The effect of vegetation structure on predation of artificial Greater Sage-Grouse nests[1]

Megan E. WATTERS[2], Tammy L. McLASH, Cameron L. ALDRIDGE[3] & R. Mark BRIGHAM,
  Department of Biology, University of Regina, Regina, Saskatchewan S4S 0A2, Canada.

Abstract: In Canada, Greater Sage-Grouse (*Centrocercus urophasianus*) are considered an endangered species by the Committee On the Status of Endangered Wildlife In Canada (COSEWIC), due to declining population numbers and distribution. Encroachment of agriculture and subsequent destruction of suitable sagebrush (*Artemisia* spp.) habitat is thought to be responsible for historical population declines. However, subtle changes in habitat quality may also result in reduced escape and nesting cover, which may lead to increased levels of predation. We examined the influence of vegetation cover and height on the fate of artificial Greater Sage-Grouse nests. Because most natural sage-grouse nests are associated with sagebrush, we predicted that sagebrush height and cover would be crucial to the success of nests. Lateral cover is important in protecting nests from detection by predators, and thus we predicted that nests surrounded by shorter grass would suffer greater predation rates than nests with taller grass. To experimentally test this hypothesis, we trimmed grass surrounding some artificial nests. Richardson's ground squirrels (*Spermophilus richardsonii*) were the primary predators of artificial nests, with some predation by corvids and badgers (*Taxidea taxus*). Successful nests tended to be surrounded by shorter sagebrush, taller grasses, and taller, denser forbs than predated nests. Trimming grass around nests did not affect nest fate. However, ground squirrels typically attacked nests with less forb cover and fewer sagebrush, and avian predators tended to destroy nests at inactive leks with greater lateral cover. Thus, lateral cover provided by forbs and sagebrush appeared to be important for protecting nests from mammalian predators. These results suggest implementing management strategies that improve sagebrush habitat by providing tall, dense forbs and sagebrush, which could increase Greater Sage-Grouse nest success and recruitment.
Keywords: Alberta, Greater Sage-Grouse, *Centrocercus urophasianus*, artificial nests, nest predation, ground squirrel, conservation, endangered species, vegetation cover.

Résumé : La Gélinotte des armoises (*Centrocercus urophasianus*) est considérée comme une espèce en danger de disparition par le Comité sur la situation des espèces en péril au Canada (COSEPAC) en raison du déclin de sa population et de sa répartition de plus en plus restreinte. L'empiètement et la destruction des habitats d'armoise (*Artemisia* spp.) propices à la survie de ces oiseaux par les activités agricoles seraient à l'origine de leur déclin. Des changements subtils de la qualité de l'habitat peuvent également entraîner une diminution du couvert protecteur et de nidification, ce qui peut se traduire par une plus forte prédation. Nous avons étudié l'influence du couvert végétal et de la hauteur de la végétation sur le sort de nids artificiels de Gélinotte des armoises. Puisque la plupart des nids de cet oiseau sont associés à l'armoise en milieu naturel, nous avons émis l'hypothèse que la hauteur de l'armoise et l'importance de son couvert constituent des facteurs-clés assurant le succès de nidification. Comme le couvert latéral est important pour diminuer la visibilité des nids face aux prédateurs; nous avons supposé que les nids entourés d'herbes basses subissent de plus hauts taux de prédation que les nids protégés par des herbes plus hautes. Afin de vérifier cette hypothèse, nous avons coupé les herbes entourant certains nids artificiels. Les Spermophiles de Richardson (*Spermophilus richardsonii*) ont été les principaux prédateurs des nids artificiels; des corvidés et des blaireaux (*Taxidea taxus*) se sont également attaqués aux nids. Les nids entourés d'armoise de faible taille, d'herbes hautes et d'herbacées non graminoïdes hautes et denses ont généralement connu le meilleur succès de nidification. La coupe des herbes autour des nids n'a pas affecté le succès de nidification. Par contre, les spermophiles ont attaqué de préférence les nids dont le couvert se composait de peu d'herbacées non graminoïdes et de peu d'armoise, alors que les oiseaux détruisaient plutôt les nids des leks inactifs au couvert latéral bien développé. Le couvert latéral offert par les herbacées non graminoïdes et l'armoise semble donc important pour protéger les nids des mammifères prédateurs. Afin d'augmenter le succès de nidification et le recrutement de la Gélinotte des armoises, il serait souhaitable de développer des stratégies d'aménagement visant à améliorer son habitat préférentiel, c'est-à-dire en favorisant la présence d'armoise et d'herbacées non graminoïdes grandes et denses.
Mots-clés : Alberta, Gélinotte des armoises, *Centrocercus urophasianus*, nids artificiels, prédation des nids, spermophile, conservation, espèce en danger de disparition, couvert végétal.

Introduction

Based on the currently occupied range, the Canadian Greater Sage-Grouse (*Centrocercus urophasianus* Bonaparte) population has declined by 66-92% over the last 30 years (Aldridge, 2000). Greater Sage-Grouse currently occupy about 10,000 km² in southeastern Alberta and southwestern Saskatchewan (Aldridge, 2000) and are considered an endangered species by the Committee On the Status of Endangered Wildlife In Canada (COSEWIC, 1998). Historical population declines have been attributed to loss of suitable habitat, primarily due to agricultural encroachment and removal of the sagebrush steppe ecosystem (Patterson, 1952; Wallestad & Pyrah, 1974; Schroeder,

²Author for correspondence, current address: Department of Biological Sciences, University of Alberta, Edmonton, Alberta T6G 2E9, Canada, mwatters@ualberta.ca
³ Current address: Department of Biological Sciences, University of Alberta, Edmonton, Alberta T6G 2E9, Canada.

Young & Braun, 1999). Destruction of suitable habitat may force birds to use sub-optimal habitat, leading to reduced nesting success and ultimately population decline (Wallestad & Pyrah, 1974).

Nest fate may depend upon a number of variables, including the type and density of predators, health of the parent birds, and amount of available vegetation to provide nest concealment (Martin, 1993). Vegetation structure likely affects the degree of concealment of a nest (Redmond, Keppie & Herzog, 1982), with different vegetation structures providing different elements of concealment. Redmond, Keppie and Herzog (1982) found that superior lateral cover provided by dwarf shrub ground vegetation resulted in high nest success for Spruce Grouse (*Falcipennis canadensis*). In non-forest habitats, grasses and forbs are thought to provide lateral cover, which may obscure the nest from detection by mammalian predators (Larivière & Messier, 1998). Taller shrubs, such as sagebrush, provide canopy cover, which protects nests from visual detection by avian predators (Guyn & Clark, 1997). Previous studies have found that greater densities of taller grasses, forbs, and sagebrush are associated with successful nests (DeLong, Crawford & DeLong, 1995; Sveum, Edge & Crawford, 1998). Thus, although sagebrush has been shown to be important for successful nesting by Sage-Grouse, other vegetation types are also likely important.

Artificial nests have been used to gauge the relative importance of predators and vegetation characteristics to the bird species under consideration (O'Reilly & Hannon, 1989; DeLong, Crawford & DeLong, 1995; Ortega *et al.,* 1998). The addition of clay or plasticine eggs can be used to identify nest predators through the use of dentition records for small mammals and medium-sized predators (Bayne, Hobson & Fargey, 1997; Marini & Melo, 1998).

The purpose of our study was to use artificial nests to experimentally examine the effects of vegetation characteristics on nest fate. We hypothesised that successful nests would be surrounded by taller and denser grasses than those at predated nests. In 1998, we examined the vegetation characteristics affecting the fate of artificial Greater Sage-Grouse nests in southeastern Alberta, Canada. We found that relatively dense forb and sagebrush cover increased the chance of success for these nests. In 1999, we further tested the importance of grass cover and height by trimming grass to ≤ 10 cm in height around half of the artificial nests we set out. We predicted that nests at which the grass was trimmed would experience higher rates of predation. Because lateral cover is thought to be important for hiding nests from mammalian predators, we also predicted that most predation events by mammals would be at nests with short grass.

Methods

STUDY SITE

Our study was conducted during May and June in 1998 and 1999, in a 4,000-km² region in southeastern Alberta (49° 24' N, 110° 42' W). The topography of the landscape consists of gently rolling hills with some badlands. Although there is some cultivation habitat, the area is primarily used for cattle ranching and petroleum extraction. A total of 8 known active Greater Sage-Grouse leks occur in this area (Aldridge, 2000).

Common shrubs in the area include silver sagebrush (*Artemisia cana* Pursh), snowberry (*Symphoricarpus albus* [L.] Blake), and prairie rose (*Rosa arkansana* Porter). Common forbs include prairie sage (*A. ludoviciana* Nutt.) and pasture sage (*A. frigida* Willd.). Unpalatable forbs (those upon which Greater Sage-Grouse do not forage) include ball cactus (*Coryphantha vivipara* [Nutt.] Britt & Rose) and prickly pear cactus (*Opuntia* spp.). Common grasses include blue grama (*Bouteloua gracilis* [HBK] Lag.), june grass (*Koeleria macrantha* [Ledeb.] J. A. Schultes f.), and needle and thread grass (*Heterostipa comata* Trin & Rupr.).

ARTIFICIAL NESTS

To mimic Greater Sage-Grouse eggs in our study, we used medium-sized brown chicken eggs that averaged (mean ± standard deviation) 56.9 ± 2.0 mm by 41.7 ± 3.1 mm (n = 50) and brown plasticine shaped into eggs with dimensions of 55.5 ± 5.4 mm by 38.7 ± 2.1 mm (n = 70). These dimensions approximate real Greater Sage-Grouse eggs (55.0 mm by 38.0 mm; Patterson, 1952). Rubber gloves were worn at all times when handling eggs (DeLong, Crawford & DeLong, 1995), and all chicken and plasticine eggs were rinsed in rain water, sprinkled with Greater Sage-Grouse droppings and feathers, and left outside for four days to reduce human scent (Bayne, Hobson & Fargey, 1997).

In 1998, artificial nests were set out on 28/29 May around each of 4 active leks. Similarly, on 18 and 20 May 1999, artificial nests were set out at each of the four active leks used in 1998, and also at 4 currently inactive leks, for a total of eight groups of nests. Rubber boots and gloves were worn while setting out nests to minimize scent trails to nests (DeLong, Crawford & DeLong, 1995; Bayne, Hobson & Fargey, 1997; Ortega *et al.,* 1998). Five nests were placed on each of four different transects, each radiating from the center of a lek, for a total of 20 nests per lek (Figure 1). The
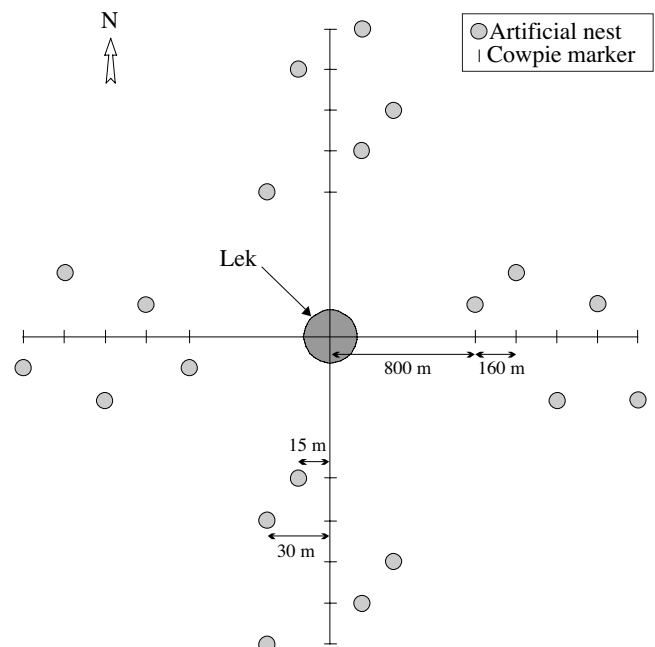

FIGURE 1. Arrangement of artificial nests around Greater Sage-Grouse leks.

first nest was placed 800 m from the center of the lek in each ordinal direction and then at 160-m intervals along each transect.

We used a cowpie as a natural marker at the 800-m location and each consecutive 160-m location. Nests were placed either 15 or 30 m right or left (randomly determined) of the cowpie under the nearest sagebrush. Artificial nests were made to mimic a natural Greater Sage-Grouse nest by scraping a shallow hollow in the ground and lining it with grass previously clipped from around leks. Two chicken eggs and one plasticine egg were placed in each nest. In 1999, we randomly chose nests (about half) at which to experimentally manipulate grass height. We trimmed the grass to ≤ 10 cm within a 0.5-m radius of 76 of 160 nests, while at the other 84 nests the grass was not manipulated. We revisited artificial nests after 27 days in 1998 and after 32 days in 1999 (Greater Sage-Grouse incubation averages 27 days; Schroeder, Young & Braun, 1999, Aldridge & Brigham, 2001), in the same order as they were set out. Nest fate, condition, and location of the eggs were recorded. Nests were considered successful if all three eggs were unmarked and in the nest, or if the eggs had only claw or tooth marks of mice. Mice are too small to eat grouse eggs and thus are not considered potential predators (Einarsen, 1900). If a predation event occurred, the plasticine egg was collected (if present), and bite marks in the eggs were compared to dentition of small mammal skulls and the beaks of birds to identify predators (Pasitschniak-Arts & Messier, 1995).

VEGETATION MEASUREMENTS

When nests were revisited, we measured the percent cover of sagebrush, other shrubs, grasses, forbs, unpalatable forbs (those not consumed by Greater Sage-Grouse), and bare ground (which included dead/fallen vegetation) in a 1-m^2 quadrat centered on the nest. Each vegetation type was assigned a percent value in 5% increments. Shrub and understory vegetation were not stratified into separate layers when estimating cover, such that the total cover estimate for each quadrat did not exceed 100%. The mean maximum height of each vegetation type was estimated by averaging three measurements of the tallest plants of that type. These cover and height measurements provided an index of concealment in the area directly surrounding the nest. In 1999, we used a white disk, similar to a secchi disk, with eight different wedges to assess the structural cover directly over the nest bowl. This disk was placed on the nest bowl and observed from a height of 1 m directly above the nest and from 1 m away at a height of 1 m in the 4 ordinal directions. For each observation, the number of wedges intercepted by vegetation was summed to get an index of nest cover (referred to as secchi index), similar to Guyn and Clark (1997), and the five scores were summed to give an index of overall nest coverage.

STATISTICAL ANALYSES

Data from 1998 and unmanipulated 1999 nests were combined and logistic regression used to analyse the effects of lek location and vegetation characteristics on nest fate. Using a Chi-squared test (α = 0.05), we then analysed the effects of trimming for the subset of the 1999 data only.

The effect of the trimming treatment, lek status, distance and direction from lek center, and contribution of each vegetation group to the fate of the nest was examined by performing a forward stepwise logistic regression (DeLong, Crawford & DeLong, 1995). Correlated variables (r ≥ 0.70; Pearson Correlation Coefficient) measure similar characteristics, and thus, only one of the pair of correlated variables was included in regression analyses (Dunn & Braun, 1986). Like Dunn and Braun (1986), we chose the variable on the basis of ease of biological interpretation.

A series of models were computed using statistical software available with SPSS and Statistica (SPSS, 1999; StatSoft, Inc., 1999). Akaike's Information Criterion (AIC) procedure was used to select the best model (Anderson, Burnham & Thompson, 2000). We report all models with a ∆AIC of ≤ 1.00, although discussion will focus on the results of the best model (∆AIC = 0).

A second forward stepwise logistic regression analysis was performed using data from unsuccessful nests only to identify vegetation and lek characteristics at nests predated by small mammals versus those at nests predated by birds. We used ground squirrel and avian predators as dependent variables. Once again, we followed AIC procedure and report models with a ∆AIC of ≤ 1.00. All statistical tests were performed assuming an α value of 0.05.

Results

In 1998, all 80 nests were recovered, and in 1999 we recovered all but two of 160 artificial nests. Over both years of the study, 42 (18%) of the total 238 nests were successful. Richardson's ground squirrels were identified as nest predators for 127 (65%) of the 196 unsuccessful nests, while birds were responsible for 35 (18%) of the predation events and badgers were responsible for 6 (3%) of the predation events. At 57 (29%) of the unsuccessful nests, the 3 eggs were absent, possibly removed by larger mammals such as cows or canids. Seven percent of the plasticine eggs indicated visits by different predators, as some had both tooth and beak marks; therefore, it was not always possible to unequivocally determine which predator initially attacked the nest.

Data were checked for outliers by calculating Leverage values (SPSS) and excluding the 2 cases for which Leverage values exceeded (k+1)/N (Menard, 1995). Data were also checked for multicollinearity (SPSS), and if correlations were found, we removed one or more of the affected variables.

When both years of data were combined, we found that lek status, distance of the nest from the lek center, and direction from the lek did not appear in any models predicting nest fate. To detect correlation between variables, we calculated Pearson correlation coefficients for all variables in the combined data set of unmanipulated nests. We found that shrub cover and height were highly correlated (r = 0.998), as were unpalatable forb cover and height (r = 0.990). The secchi index value was positively correlated with sagebrush cover in the plot (r = 0.58). For each case when a significant correlation (r > 0.70) existed between cover and height of a vegetation, only the cover variables were entered into the model. Thus, the following variables were tested in the nest fate and predator type models: number of sagebrush plants around nest, sagebrush cover and

height, shrub cover, unpalatable forb cover, forb cover, forb height, and grass cover and height.

The best-fit model that predicted nest fate at unmanipulated nests over both study years included forb cover, sagebrush cover, and number of sagebrush around the nest (ΔAIC = 0, 65.4% correct classification). Successful nests had greater forb and sagebrush cover, but fewer sagebrush plants around them (Table I). A second model that included grass height was also very effective at predicting nest fate (ΔAIC = 0.261, 65.4% correct classification). Grass height was greater at successful nests relative to predated nests (34.5 cm versus 30.0 cm). Grass cover and height, forb cover, and number of sagebrush plants occurred in a third model (ΔAIC = 0.863, 64.2% correct classification). Grass cover was 37.0% at predated nests, but only 32.4% at successful nests.

In 1998, we found that the average height of grass at successful nests was 22.6 ± 7.4 cm (n = 17), and the grass height at unsuccessful nests was 17.8 ± 5.8 cm (n = 63). In 1999, grass height at successful and unsuccessful nests was 42.6 ± 13.8 (n = 25) and 36.3 ± 11.9 (n = 133), respectively.

Of the 76 nests where we trimmed grass in 1999, 8 were successful, while 17 of the 82 untrimmed nests were successful (χ^2_1 = 2.70, P > 0.10). Thus, trimming the grass did not significantly affect nest fate. At the outset of the experimental treatment in 1999, grass around nests was trimmed to be shorter (9.5 ± 1.7 cm versus 21.9 ± 4.1 cm; P < 0.001) than unmanipulated grass. At the end of 32 days, trimmed grass was still shorter (32.4 ± 9.7 cm versus 40.8 ± 14.3 cm; P < 0.001) than unmanipulated grass.

We entered the same variables into a second logistic regression analysis to develop a model that would predict predator type (ground squirrels versus birds). Only those eggs for which predator type could be positively identified were used in analyses. A single model had a ΔAIC ≤ 1.00. In that model, ground-squirrel-predated nests were surrounded by less forb cover and fewer sagebrush plants and occurred at active leks, compared with avian-predated nests (ΔAIC = 0, 74.3% correct classification; Table II). More ground-squirrel predation events occurred at nests surrounding active leks than at inactive leks ($F_{1, 103}$ = 11.632, P = 0.001).

Discussion

In general, cover provided by sagebrush and forbs were the most important predictors of nest predation. Successful nests were surrounded by fewer sagebrush plants (Table I). We suggest that lateral cover provided by forbs and greater numbers of sagebrush plants were important in protecting artificial Greater Sage-Grouse nests from predation by small mammals. Avian predation was more common at inactive leks. Reduced grass cover, although less important than forb cover and number of sagebrush plants, did appear to increase the chances of ground-squirrel predation. This suggests that grazed vegetation, including grasses and forbs, should be considered in managing habitat for Greater Sage-Grouse.

We found that experimentally reducing grass height surrounding nests did not lead to increased nest predation, although predation tended to occur at a higher rate at nests with trimmed grass. These unexpected results may have

TABLE I. Nest fate based on the three vegetation characteristics in all logistic regression models with ΔAIC ≤ 1.00. Means are shown ± SD of vegetation for successful and unsuccessful nests, with percent cover and height (cm). Exp β represents the log odds ratio, the number by which the odds of nest success change given an increase of 1 in that variable.

Model	Variables	Successful nests (n = 34)	Unsuccessful nests (n = 130)	Estimated coefficient	SE	Exp β
MODEL 1						
ΔAIC = 0	Forb cover	11.1 (7.2)	8.2 (6.4)	0.108	0.036	1.115
	Sagebrush cover	26.5 (13.0)	24.9 (14.4)	0.030	0.014	1.030
	# sagebrush	3.1 (3.2)	3.4 (3.2)	-0.175	0.102	0.839
MODEL 2						
ΔAIC = 0.261	Forb cover	11.1 (7.2)	8.2 (6.4)	0.105	0.037	1.110
	Sagebrush cover	26.5 (13.0)	24.9 (14.4)	0.028	0.014	1.028
	# sagebrush	3.1 (3.2)	3.4 (3.2)	-0.170	0.102	0.844
	Grass height	34.5 (15.2)	30.0 (13.8)	0.017	0.013	1.017
MODEL 3						
ΔAIC = 0.863	Grass cover	32.4 (14.7)	37.0 (17.0)	-0.025	0.014	0.975
	Grass height	34.5 (15.2)	30.0 (13.8)	0.028	0.014	1.028
	Forb cover	11.1 (7.2)	8.2 (6.4)	0.080	0.036	1.083
	# sagebrush	3.1 (3.2)	3.4 (3.2)	-0.160	0.102	0.852

TABLE II. Vegetation and lek characteristics of predated nests in the predator logistic regression model with ΔAIC ≤ 1.00. Means are shown ± SD of vegetation for Richardson's ground squirrel (RGS) and bird predated nests, with percent cover and height (cm). Exp β represents the log odds ratio, the number by which the odds of a certain predator type change given an increase of 1 in that variable.

Model	Variables	RGS predated nests (n = 89)	Bird predated nests (n = 16)	Estimated coefficient	SE	Exp β
MODEL 1						
ΔAIC=0	Forb cover	7.4 (5.4)	11.6 (8.5)	-0.156	0.055	0.856
	Lek status	Active	Inactive	2.356	0.103	10.552
	# sagebrush	3.3 (3.1)	4.8 (4.4)	-0.280	0.728	0.756

been related to the unusually lush growth of vegetation during the spring of 1999, which meant that trimmed grass was taller than untrimmed grass in 1998. We suggest that trimming might have had a significant effect on nest fate if the experiment had been conducted in a year with reduced spring precipitation. This is supported by the trend of trimmed nests having greater rates of predation than unmanipulated nests.

Ground squirrels were the major predators of artificial nests. They are also responsible for about half of all nest predation events on real Greater Sage-Grouse nests in the study (C. L. Aldridge, unpubl. data). Thus, when available, lateral cover such as that provided by grasses and forbs should be selected by birds to reduce predation risk (Redmond, Keppie & Herzog, 1982; DeLong, Crawford & DeLong, 1995; Sveum, Edge & Crawford, 1998).

According to the best model (ΔAIC = 0), successful nests had greater forb cover than unsuccessful nests (Table I). Larivière and Messier (1998) suggested that dense forbs may impede the movement of small mammals, thereby decreasing nest predation. Based on our best-fit model, an increase in forb cover from 8 to 11% would improve nest success by 4%. Our results confirm the importance of herbaceous understory suggested by Connelly *et al.* (2000) and the necessity to include grasses and forbs in Sage Grouse management plans.

It is clear that many types of vegetation, in addition to sagebrush, influence the fate of artificial Greater Sage-Grouse nests. Gregg *et al.* (1994) reported that Sage Grouse nests were more successful when surrrounded by grass ≥ 18 cm in height and under sagebrush 40-80 cm in height. Aldridge and Brigham (2001) found that at various scales surrounding nest sites, successful nests had taller forbs and grass, but less grass cover. Perhaps forb cover is especially important for successful nesting by Greater Sage-Grouse populations at the northern edge of the range, because *A. cana* does not provide the same degree of nest concealment that the larger *Artemisia tridentata* Nutt. provide throughout the core of the Greater Sage-Grouse range.

Our predator model indicates that nests predated by ground squirrels had less forb cover (Table II), suggesting these nests were more visible and/or accessible to mammalian predators. In addition, the chance of ground-squirrel predation was reduced by 76% for each additional sagebrush around the nest, suggesting that sagebrush plants provide lateral cover in addition to canopy cover.

The odds of avian predation were 10.6 times greater at nests surrounding inactive leks. The fact that avian predation was more common at inactive leks suggests that these leks may have become inactive due to high rates of predation by corvids and possibly raptors. Greater Sage-Grouse may prefer to nest in areas where avian predators are less common, and thus leks in these areas have remained active.

Although they are commonly used, there is debate surrounding the use of artificial nests and the effectiveness of such nests in mimicking predation events on natural nests. Over the course of this study, 46.2% (*n* = 26; Aldridge and Brigham, 2001) of natural Greater Sage-Grouse were successful, while artificial nests in our study were successful only 16% of the time. This suggests that artificial nests incur higher rates of predation than natural Greater Sage-Grouse nests. Therefore, we concur with the idea that artificial nests should not be used to directly predict predation on natural nests, but may be used to identify potential predators of natural nests and vegetation characteristics related to nest success.

Management Suggestions

Our study indicates that vegetation structure is important to the fate of artificial Greater Sage-Grouse nests. Although grazing has yet to be shown to have a direct negative effect on Sage Grouse (Connelly *et al.*, 2000), the impact of ungulate use of sagebrush steppe can be surmised. Grazing can have a profound impact on the vegetation of an ecosystem, by reducing the herbaceous material in a region (Austin & Urness, 1998), decreasing vegetation height and density, and creating open areas preferred by Richardson's ground squirrels (Laundre & Appel, 1986; Michener, 1996; Baker, Stanley & Sedgwick, 1999). Higher predator densities typically lead to higher rates of nest predation (Ritchie, Wolfe & Danvir, 1994), and thus heavy grazing may increase ground squirrel populations, leading to increased predation rates. Grazing reduces vegetation structure and thus increases the visibility of the nests. Quantitative studies are necessary to measure the effects of grazing on the nest success of Canadian Greater Sage-Grouse. The cumulative effects that altered grazing regimes will have on predator communities, specifically ground squirrels, also need to be monitored, especially in conjunction with natural nests.

In summary, we concur with the management guidelines established by Connelly *et al.* (2000). Local knowledge and consistent monitoring of Greater Sage-Grouse populations will help researchers and land-owners understand the requirements of each population and lead to effective land management and habitat conservation.

Literature cited

Aguiar, M. R. & O. E. Sala, 1998. Interactions among grasses, shrubs, and herbivores in Patagonian grass-shrub steppes. Ecologia Austral, 8: 201-210.

Aldridge, C. L., 1998. Status of the Sage grouse (*Centrocercus urophasianus urophasianus*) in Alberta. Alberta Environmental Protection, Wildlife Management Division, and Alberta Conservation Association, Wildlife Status Report No. 13, Edmonton, Alberta.

Aldridge, C. L., 2000. Reproduction and habitat use by Sage grouse (*Centrocercus urophasianus*) in a northern fringe population. M.Sc. Thesis, University of Regina. Regina, Saskatchewan.

Aldridge C. L. & R. M. Brigham, 2001. Nesting and reproductive activities of Greater Sage-Grouse in a declining northern fringe population. Condor, 103: 537-543.

Anderson, D. R., K. P. Burnham & W. L. Thompson, 2000. Null hypothesis testing: Problems, prevalence and an alternative. Journal of Wildlife Management, 64: 912-923.

AOU (American Ornithologists' Union), 1983. Checklist of North American Birds. 6th Edition. Allen Press, Lawrence, Kansas.

Austin, D. D. & P. J. Urness, 1998. Vegetal change on a northern Utah foothill range in the absence of livestock grazing between 1948 and 1982. Great Basin Naturalist, 58: 188-191.

Baker, B. W., T. R. Stanley & J. A. Sedgwick, 1999. Predation of artificial ground nests on white-tailed prairie dog colonies. Journal of Wildlife Management, 63: 270-277.

Bayne, E. M., K. A. Hobson & P. Fargey, 1997. Predation on artificial nests in relation to forest type: Contrasting the use of quail and plasticine eggs. Ecography, 20: 223-239.

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

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

COSEWIC, 1998. Canadian Species at Risk. Committee on the Status of Endangered Wildlife in Canada, Ottawa, Ontario.

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

Dunn, P. O. & C. E. Braun, 1986. Summer habitat use by adult female and juvenile Sage grouse. Journal of Wildlife Management, 50: 228-235.

Einarsen, A. S., 1900. Determination of some predator species by field signs. Oregon State Monographs, Studies in Zoology, No. 10. Oregon State College, Corvallis, Oregon.

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

Guyn, K. L. & R. G. Clark, 1997. Cover characteristics and success of natural and artificial duck nests. Journal of Field Ornithology, 68: 33-41.

Larivière, S. & F. Messier, 1998. Effect of density and nearest neighbours on simulated waterfowl nests: Can predators recognize high-density nesting patches? Oikos, 83: 12-20.

Laundre, J. W. & N. K. Appel, 1986. Habitat preferences for burrow sites of Richardson's ground squirrels in southwestern Minnesota. Prairie Naturalist, 18: 235-239.

Marini, M. A. & C. Melo, 1998. Predators of quail eggs and the evidence of the remains: Implications for nest predation studies. Condor, 100: 395-399.

Martin, T., 1993. Nest predation and nest sites: New perspectives on old patterns. BioScience, 43: 523-532.

Menard, S., 1995. Applied Logistic Regression Analysis. Sage Publications Inc., Thousand Oaks, California.

Michener, G. R., 1996. Establishment of a colony of Richardson's ground squirrels in southern Alberta. Pages 303-308 *in* W. D. Willms & J. C. Dormaar (ed.). Proceedings of the 4th Prairie Conservation and Endangered Species Workshop. Provincial Museum of Alberta Natural History Occasional Paper 23, Lethbridge, Alberta.

O'Reilly, P. & 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.

Ortega, C. P., J. C. Ortega, C. A. Rapp & S. A. Backensto, 1998. Validating the use of artificial nests in predation experiments. Journal of Wildlife Management, 62: 925-932.

Pasitschniak-Arts, M. & F. Messier, 1995. Predator identification at simulated waterfowl nests using inconspicuous hair catchers and wax-filled eggs. Canadian Journal of Zoology, 73: 984-990.

Patterson, R. L., 1952. The Sage grouse in Wyoming. Wyoming Game and Fish Commission. Sage Books, Inc., Denver, Colorado.

Redmond, G. W., D. M. Keppie & P. W. Herzog, 1982. Vegetative structure, concealment, and success at nests of two races of Spruce Grouse. Canadian Journal of Zoology, 60: 670-675.

Ritchie, M. E., M. L. Wolfe & R. Danvir, 1994. Predation of artificial Sage grouse nests in treated and untreated sagebrush. Great Basin Naturalist, 54: 122-129.

Schroeder, M. A., J. R. Young & C. E. Braun, 1999. Sage grouse (*Centrocercus urophasianus*). *In* A. Pool & F. Gill (ed.). The Birds of North America, No. 425. The Birds of North America, Inc., Philadelphia, Pennsylvania.

SPSS, 1999. SPSS for Windows, SPSS, Inc., Chicago, Illinois.

StatSoft, 1999. STATISTICA for Windows. StatSoft, Inc., Tulsa, Oklahoma.

Sveum, C. M., J. A. Crawford & W. D. Edge, 1998. Use and selection of brood-rearing habitat by Sage grouse in south-central Washington. Great Basin Naturalist, 58: 344-351.

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

Wallestad, R. O. & D. B. Pyrah, 1974. Movement and nesting of Sage grouse hens in central Montana. Journal of Wildlife Management, 38: 630-633.