

Using Survival Analysis of Artificial and Real Brewer's Sparrow (*Spizella breweri breweri*) Nests to Model Site Level and Nest Site Factors Associated with Nest Success in the South Okanagan Region of Canada¹

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Abstract

Predation is the predominant cause of nest failure for the Brewer's Sparrow (*Spizella breweri breweri*), a provincially red-listed shrub-steppe species that has experienced significant declines throughout most of its range. We monitored Brewer's Sparrow nests and conducted an artificial nest experiment, in the South Okanagan Valley, British Columbia (B.C.), to investigate factors associated with nest predation. Avian predation of artificial nests was higher when nests were placed in smaller shrubs, set out earlier in the season and when corvid numbers were high. Predator imprints on clay eggs in the artificial nest experiment showed that rodent predation increased through the season. Results from real nests indicate that nest initiation date was also an important predictor of nesting success with more predation by all predators later in the season. Nesting density was lower at sites with more corvids, and much higher at similar sites with low corvid numbers. Our results suggest that Brewer's Sparrows select sites lower in avian nest predator activity and that this results in the effect of other predators such as rodent becoming more apparent.

Keywords: artificial nests, Brewer's Sparrow, corvids, depredation, predator avoidance, *Spizella breweri breweri*, survival analysis, timing.

Introduction

Like many other species in shrub-steppe habitat, Brewer's Sparrow numbers are declining at an estimated 3.2 percent per year range wide (Sauer et al. 2001). Brewer's Sparrow is red-listed in British Columbia (BC), due to small population numbers and threatened sagebrush habitats (Sarell and McGuiness 1996). The BC population is at the northern extent of the species' range and may play a crucial role as a source population for declining populations in the south. It is therefore important to understand the factors that affect this population and to address problems that may further reduce population size.

Several studies have assessed nest placement and nest site characteristics for Brewer's Sparrows (Petersen and Best 1985, Knick and Rotenberry 1995). Only a few studies have attempted to determine what influence habitat differences have on Brewer's Sparrow nesting success (Reynolds 1981, Mahony unpubl. ms.). However, in these studies, sample sizes were small and associations were only tested at the nest shrub or nest patch level. Our objectives are to examine the relative importance of site level and individual nest variables on the nesting success of artificial nests and then to compare the results to those from real Brewer's Sparrow nest survival. Site level factors tested in this study include the associations of nest survival with nesting density and predator activity. Individual nest variables modeled using survival analysis are nest concealment, distance to nearest tree, density of trees, distance to the nearest neighbour and timing.

Methods

Artificial nest experiments and real nest monitoring were conducted simultaneously to determine factors associated with nest survival during the summer of 2000, from 1 May to the end of July, coinciding with Brewer's Sparrow's breeding season (Cannings et al. 1987). The six sites used for the artificial nest experiment were located in the shrub-steppe habitat of the South Okanagan region, British Columbia, Canada, in the region between the villages of Keremeos (49° 12'N, 119°49'E) and Okanagan Falls (49°20'N, 119°

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34'E). Using survey data from Paczek (2002), we were able to select six sites with known Brewer's Sparrow relative abundance and comparable characteristic known to be associated with Brewer's Sparrow abundance. Because these characteristic were selected based on correlations with abundance it was difficult to obtain constant sites, however all our sites were had comparable lupine, parsnip buckwheat, and sagebrush cover but varied in litter cover. Litter cover was assumed not to affect the distribution of corvids or nest predation rate. Rather, its influence would primarily be in site selection for food availability.

Artificial Nests

We compared the nest predation rates in three sites with low relative abundance to three sites with high relative abundance. We established eight transects of artificial nests at each of the six sites. Each transect consisted of six artificial nests placed at 5, 30, 55, 80, 105, and 130 m (25 m increments) from the base of isolated conifer trees. Trees had a mean height of 16 meters (range 5-30 m).

Every attempt was made to mimic the dimensions and construction of the Brewer's Sparrow nest to provide a similar search image for predators. We used commercially purchased realistic woven-grass canary nests (approximately 10 cm in diameter and 4 cm deep; Hagen[®] item B-1980) and two colored clay eggs for artificial nests. Two kinds of non-toxic clay with negligible odor were used to make the eggs: 1) Sculpey II[®], which can be permanently hardened by baking. This is useful because it provided a permanent record, and 2) Aken plastaline[®] (Plastaline modeling clay; Van Aken international, Rancho Cucamonga, CA) was also used as it was the clay most commonly used in artificial nest experiments. Modeling clay provided an excellent substrate for recording tooth or beak imprints. Clay eggs were placed in nests for a 12-day cycle, based on the approximate incubation period of Brewer's Sparrows of 11 days (Rotenberry and Wiens 1991). The nests were checked between sunrise and 12:00 on the 3rd, 6th, and 12th day of each trial. A nest was considered depredated if one or both eggs were missing, or marked with direct evidence of predation such as beak, tooth, or scratch marks. Untouched eggs were removed on the last (12th) day. After being left empty for 8 days, the nests were moved at least 5 m in random directions and reset for another 12 days, three trials in total were run.

Real Nests

Real nest searching and survival monitoring was conducted at 10 sites, six of which overlapped the artificial nest experiment sites. Real nest monitoring was conducted on a three-day rotation for six sites and a four-

day rotation for the remaining four sites. Nests were considered successful if they were found empty after the expected fledging date (8-9 days after hatching), and signs of a successful fledge were observed. Nests that were abandoned with all the eggs intact were removed from the analysis. To avoid pseudo-replication (Hurlbert 1984), only first nesting attempts were used in the data analysis, and re-nests were disregarded.

Multivariate Analysis to Model Predation Patterns for Each Predator Type

To assess factors that are associated with nest survival we modeled the follow individual nest variables using survival analysis; nest concealment, distance to the nearest neighbour, tree encroachment predictors (distance to nearest tree, density of trees) and timing.

Characteristics of nest placement were measured: height of above the ground (m), plant height (m), plant species in which the nest was built or placed, number of supporting branches, and percentage overhead cover. These characteristics were measured for every real and artificial nest. To prevent abandonment, measurements were taken once a nest became inactive. Nest height was measured from the ground to the rim of the nest with a meter stick. Plant height was measured from the ground to the top of the plant that the nest was built or wired in. Cover height was calculated by subtracting the difference between plant height and nest height. Percent overhead cover was estimated from the amount of vegetation covering the nest one meter above the nest. To avoid observer bias, one person estimated percent overhead cover and counted the number of supporting branches for all of the nest sites. However, percent cover estimates and branch counting were prone to measurement error and were not used in the model building process; rather they were used to compare general nest characteristics between real and artificial nests.

Nearest neighbour distances or the distances between nests were estimated using precise geographical locations of all nests were measured and mapped in AutoCAD[®] (Autodesk 2002). Nearest neighbour was used as an individual nest variable in the analysis of real nests only. It was not used in the artificial nest analysis because the artificial nests were all placed equal distances apart, at 25 meters increments.

To determine the effect of tree encroachment on nest predation, tree density and horizontal distance to the closest tree were measured using a Nikon Laser 800 Rangefinder directed perpendicularly to the trunk of a tree. Tree density was the count of all trees greater than five meters high (conifer and deciduous) within 100 meters of the nest. Tree density estimates were grouped categorically; 0-5 trees was low tree density, 6-10 trees

was medium density and high tree density was greater than or equal to 11 trees within 100 m. Measurements were recorded for all artificial and real nests.

Clutch initiation date was determined from either nest observations or counting backwards from the hatching or fledging date. The hatching date for Brewer's Sparrow eggs is 10-12 days with a mean of 11 days (Reynolds 1981, Rotenberry and Wiens 1991) and was used to calculate laying date or the start of the egg stage. Fledging was expected to occur between 7-9 days after hatching. Thus, an eight day (Rotenberry and Wiens 1991) mean fledging time was used to calculate hatching date, the start of the nestling stage.

Model building using survival/failure time analysis under Cox's Model, in combination with forward step-wise selection process, was used to determine which factors most strongly influenced nest predation rate. Akaike Information Criterion (AIC) (Burnham and Anderson 1998) was used at each step of the modeling process to evaluate and select the most parsimonious model that best fit the data, and to determine the contribution of each variable to the model, using methods suggested by Collett (1994). Because, there were several cases where the models were tied for best fit (AIC within 1 or 2 units), we assessed the uncertainty around the models selected using Akaike Weights (w) (Burnham and Anderson 1998) of models. The variables entered into the Cox's regression models were: distance from tree; tree density within 100 meters from the nest; plant height (correlated with height of nest placement); distance to the nearest neighbour for real nest predation only; and clutch initiation date (time).

Site Level Variables for Univariate Analysis

To assess the importance of nest patch area, predator abundance, predator activity, breeding pair density, and nest density estimates, the Mayfield daily survival rate was calculated for each site by grouping all nests at each site. Appropriate modifications were made (maximum likelihood estimator of survival rate; MLE) as nests were visited periodically and the exact date of depredation is unknown (Bart and Robson 1982, Krebs 2000).

Each predator type was analyzed separately for artificial nests; avian, mammalian, and pooled predators. The daily survival rate (DSR) for real nests includes all predator types, as the predator type cannot be determined with confidence (Pietz and Granfors 2000). Univariate correlation statistical tests were performed using STATISTICA[®] (Statsoft Inc. 1999). MLE was calculated using the program SURVIVAL (Krebs 2000). All correlation analyses are Spearman Rank correlation (r_s).

The effects of population size and density of Brewer's Sparrows on nest predation were investigated using two measures of density: 1) nest density (number of nests per ha) and 2) breeding pair density (number of singing males/area), estimated using a combination of line and point count survey procedures (Recher 1988, Zanette and Jenkins 2000). Additionally, the area occupied by the population was calculated to determine the potential effects of nesting patch size on the nesting success.

Potential nest predators were monitored throughout the study at six sites using a measure of activity level. To produce an avian nest predator activity index, each observer independently recorded potential predators encountered while conducting fieldwork, the frequency of observations, and the number of hours spent in the area. Moving predators were recorded only where first seen, and repetitive daily sightings of the same species in the same place were recorded only once by that person for that day. To avoid overestimates, duplicate auditory or visual detections coming from the same direction were omitted. Results for all observer-days were combined to calculate the average number of predators seen per hour (encounter rate). Counts were not conducted during inclement weather. Predator activity was compared to the number of Brewer's Sparrow nests present at the site to determine if there were fewer predators at sites 'high' in Brewer's Sparrows. Sites designated as 'low' Brewer's Sparrow sites had less than five nests per site and 'high' Brewer's Sparrow sites had greater than five nests.

Results

Multivariate Analysis

For real nests, clutches initiated earlier in the season had a greater chance of survival than later nests ($\Delta AIC_c = 0.00$, $w = 0.36$, $p < 0.05$). Artificial nests showed a similar trend for predation by pooled predators ($\Delta AIC = 1.62$, $w = 0.26$, $p < 0.01$), and by mammals ($\Delta AIC = 0.00$, $w = 1.00$, $p < 0.00$). Avian predation of artificial nests decreased through the season, but not significantly ($\Delta AIC = 7.40$, $w = 0.02$, $p = 0.12$).

The effect of plant height on nest survival differed between real and artificial nests. Plant height did not influence survival of real nests. However, artificial nests placed in taller shrubs experienced less avian predation ($\Delta AIC = 1.82$, $w = 0.26$, $p < 0.01$). Plant height in combination with time was a competing model, as artificial nests placed in taller shrubs and initiated later experienced less avian predation risk ($\Delta AIC = 0.00$, $w = 0.66$, $p < 0.00$). Predation of artificial nests by pooled predators also decreased with

increased plant height, but only in combination with time ($\Delta AIC = 0.00$, $w = 0.59$, $p < 0.01$).

Plant height was not an important variable for real nest survival, perhaps because plant height was associated with cover ($r_s = 0.79$, $p < 0.00$, $n = 122$). There were significant differences between plant heights, percent overhead cover and cover height between real and artificial nests (Mann-Whitney U-test; $z = 5.82$, $p < 0.00$, $z = 10.64$, $p < 0.00$, and $z = 7.02$, $p < 0.00$, respectively). Despite placing artificial nests at previously reported nest heights for Brewer's Sparrows, real nests were placed in plants with a higher mean height (mean 87.39 ± 25.4 SD) than artificial nests (mean 72.88 ± 26.5 SD). The mean cover height for the real nests was 55 cm whereas for artificial nests the mean cover was much less at 42.5 cm).

Univariate Analysis

Potential avian nest predators were mostly within the family Corvidae and included the American Crow (*Corvus brachyrhynchos*), Common Raven (*Corvus corax*), and Black-billed Magpie (*Pica pica*). Nesting density had no effect on nest survival. Predator activity was significantly higher in sites that were lower in Brewer's Sparrow abundance, when compared to the other higher abundance sites ($n = 6$, $r_s = -0.81$, $p < 0.05$). Avian nest predator activity was associated with reduced survival of real nests ($n = 4$, $r_s = -1$, $p < 0.00$) and reduced artificial nest survival attributable to avian predators ($n = 6$, $r_s = -0.83$, $p < 0.04$), which provides evidence that when avian nest predator activity is high nest survival decreases. In contrast, mammalian predation did not vary significantly between high and low Brewer's Sparrow abundance sites (Mann-Whitney U-test $z = -0.77$, $p = 0.44$).

Discussion

Temporal Changes

Increased predation later in the season was the most important factor affecting nest predation of real nests. Artificial nests indicated that mammalian predation rate also increased through the season. A similar increase in mammalian predation has been associated with a seasonal increase in abundance and dispersal of hungry juveniles (Briese and Smith 1974) and is likely to case at our sites (Klenner, pers. comm.¹). Snakes have been documented as important predators in shrub lands (Best 1978, Thompson et al. 1999), but were

rarely attracted to artificial nests (Marini and Melo 1998). Thus, increased predation in real nests over time might have been attributable to snakes as well as small mammals, but this could not be documented using artificial nests.

In contrast to our results, the reverse pattern of decreased predation through time has been documented elsewhere. Increased nest predation early in the season has been linked with the dispersal of juveniles and fledging avian predators (Zimmerman 1984, Patnode and White 1992, Sloan et al. 1998). Corvids breeding in the spring are known to use the eggs of other species to supplement the diet of their weaning or fledging young (Boarman and Heinrich 1999). This explanation does not seem probable for this study, although many of the nest predators were corvids, timing did not have a strong effect on the avian predation rate of artificial nests. Additionally, avian predation of real nests might have been minimized, if Brewer's Sparrows avoided sites high in corvids when selecting sites. Our results suggest that birds were the primary predators for artificial nests but mammalian predation might have been the dominant predator of real nests (Willebrand and Marcstrom 1988, MacIvor et al. 1990).

Plant height and nest height were strongly associated and provided an index of nest concealment. Concealment was not related to the survival of real Brewer's Sparrow nests but was for artificial nest. Our results are contrary to those in Martin's (1992) review, which found that artificial and real nests that are more concealed were less likely to be depredated. However, several studies have found an effect of nest concealment on artificial nests but failed to find one for in real nests (Storaas 1988, Cresswell 1997). There are three plausible explanations for this contradiction:

- 1) Concealment may be important for Brewer's Sparrows but they were selecting for overall cover at the nest-patch scale (Martin and Roper 1988, Martin 1992), which was not measured in this study.
- 2) Shrub cover was already at an optimal level so that the range in cover did not provide enough statistical evidence of minor changes in predation rate.
- 3) Avian predation was not as important as ground-dwelling predators, making the influence of overhead cover negligible.

Real nests found in this study were placed in plants with a higher mean height than what has been documented in other studies ($69 \text{ cm} \pm 15 \text{ SD}$, $n = 58$ [Petersen and Best 1985], $66.9 \text{ cm} \pm 11.3 \text{ SD}$, $n = 27$ [Rich 1980], $71.36 \text{ cm} \pm 1.23 \text{ SD}$, $n = 89$ [Rotenberry

¹Walt Klenner is a wildlife biologist at British Columbia Ministry of Forests and works on small mammals in the South Okanagan.

et al. 1999]). This may be an indication that mammal and snake predation may have been more important than that of avian predation. Additionally, Sullivan and Dinsmore (1990) found that cover height reduced crow predation of egg up until 20cm, but beyond 20 cm there was no substantial reduction in predation. The majority of real nests at our sites had more than 20 cm of cover height with an average of 55 cm (range 17-164 cm). Brewer's Sparrows at our sites may be nesting under an optimal amount of cover, thus the changes within the range of cover may not be extreme enough to alter predation rates.

Predator Avoidance through Site Selection

Our results suggest that Brewer's Sparrows prefer to nest in sites that are lower in corvid numbers. Nest predator avoidance can be identified by a reduction in the number of nests found at these sites. Only four real nests were found at sites high in avian predators and these nests were distributed at a lower mean density. This suggests that Brewer's Sparrows may avoid nesting in areas high in corvid numbers. The relationship between nest predator activity and nest predation rates is not surprising and is consistent with other studies (Zanette and Jenkins 2000). Increased predator activity and predation should result in a selective force for Brewer's Sparrows to nest in areas that are lower in nest predator activity. Paczek (unpubl. data) also suggests that Brewer's Sparrows were negatively correlated with avian nest predators ($n=159$, $r_s = -0.48$, $p = 0.00$).

Our artificial nest results support research that found predator presence was correlated to the potential rate of predation by that predator (Angelstam 1986, Andrén 1992). This supports that notion that surveys of nest predators can increase the understanding of predation risk and particular sites (Sloan et al. 1998). Andrén (1995) stresses the importance of knowing predator community composition for understand changes in predation patterns. For instance, mammalian predation did not differ between high and low Brewer's Sparrow density (see Welstead 2002 for details). These differences in spatial patterns of nest predation with predator types have been well documented (Nour et al. 1993, Haskell 1995, Hannon and Cotterill 1998).

Management Implications

It is advised that long term monitoring of corvid populations be conducted and the influence of avian nest predator numbers be a consideration when investigating the impacts of urban sprawl and agricultural conversion in the South Okanagan. Density of corvids tended to increase proportionally with the encroachment of agricultural land into to natural habitat (Andrén 1992). If Brewer's Sparrows require sites that

are low in corvid numbers for nesting and if corvid numbers increase in the South Okanagan, it maybe hard for Brewer's Sparrows to select sites low in corvid numbers.

Additionally, tree encroachment, which is a concern in the South Okanagan due to fire suppression (Turner and Krannitz 2001), may be a contributing factor to the increase in density of nest predators (Krannitz and Rohner 2000). Encroaching trees provide perching and nesting sites for a number of avian nest predators such as corvids (Loman and Göransson 1978, Sullivan and Dinsmore 1990).

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