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Original Article

Effects of Road Construction Noise on the Endangered Golden-Cheeked Warbler

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ABSTRACT Noise pollution can mask or distort bird songs, which can inhibit mating success, predator detection, and parental response to begging calls. Using an impact assessment design, we examined the potential influence of road construction and road noise on territory placement, reproductive success, and density of the federally endangered golden-cheeked warbler (*Dendroica chrysoparia*) at 3 sites: adjacent to road construction, adjacent to road-noise only, and a control with no noise or activity. Although not statistically significant, reproductive success was about 20% higher and stable at road-noise-only sites relative to other treatments. Warbler density was similar among sites (construction = 0.305 birds/ha; road-noise = 0.357 birds/ha; and control = 0.328 birds/ha). Average distance from road was similar for territories with paired adults (road-noise = 291 m [SE = 26], construction = 263 m [SE = 19]) and those with successful pairs (road-noise = 292 m [SE = 27]), construction = 243 m [SE = 21]). Overall noise levels were low: ambient noise was similar in the construction and road-noise-only sites ($\overline{X}$ = 32 dB) and showed little auditory difference from the control ($\overline{X}$ = 28 dB). Our results indicate that construction activities and road-noise did not appear to impact territory placement, reproductive success, or local densities of golden-cheeked warblers under the treatment regime we studied. © 2011 The Wildlife Society.

KEY WORDS ambient noise, construction noise, *Dendroica chrysoparia*, density, distance from road, golden-cheeked warbler, impact assessment design, reproductive success, road-noise only.

Birds may be particularly sensitive to noise resulting from human disturbance because auditory signals are their primary communication mechanism. Noise that distorts or masks communication signals can influence population density, mating behavior, and breeding success. Ambient noise may reduce male to female communication, increase redundancy of songs, drown out begging calls, or inhibit predator detection (Benson 1995, Brumm and Slater 2006, Habib et al. 2007). Noise may require birds to sing at higher frequencies and amplitudes, at higher energetic cost (Manabe et al. 1998, Slabbekoom and Peet 2003, Wood and Yezerinac 2006). Noisy environments influence bird community composition by favoring certain species (Stone 2000, Rheindt 2003) and can modify community structure by disrupting, for example, predator–prey interactions (Rheindt 2003, Francis et al. 2009). Other impacts of noise on birds include reduced pairing success (Habib et al. 2007), reduced densities near roads (Reijnen and Foppen 1994, Rheindt 2003), or increased food availability (Morgan et al. 2010).

As demand for transportation networks increases, road and construction noise will increase as pervasive disturbances in many avian habitats. An average road-construction site produces sound pressure up to 80 dB, which is a sound level that annoys humans but is not known to cause hearing damage (Legris and Poulin 1998, Ristovska et al. 2009). Road construction noise is 16 times greater than a baseline level of 40 dB, or the ambient noise of a suburban area with medium traffic (Mendes et al. 2011).

Golden-cheeked warblers (*Dendroica chrysoparia*), a federally endangered passerine with a breeding range restricted to central Texas, USA (Ladd and Gass 1999), were placed on the federal endangered species list in 1990 due to habitat loss and fragmentation, which continues to be a threat. Between 2010 and 2030 the human population in the species' breeding range is projected to increase by >26% (Groce et al. 2010). By 2008 there were approximately 100,000 lane miles (approximately 160,000 km) of road constructed across the species' range, representing a 5.5% increase since species listing (Groce et al. 2010). Continued road construction and

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repair will be a recurring activity throughout the warbler's range for the foreseeable future, but the impact of the resulting noise on golden-cheeked warbler demography is unknown. Because golden-cheeked warblers rely on 2 different songs and a variety of calls to communicate during the breeding season (Bolsinger 2000, Loman 2010), anthropogenic noise that masks or distorts these vocalizations could potentially impact an already endangered population.

Our objective was to monitor golden-cheeked warblers exposed to various types of disturbance (construction noise, road noise) and those unexposed to noise and to evaluate territory placement and reproductive success in relation to distance from road. Because construction had already started and no treatment replication was plausible, we implemented a study design appropriate for such assessments. Impact assessment designs are applicable to situations where replication is not feasible, including natural occurrences such as fires, floods, and disease, and human-related disasters such as toxic spills (Morrison et al. 2008). A notable example of an appropriate impact assessment design, the *Exxon Valdez* oil spill, was detailed by Wiens and Parker (1995). Our objectives were to evaluate whether 1) road noise affected warbler reproductive activities, 2) whether construction noise exacerbated the effect of road noise, and 3) whether construction noise affected the warblers differently than road noise.

STUDY AREA

Our research was conducted in Real and Uvalde counties in central Texas, USA. Our road-construction site was located on private land (Big Springs Ranch) along a 9-km stretch of U.S. Highway 83. Big Springs Ranch was a 2,800-ha private ranch where much of the land remained unaltered golden-cheeked warbler habitat (oak [*Quercus* spp.]–juniper [*Juniperus ashei*] woodland). The adjacent highway was being widened from 2 lanes to 4 lanes to improve traffic flow and safety, but not due to increased traffic. Activities at the road-construction site included road grading, excavation, paving, and pilot-car operation. We used a portion of Garner State Park that was adjacent to Highway 83 for our road-noise-only site because no construction activities were occurring within the area. Garner State Park was located approximately 35 km from Big Springs Ranch and allowed for considerable access to roadside warbler habitat. We used areas on Big Springs Ranch $\geq$1,000 m from the roadway for control sites. Reijnen et al. (1997) estimated a disturbance zone of approximately 800 m in woodlands adjacent to roads with a vehicle load of 50,000 vehicles/day; the vehicle load adjacent to our study area was $<$2,000 vehicles/day. Therefore, we assumed that disturbance of golden-cheeked warblers $\geq$1,000 m from Highway 83 under such low vehicle-load conditions would be negligible.

METHODS

Study Design

Our study design was that of an impact assessment due to lack of opportunity to collect specific pretreatment data for treated (construction) or control sites and lack of replication of treatment. Under such a design, impact (positive or negative) is determined relative to conditions on associated control sites (Morrison et al. 2008:247–251). Thus, we followed the basic after-only design, which is widely used in impact assessment when disturbances (planned or unplanned) have no pretreatment data available (Wiens and Parker 1995, Morrison et al. 2008:247). More specifically, we followed the impact-reference (control) design, which mimics a classical experimental treatment and control design where samples are gathered from sites within the disturbed area and from nondisturbed control areas. Control sites are selected that would be expected to undergo the same overall natural environmental perturbations (e.g., drought) as the disturbed site (Parker and Wiens 2005). In our study, we met this assumption by locating controls in the same general region as the disturbed site, and gathered data on all sites simultaneously to ensure comparability.

Ambient Noise

We used automatic recording units (ARUs; see Rognan et al. [2009] for unit description) to assess ambient noise in the construction, road-noise-only, and control sites. Each ARU was programmed to record from 0600 hours to 1200 hours daily from 15 March until 15 June 2007–2009 (Collier et al. 2010). Warblers sing infrequently in the afternoon; hence, the daily cessation of recordings. We placed ARUs from 30 m to 460 m from Highway 83 in the construction and road-noise-only sites and within randomly chosen territories in the control site. We selected ARU locations based on points identified to be preferred golden-cheeked warbler song posts on the basis of repeated early season observations of singing males, thereby taking advantage of asymmetrical territorial singing behavior (Bolsinger 2000), and best capturing the localized noise exposure to focal vocal males.

Avian Surveys

We conducted line-transect surveys from 12 to 24 March 2007–2009 to determine presence and location of golden-cheeked warblers. We placed 6 transects in the road-construction site perpendicular to the road along the construction route. Transects varied in length depending on the extent of suitable habitat (1 transect at 400 m, 3 transects at 500 m, and 2 transects at 600 m). We placed 4 transects in the road-noise-only sites perpendicular to the road in suitable golden-cheeked warbler habitat (3 transects at 600 m in length and 1 transect 500 m in length). We placed 4 transects in the control area beginning $\geq$1,000 m from the highway within suitable warbler habitat (3 transects at 600 m in length and 1 transect 500 m in length). All transects were placed in patches of mature woodland habitat that exceeded the threshold size (approx. 20 ha) known to provide for occupancy and nesting by golden-cheeked warblers (Butcher et al. 2010).

We began transect surveys at sunrise and completed surveys within 60–90 min, depending on transect length. Upon detection of a golden-cheeked warbler, we used a handheld global positioning system (GPS) to mark our location and we recorded approximate distance and direction to each detected individual. We spot-mapped territories (International Bird Census Committee 1969) for all golden-cheeked warblers recorded during transect surveys by following each singing male for 60 min or until 10 GPS waypoints were recorded during each visit. Beginning 25 March and continuing throughout the breeding season, we monitored presence and territory location through reproductive success surveys as described below.

Reproductive Success

We used a reproductive index (Vickery et al. 1992) to determine reproductive success of golden-cheeked warbler territories. We chose the Vickery method because it does not necessitate disruption of nesting activities and has been used successfully to determine golden-cheeked warbler reproductive success (Butcher et al. 2010). Rankings we used were: 1 = territorial male present ≥4 weeks; 2 = female observed in territory during ≥1 survey; 3 = evidence of nest building; male observed carrying food to presumed female on nest; female observed laying or incubating eggs; 4 = female observed carrying food to presumed nestlings; male observed feeding nestlings; 5 = ≥1 fledgling of the same species as the parent observed with the pair.

We surveyed each territory weekly, from 24 March until 18 June. Surveys lasted ≤60 min to allow sufficient time to follow birds moving long distances and to provide sufficient time to observe breeding behaviors. If the bird was not located within 30 min, observers moved on to the next territory. When we did not locate a bird within a territory during a visit, we surveyed that territory first during the next weekly visit. We recorded GPS waypoints of the birds' locations and behaviors throughout each territory survey. We rotated observers among sites and territories to balance observer bias.

Analysis

We analyzed all available audio recordings from 15 March to 15 June for 2007 (n = 279), 2008 (n = 487), and 2009 (n = 651), totaling 8,502 hr. Recordings that were truncated and, therefore, did not span the full 6-hr period, and those that showed evidence of digital distortion, were excluded from analysis (accounting for about one-third of the recordings). Long-term noise-exposure levels in each site were established using SonoBird™ Noise Analyzer v1.0.0 (DNDesigns, Arcata, CA). We used factorial analysis of variance to compare differences in noise levels among construction, road-noise-only, and control sites in each year (Zar 2010:265–269). We used linear regression to compare noise levels at varying distances from road between the construction and road-noise-only sites (Zar 1996:317–330).

We considered territories successful if adults were seen with fledglings ≥1 time, and unsuccessful if the male was observed with a female ≥1 time but we did not find fledglings in the territory. We considered males unpaired if they were never observed with a female and excluded them from reproductive success analyses. We used logistic regression to evaluate the effect distance from road (distance was based on the territory centroid) had on reproductive success. For density calculation, we divided total number of territories by estimated area surveyed to determine territorial males/ha for each of the study sites in all years. We used a minimum convex polygon (ArcMap 9.2) to estimate the annual area surveyed per site. These estimates were annualized due to survey effort varying among years (i.e., effort increased consecutively from 2007 to 2009).

RESULTS

Ambient Noise

We placed ARUs at 44 total locations within known warbler territories. Ambient noise levels (dB) differed among sites ($\overline{X}_{\text{construction}}$ = 33 dB ± 0.81; $\overline{X}_{\text{road-noise-only}}$ = 32 dB ± 0.92; $\overline{X}_{\text{control}}$ = 28 dB ± 1.03; $F_{8,35} = 2.663$, $P = 0.021$) but was not likely of any direct biological importance. Although we found a negative relationship between distance and noise level, the regression curve was flat and had low explanatory power ($R^2 = 0.086$).

We found little variability in reproductive success between the construction and control sites (2007: construction = 90%, control = 78%, road noise = 92%; 2008: construction = 62%, control = 62%, road noise = 93%; 2009: construction = 72%, control = 71%, road noise = 88%).

Average distance from road was similar for territories with paired adults (road-noise = 291 m [SE = 26], construction = 263 m [SE = 19]) and those with successful pairs (road-noise = 292 m [SE = 27]), construction = 243 m [SE = 21]). Our logistic model indicated a negative slope for the effect of distance from road on territory success (−0.003 [SE = 0.001]) and success was predicted to decline as distance from the road increased (Fig. 1). Mean territory distance from road was similar across the 3 years in both the construction and road-noise-only site for all territories, paired territories, and successful territories (Table 1). Based on our survey data, golden-cheeked warbler density

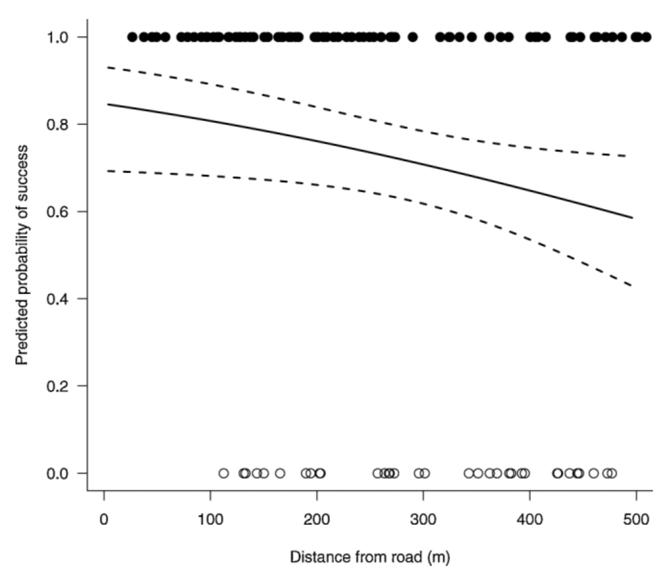

Figure 1. Probability of reproductive success of golden-cheeked warblers given distance from Highway 83 in Real and Uvalde counties, Texas, USA, 2007–2009. Filled and open circles represent successful territories and unsuccessful territories, respectively, at various distances from the highway (in m).

Table 1. Minimum, maximum, mean, and standard error of the distance (unit) of golden-cheeked warbler territory centers from Highway 83 in construction and road-noise-only sites in Real and Uvalde counties, Texas, USA, 2007–2009.

	n	Min.	Max.	Mean	SE
Construction					
Paired	66	37	655	263	19
Unpaired	6	203	445	334	35
Successful	49	37	643	243	21
Unsuccessful	17	131	655	323	38
Road-noise only					
Paired	43	26	606	291	26
Unpaired	9	203	569	363	40
Successful	39	27	607	292	27
Unsuccessful	4	112	446	284	88

in the construction site was 0.305 birds/ha, similar to the 0.357 birds/ha in the road-noise-only site and 0.328 birds/ha in the control site.

DISCUSSION

Over 3 years of sampling, including 167 territories distributed across a gradient of disturbance conditions, we did not detect any impact of construction noise, nor road proximity, on the reproductive success of golden-cheeked warblers. Note that the density of birds in the 3 site types was also similar, indicating that construction and road noise also did not seem to influence density. Although our results indicated a negative effect of distance from road on reproductive success—meaning that as you get further away from a road, territory success declines—there is likely no biologically meaningful effect of road on reproductive success at the distances we measured.

Although our results suggest that local factors unrelated to noise may account for population differences among our 3 study sites, these potential site factors do not alter our conclusion of no effect due to construction noise because of our use of the impact assessment design. The impact assessment design examines the relative difference between impacted and nonimpacted sites given that all sites are operating under similar environmental processes (Parker and Wiens 2005). Additionally, all of our measured response variables were similar and high across all study sites, indicating that any potential negative response to construction noise that we might have missed was extremely small and did not affect reproduction. Although we did not evaluate edge effects for our study, previous studies of golden-cheeked warblers have reported higher nest success in areas with less forest edge (Peak 2007, Reidy et al. 2009). Although some research has found that golden-cheeked warblers prefer landscape compositions with a high percentage of woodland cover (Magness et al. 2006), more recent work has shown high productivity when cover is <50% (M. Morrison, Texas A&M University, unpublished work). Territories in the road-noise-only site were located primarily in 1 contiguous 743-ha patch with 72% woodland cover, whereas territories in the construction site were located in 4 smaller habitat patches composed of 46%, 55%, 67%, and 70% woodland cover (28 ha, 48 ha, 37 ha, and 572 ha, respectively), with 5 of 6 transects located in patches with ≤67% cover (M. A. Lackey, Texas A&M University, unpublished work). However, previous work showed that occupancy and reproductive success of this species was not negatively impacted until patches decreased below 20 ha in size (Butcher et al. 2010). The large size and high cover in the road-noise-only site could have resulted, however, in the higher success we found relative to the other sites.

The level of noise produced from the road construction on Highway 83 did not represent a substantially louder noise regime in the study site than from highway noise alone. Noise in the treatment sites was only 4 dB higher than noise in the control site, likely accounting for little biological difference and suggesting that differences observed among sites were due to factors unrelated to noise. Sound reflection and uneven absorption due to topography, as well as uneven distribution of noise sources in the construction zone, may account for the low correlation between distance and noise level.

Our results are consistent with previous work that found no biological differences between golden-cheeked warbler presence at high-noise and low-noise song posts near a highway (Benson 1995). However, our study sites were located in rural counties with vehicle loads of <2,000 vehicles/day. Previous studies reporting negative effects of road noise on songbird populations have been located near roads with 10,000–60,000 vehicles/day and have shown biological effects from 40 m to 3 km away from roadways (Reijnen et al. 1995, 1997; Federal Highway Administration 2004). Alternatively, low background noise from the road could mean that birds in our study areas were not habituated to a loud noise regime and, thus, would have been more sensitive to the addition of construction noises. A companion project using our study sites that presented construction sounds at close range to individual golden-cheeked warblers did not, however, detect any negative response by the tested birds (Lackey 2010, Lackey et al., in press). Given the difference in vehicle loads, however, it is conceivable that golden-cheeked warblers may react differently to road noise in areas with higher traffic volume than did warblers from our study.

MANAGEMENT IMPLICATIONS

Although noise was variable among sites, construction noise does not appear to impact golden-cheeked warblers along Highway 83. Golden-cheeked warblers did not establish territories away from the road, nor were there differences in territory success related to distance from the road. Our results suggest that properly planned construction activities in low-traffic zones have little impact on territory selection or reproductive success of golden-cheeked warblers.

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LITERATURE CITED

Benson, R. H. 1995. The effect of roadway traffic noise on territory selection by golden-cheeked warblers. Bulletin of the Texas Ornithological Society 28:42–51.

Bolsinger, J. S. 2000. Use of two song categories by golden-cheeked warblers. Condor 102:539–552.

Brumm, H., and P. J. B. Slater. 2006. Ambient noise, motor fatigue, and serial redundancy in chaffinch song. Behavioral Ecology and Sociobiology 60:475–481.

Butcher, J. A., M. L. Morrison, D. Ransom, Jr., R. D. Slack, and R. N. Wilkins. 2010. Evidence of a minimum patch size threshold of reproductive success in an endangered songbird. Journal of Wildlife Management 74:133–139.

Collier, B. A., M. L. Morrison, S. L. Farrell, A. J. Campomizzi, J. A. Butcher, K. B. Hays, D. I. Mackenzie, and R. N. Wilkins. 2010. Monitoring golden-cheeked warblers on private lands in Texas. Journal of Wildlife Management 74:140–147.

Federal Highway Administration. 2004. Synthesis of noise effects on wildlife populations. U.S. Department of Transportation, Federal Highway Administration, publication no. FHWA-HEP-06-016, Washington, D.C., USA.

Francis, C. D., C. P. Ortega, and A. Cruz. 2009. Noise pollution changes avian communities and species interactions. Current Biology 19:1415–1419.

Groce, J. E., H. A. Mathewson, M. L. Morrison, and R. N. Wilkins. 2010. Scientific evaluation for the 5-year status review of the golden-cheeked warbler. Prepared for the U.S. Fish and Wildlife Service, Region 2, Albuquerque, New Mexico, USA.

Habib, L., E. M. Bayne, and S. Boutin. 2007. Chronic industrial noise affects pairing success and age structure of ovenbirds *Seiurus aurocapilla*. Journal of Applied Ecology 44:176–184.

International Bird Census Committee. 1969. Recommendations for an international standard for a mapping method in bird census work. Bird Study 16:249–255.

Lackey, M. A. 2010. Avian response to road construction noise with emphasis on the endangered golden-cheeked warbler. Thesis, Texas A&M University, College Station, USA.

Lackey, M. A., M. L. Morrison, Z. G. Loman, R. N. Wilkins. (in press). Experimental determination of the response of golden-cheeked warblers to road construction noise. Ornithological Monographs.

Ladd, C., and L. Gass. 1999. Golden-cheeked warbler (*Dendroica chrysoparia*). Account 420 *in* A., Poole, and F., Gill, editors. The birds of North America. The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D.C., USA.

Legris, M., and P. Poulin. 1998. Noise exposure profile among heavy equipment operators, associated laborers, and crane operators. American Industrial Hygiene Association Journal 59:774–778.

Loman, Z. G. 2010. Response of a North American wood warbler, the golden-cheeked warbler (*Dendroica chrysoparia*) to anthropogenic noise. Thesis, Humboldt State University, Arcata, California, USA.

Magness, D. R., R. N. Wilkins, and S. J. Hejl. 2006. Quantitative relationships among golden-cheeked warblers and landscape size, composition, and structure. Wildlife Society Bulletin 34:473–479.

Manabe, K., E. I. Sadr, and R. J. Dooling. 1998. Control of vocal intensity in budgerigars (*Melopsittacus undulates*): differential reinforcement of vocal intensity and the Lombard effect. Journal of the Acoustical Society of America 103:1190–1198.

Mendes, S., V. J. Colino-Rabanal, and S. J. Peris. 2011. Bird song variations along an urban gradient: the case of the European blackbird (*Turdus merula*). Landscape and Urban Planning 99:51–57.

Morgan, G. M., R. K. Boughton, M. A. Rensel, and S. J. Schoech. 2010. Road effects on food-availability and energetic intake in Florida scrub-jays (*Aphelocoma coerulescens*). Auk 127:581–589.

Morrison, M. L., W. M. Block, M. D. Strickland, B. A. Collier, and M. J. Peterson. 2008. Wildlife study design. Second edition. Springer-Verlag, New York, New York, USA.

Parker, K. R., and J. A. Wiens. 2005. Assessing recovery following environmental accidents: environmental variation, ecological assumptions, and strategies. Ecological Applications 15:2037–2051.

Peak, R. G. 2007. Forest edges negatively affect golden-cheeked warbler nest survival. Condor 109:628–637.

Reidy, J. L., F. R. Thompson, III, and R. G. Peak. 2009. Factors affecting golden-cheeked warbler nest survival in urban and rural landscapes. Journal of Wildlife Management 73:407–413.

Reijnen, R., and R. Foppen. 1994. The effects of car traffic on breeding bird populations in woodland. I. Evidence of reduced habitat quality for willow warblers (*Phylloscopus trochilus*) breeding close to a highway. Journal of Applied Ecology 31:85–94.

Reijnen, R., R. Foppen, C. T. Braak, and J. Thissen. 1995. The effects of car traffic on breeding bird populations in woodland. III. Reduction in density in relation to the proximity of main roads. Journal of Applied Ecology 32:187–202.

Reijnen, R., R. Foppen, and G. Veenbaas. 1997. Disturbance by traffic of breeding birds: evaluation of the effect and considerations in planning and managing road corridors. Biodiversity and Conservation 6:567–581.

Rheindt, F. E. 2003. The impact of roads on birds: does song frequency play a role in determining susceptibility to noise pollution? Journal für Ornithologie 144:295–306.

Ristovska, G., D. Gjorgjev, A. Polozhani, M. Kocubovski, and V. Kendrovski. 2009. Environmental noise and annoyance in adult population of Skopje: a cross-sectional study. Archives of Industrial Hygiene and Toxicology 60:349–355.

Rognan, C. B., J. M. Szewczak, and M. L. Morrison. 2009. Vocal individuality of great gray owls in the Sierra Nevada. Journal of Wildlife Management 73:755–760.

Slabbekoom, H., and M. Peet. 2003. Ecology: birds sing at a higher pitch in urban noise. Nature 424:267.

Stone, E. 2000. Separating the noise from the noise: a finding in support of the "niche hypothesis," that birds are influenced by human-induced noise in natural habitats. Anthrozoös 13:225–231.

Vickery, P. D., M. L. Hunter, Jr., and J. V. Ills. 1992. Use of a new reproductive index to evaluate relationship between habitat quality and breeding success. Auk 109:679–705.

Wiens, J. A., and K. R. Parker. 1995. Analyzing the effects of accidental environmental impacts: approaches and assumptions. Ecological Applications 5:1069–1083.

Wood, W. E., and S. M. Yezerinac. 2006. Song sparrow (*Melospiza melodia*) song varies with urban noise. Auk 123:650–659.

Zar, J. H. 1996. Biostatistical analysis. Third edition. Prentice-Hall, Upper Saddle River, New Jersey, USA.

Zar, J. H. 2010. Biostatistical analysis. Fifth edition. Prentice-Hall, Upper Saddle River, New Jersey, USA.

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