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

MELISSA A. LACKEY, Department of Wildlife and Fisheries Sciences, Texas A&M University, 2258 TAMU, College Station, TX 77843, USA
MICHAEL L. MORRISON,† Department of Wildlife and Fisheries Sciences, Texas A&M University, 2258 TAMU, College Station, TX 77843, USA
ZACHARY G. LOMAN, Department of Biological Sciences, Humboldt State University, Arcata, CA 95521, USA
NANCY FISHER, Texas Department of Transportation, San Angelo District, 4502 Knickerbocker Road, San Angelo, TX 76904, USA
SHELTON L. FARRELL, Department of Wildlife and Fisheries Sciences, Texas A&M University, 2258 TAMU, College Station, TX 77843, USA
BRET A. COLLIER, Texas A&M Institute of Renewable Natural Resources, Texas A&M University, College Station, TX 77843, USA
R. NEAL WILKINS, Texas A&M Institute of Renewable Natural Resources, Texas A&M University, College Station, TX 77843, USA

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 (∇ = 32 dB) and showed little auditory difference from the control (∇ = 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 (Habib et al. 2007). Noise may reduce male to female communication, increase mating behavior, and breeding success. Ambient noise, construction noise, and road-noise were similar in the construction and road-noise-only sites. Overall noise levels were low: ambient noise was similar in the construction and road-noise-only sites (∇ = 32 dB) and showed little auditory difference from the control (∇ = 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.

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†E-mail: mlmorrison@tamu.edu

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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 ≥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 ≥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 ≥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 (DN Designs, 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 1996:317–330). 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 ($\bar{X}_{\text{construction}} = 33 \text{ dB} \pm 0.81$; $\bar{X}_{\text{road-noise-only}} = 32 \text{ dB} \pm 0.92$; $\bar{X}_{\text{control}} = 28 \text{ dB} \pm 1.03$; $F_{8,35} = 2.663, P = 0.021$) 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).
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 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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**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.

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<thead>
<tr>
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<th>Min.</th>
<th>Max.</th>
<th>Mean</th>
<th>SE</th>
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(analysis of the potential impacts of highway construction noise and activity on birds with an emphasis on the golden-cheeked warbler; contract no. 7-7XXIA001), and A. Arnold (U.S. Fish and Wildlife Service) for assisting with federal permitting and oversight. We also thank M. Priour, Big Springs Ranch, for allowing us to work on the property and for convenient housing. R. Meyers with Texas Parks and Wildlife was also helpful in allowing us to work at Garner State Park. We also thank field technicians J. Loman, A. Renteria, A. Sabella, and A. Corso for assisting with data collection and the Institute of Renewable Natural Resources for providing logistical support. Comments made by the associate editor and 2 anonymous referees improved the manuscript.

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