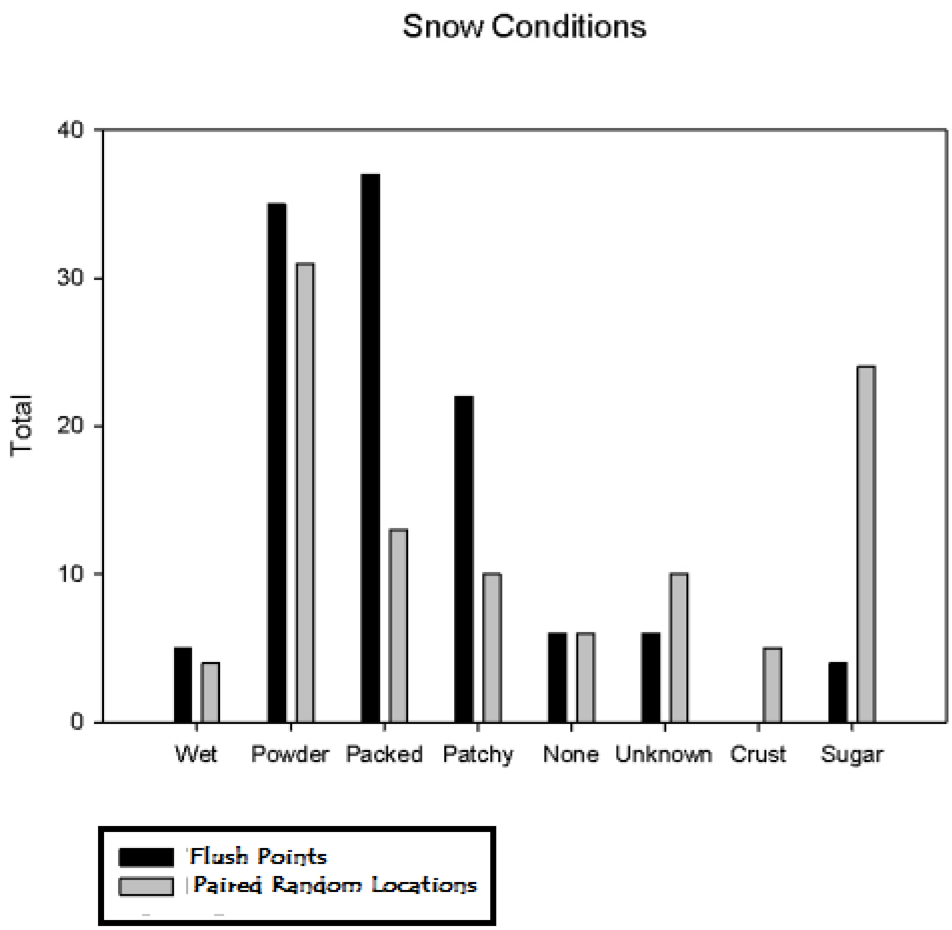

Figure 4. Snow conditions associated with 115 sage grouse winter use and 115 paired random locations in Strawberry Valley, Utah 2003-2010.

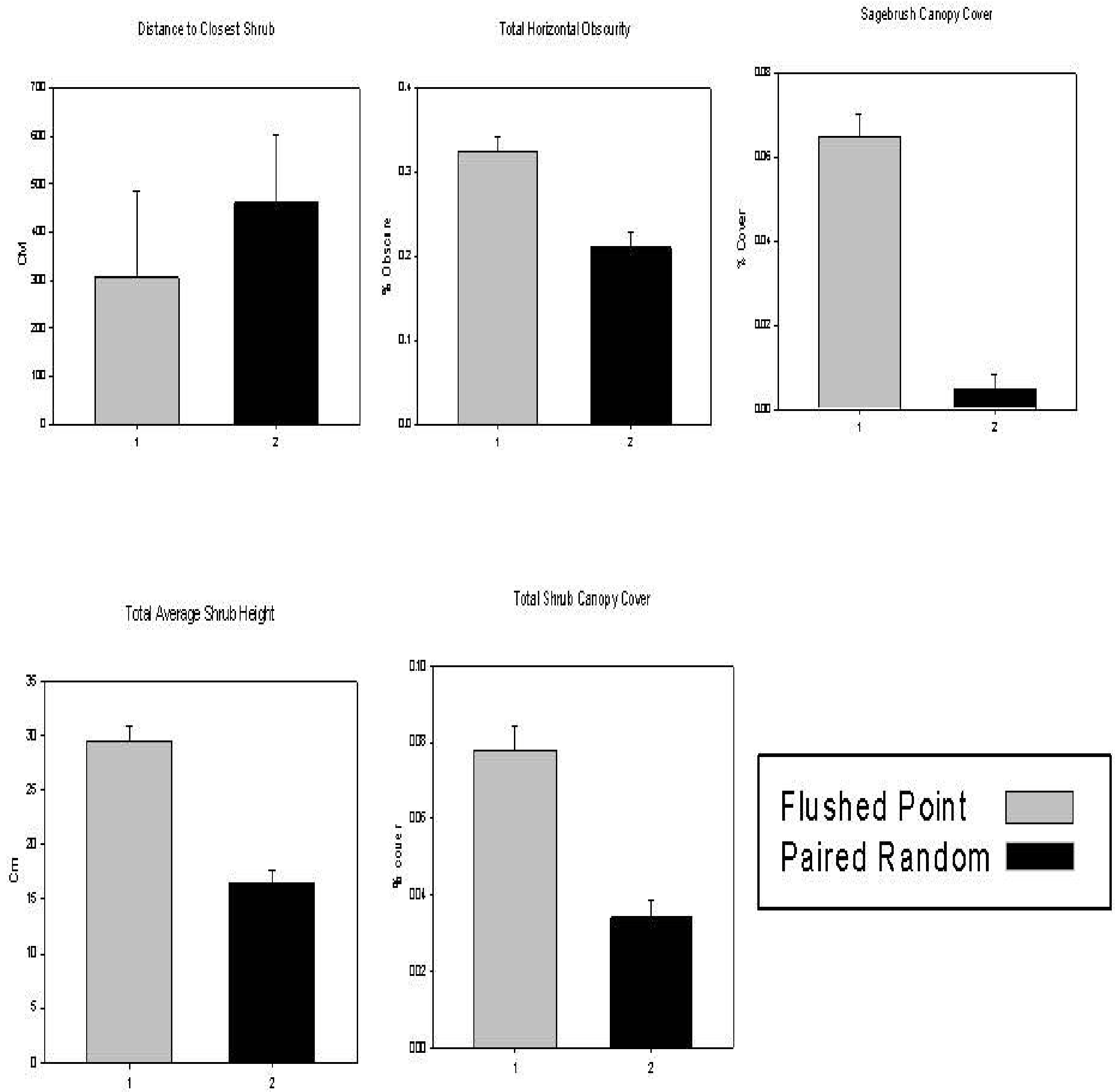

Figure 5. Mean (95% CI) values of explanatory variables for winter use and paired random locations after initiation of translocations (group B) identified as important (mean decrease in accuracy of ≥ 1) to greater sage grouse in Strawberry Valley, Utah 2003-2010.

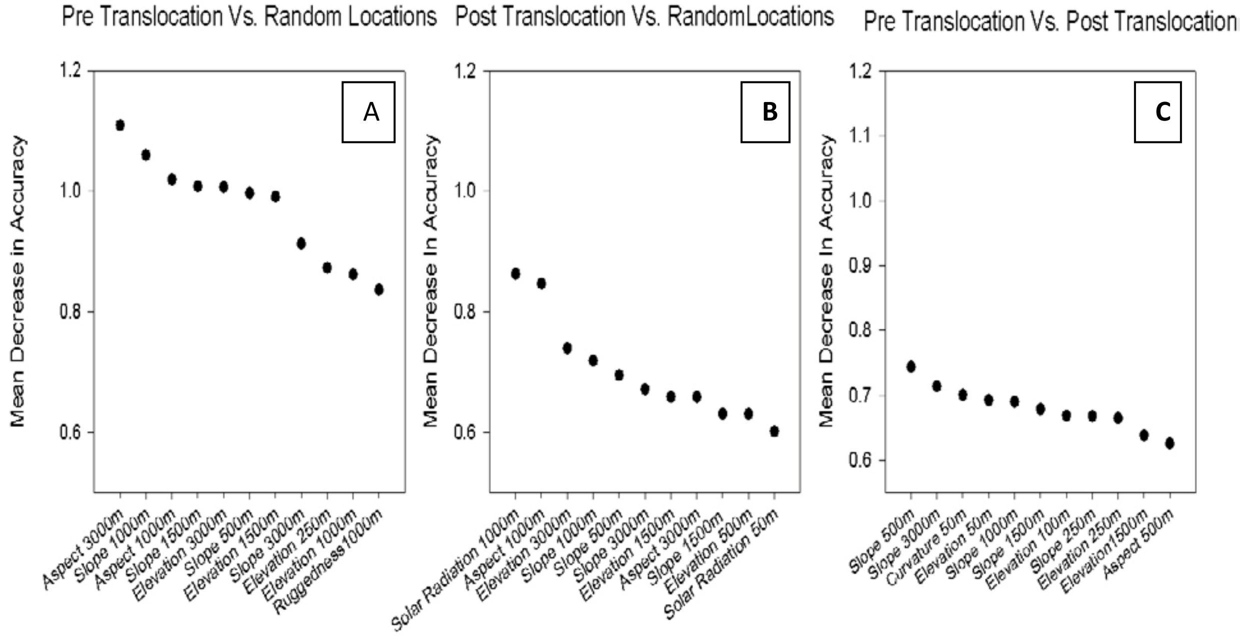

Figure 6. Variable importance plots for GIS-based explanatory variables used to differentiate sage grouse winter use locations from random sites in Strawberry Valley, Utah 1998 – 2010. Mean decrease in accuracy for a variable is the normalized difference in classification accuracy between a model including each variable and one where observations are randomly permuted for the variable in question. Higher values indicate variables that are more important to the classification.

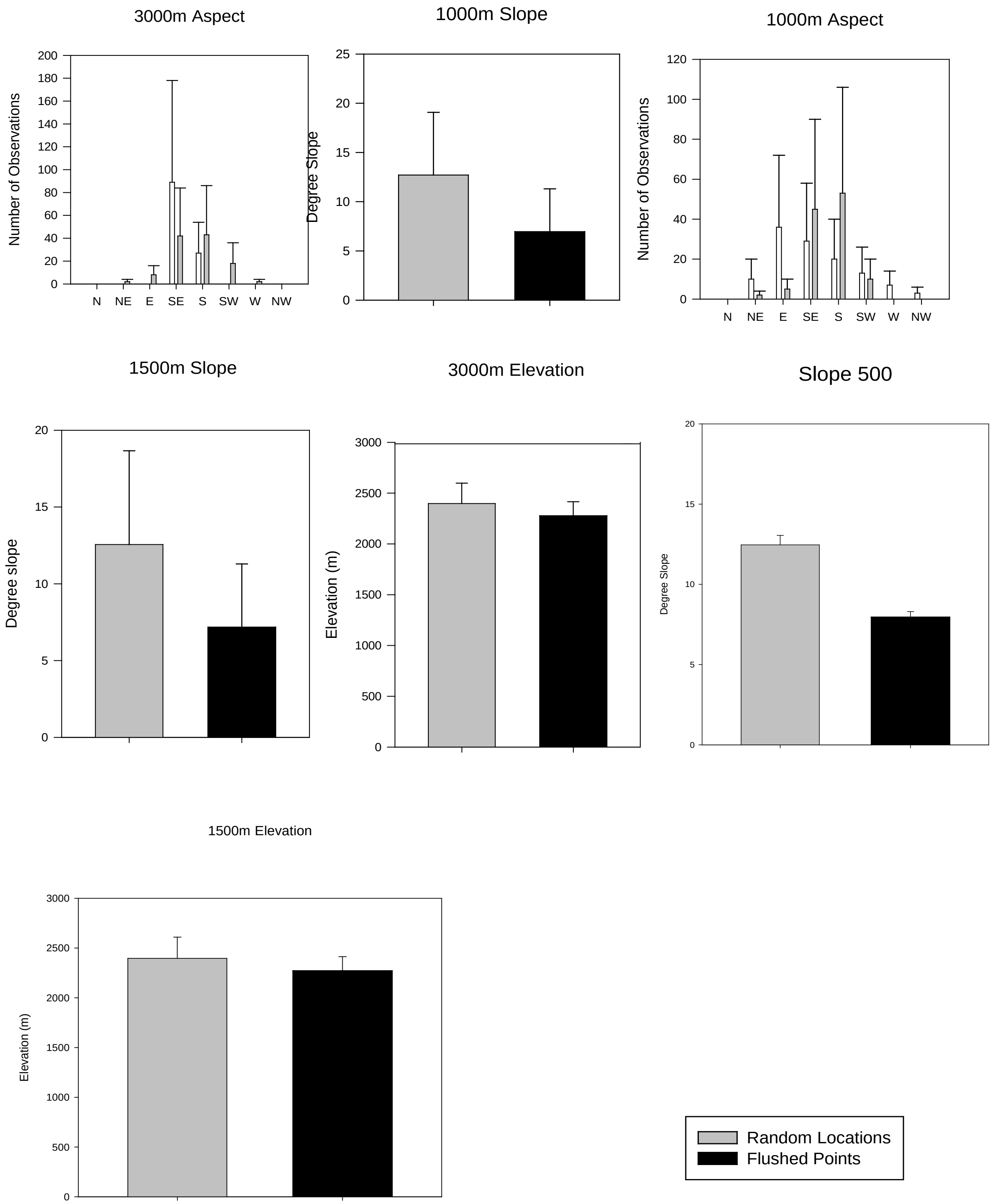

Figure 7. Means (95% CIs) associated with important (mean decrease in accuracy $\geq$ 1) variables used to differentiate winter use sites from random locations prior to translocation (group A) of sage grouse in Strawberry Valley, Utah 1998-2010..

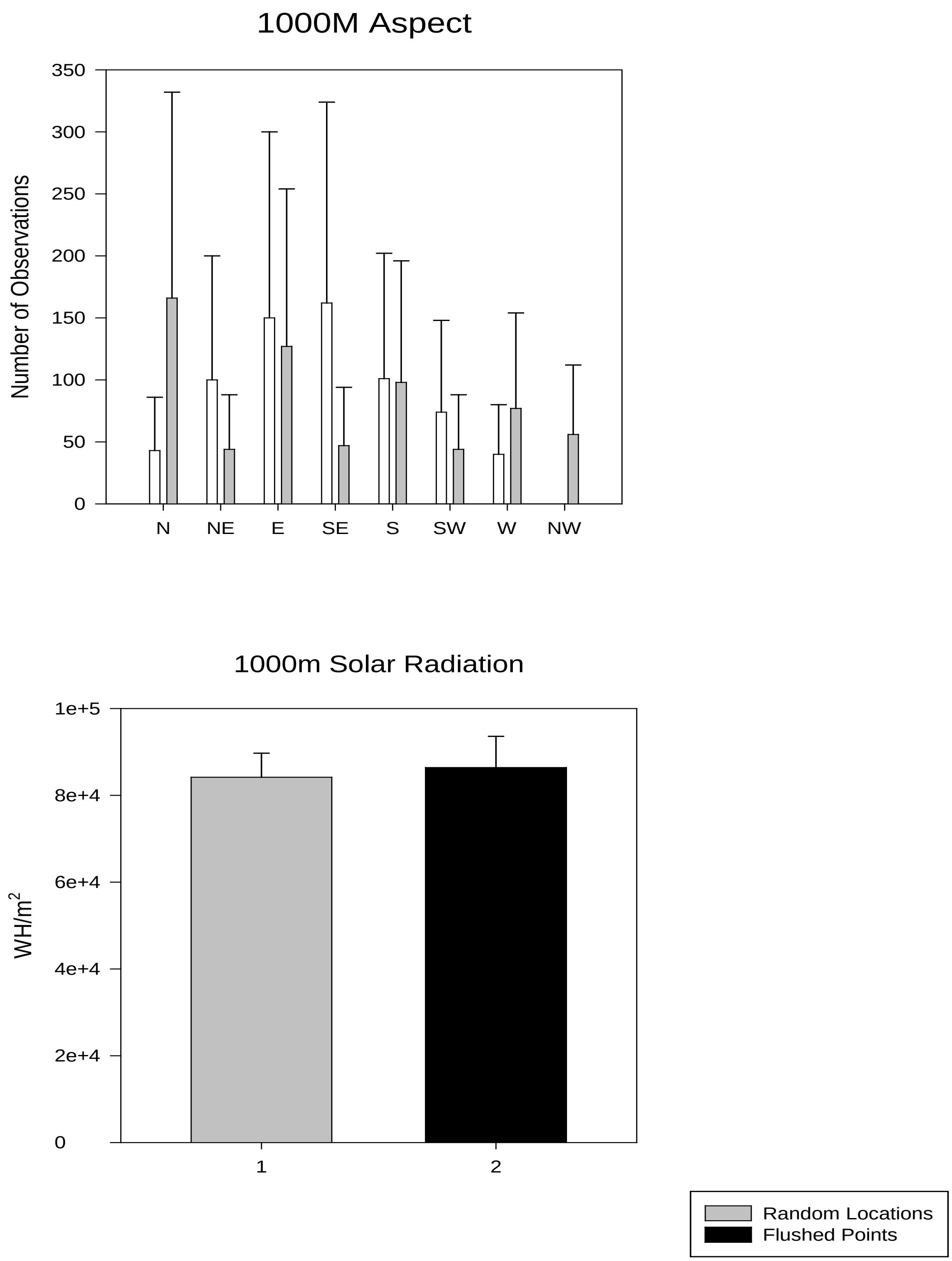

Figure 8. Mean (95% CIs) for variables important (mean decrease in accuracy near 1) in differentiating between winter use sites and random locations following initiation of translocation of greater sage grouse in Strawberry Valley, Utah, 2003-2010.

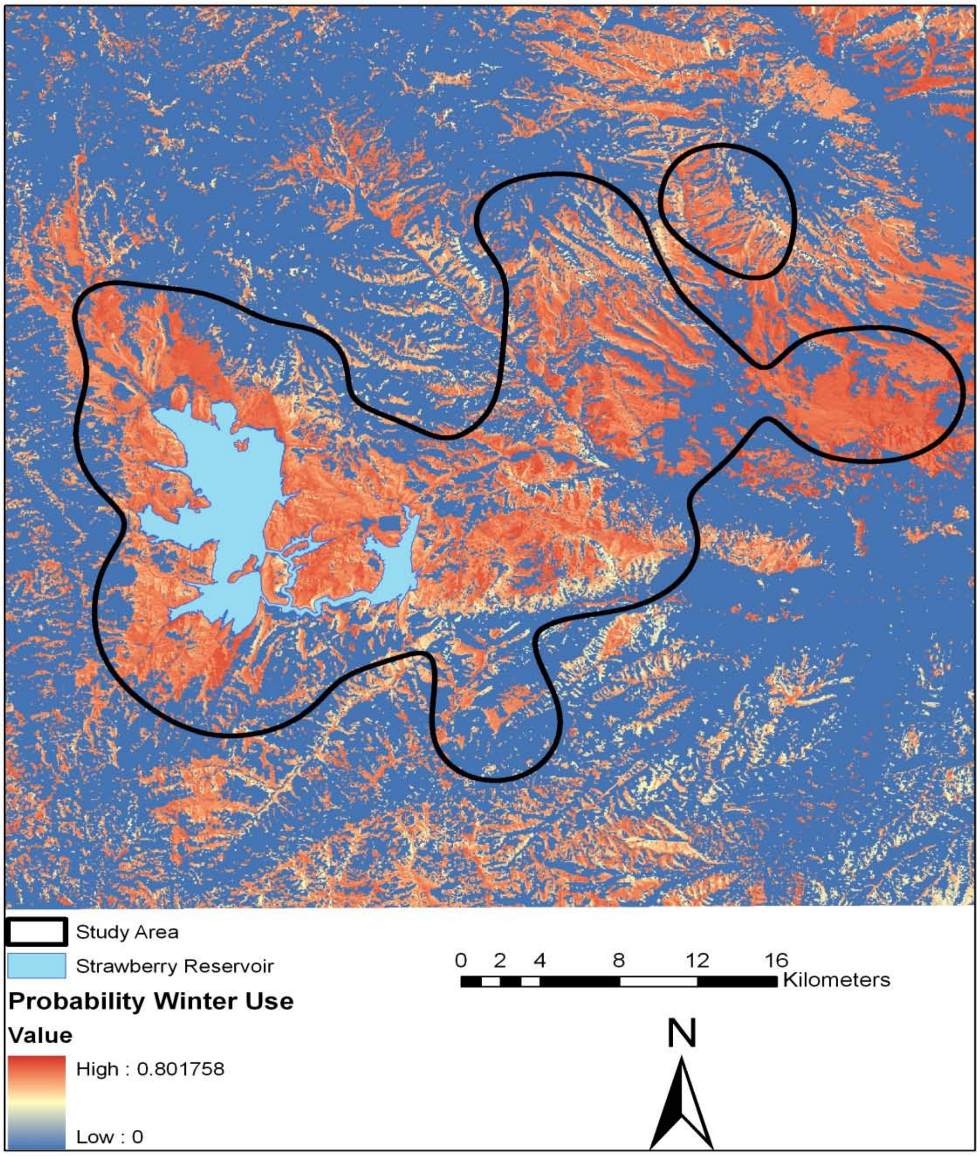

Figure 9. Predicted suitable winter habitat for greater sage grouse in Strawberry Valley, Utah. Map was produced from 684 use locations collected between 1998 and 2010.