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CHAPTER 8

EXPERIMENTAL DETERMINATION OF THE RESPONSE OF GOLDEN-CHEEKED WARBLERS (*SETOPHAGA CHRYSOPARIA*) TO ROAD CONSTRUCTION NOISE

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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. We examined the impact of road construction noise on territory selection, reproductive success, and behavior of the federally endangered Golden-cheeked Warbler (*Setophaga chrysoparia*). To examine habituation and territory placement, we (1) used construction-noise playback to individual Golden-cheeked Warblers and evaluated occurrence of behavioral response as a function of distance from the roadway, and (2) established broadcast units that simulated construction noise to determine effects on territory selection. Among 88 surveys, six birds responded to construction-noise playback; all birds that responded were located ≥140 m from the road. We established three broadcast units per season in 2008 and 2009 to test for habituation. In each year, we placed broadcast units on the edges of randomly chosen territories identified during the previous field season. We found no significant difference in mean territory shifts for territories with and without broadcast units, and territory shifts showed no patterns in directionality or reproductive success. Our results suggest that birds located in the noisiest areas have habituated to construction noise, whereas those in the quietest areas have not habituated; however, the very low number of observed responses indicated that the majority of Golden-cheeked Warblers have habituated to road and construction noise.

Key words: behavioral response, broadcast unit, construction noise playback, Golden-cheeked Warbler, habituation, reproductive success, *Setophaga chrysoparia*.

Determinación Experimental de la Respuesta de *Setophaga chrysoparia* al Ruido de la Construcción de Carreteras

Resumen.—La polución sonora puede enmascarar o distorsionar los cantos de las aves, lo que puede inhibir el éxito reproductivo, la detección de depredadores y la respuesta de los padres a los llamados que emiten sus pichones para pedir alimento. Examinamos el impacto de la construcción de carreteras sobre la selección de territorios, el éxito reproductivo y el comportamiento del ave federalmente amenazada *Setophaga chrysoparia*. Para examinar la habituación y el establecimiento de territorios, (1) reprodujimos ruido previamente grabado a los individuos de *S. chrysoparia* y evaluamos si existía una respuesta comportamental como una función

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de distancia a la carretera, y (2) establecimos estaciones de emisión que simulaban ruido de construcción para determinar sus efectos en la selección de territorios. De 88 censos, seis aves respondieron a la reproducción del ruido de construcción; todas las aves que respondieron se localizaron a más de 140 m de la carretera. Establecimos tres estaciones de transmisión por temporada en 2008 y 2009 para probar la habituación. En cada año, establecimos las unidades de transmisión en los bordes de territorios escogidos al azar durante la temporada de campo anterior. No encontramos diferencias significativas en el promedio de cambios de territorio con o sin las unidades de transmisión, y los cambios en los territorios no mostraron patrones de direccionalidad o éxito reproductivo. Nuestros resultados sugieren que las aves localizadas en las áreas más ruidosas se han habituado al ruido de construcción, mientras que aquellas de las áreas más silenciosas no se han habituado. Sin embargo, el bajo número de respuestas observadas indica que la mayoría de individuos de *S. chrysoparia* se han habituado al ruido de construcción y de carreteras..

Anthropogenic disturbance affects wildlife in a variety of ways, often resulting in population-level effects. Birds may be particularly sensitive to noise that results from human disturbance because auditory signals are their primary mechanism of communication. 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). Noisy environments influence bird community composition and structure by favoring certain species and disrupting predator–prey interactions (Stone 2000, Rheindt 2003, Francis et al. 2009). Noise may also reduce pairing success (Habib et al. 2007) and densities near roads (Reijnen and Foppen 1994, Rheindt 2003).

Immediate behavioral responses to anthropogenic noise, such as increased vigilance and flushing from nests during the breeding season, may directly influence reproductive success (Delaney et al. 1999, González et al. 2006). Habituation occurs when individuals no longer respond to repeated disturbance, and such behavior is an adaptive strategy (Thompson and Henderson 1998). Recently, several authors have provided evidence of wildlife habituation to anthropogenic disturbance (Conomy et al. 1998, Thompson and Henderson 1998, Stolen 2003).

The Golden-cheeked Warbler (*Setophaga chrysoparia; hereafter "warbler")*, a federally endangered passerine with a breeding range restricted to central Texas (Ladd and Gass 1999), was placed on the federal endangered species list in 1990 because of habitat loss and fragmentation, which continues to be a threat. The effects on warblers of the disturbance created by road construction activities are not well documented. Some studies have addressed differences in warbler populations in urban and rural areas (Reidy et al. 2008, 2009) but have not looked at road or construction noise as specific disturbance factors. As the demand for road networks increases, road and construction noise will likely be persistent disturbance factors near warbler habitat, and the implications of noise disturbance are increasingly under question.

Dearborn and Sanchez (2001) suggested that territory selection is more important than nest-site selection for breeding success in warblers. Additionally, males have exhibited varying degrees of participation in nest-site selection (Graber et al. 2006). Thus, noise disturbance could potentially influence territory location and nest-site selection for the warbler. In addition, the warbler uses two different songs to communicate during the breeding season (Bolsinger 2000); anthropogenic noise that masks or distorts these songs could have a significant impact on an already endangered population. While conducting an impact assessment in 2007, we observed warblers in close proximity to construction noise and activities (Lackey 2010). However, we did not know whether these birds had a behavioral response at the onset of construction, or whether the disturbance displaced certain individuals. In previous work evaluating effects of traffic noise on warbler territory selection, Benson (1995) found no evidence that the warblers select territories on the basis of road noise. Benson (1995) suggested that further research be done to evaluate effects of road noise and encouraged conducting experiments rather than only observational studies. Difficulties in assessing biological effects of noise on wildlife include accurately reproducing the sound source, accounting for moving sound sources, and accounting for visual cues that accompany the actual disturbance (Pater et al. 2009); our experimental approach isolated noise effects from these other confounding factors.

We used construction-noise playback to individual birds and evaluated occurrence of behavioral response as a function of distance from the roadway, and we established construction-noise broadcast units to determine effects on territory selection. We hypothesized that birds found closest to the construction activity would have fewer behavioral responses to recordings of construction noise, and that responses would steadily increase with increasing territory distance from construction activity. Our second goal was to examine site fidelity and territory location in response to simulated construction noise to assess whether warblers or certain individuals are habituating to construction noise. We hypothesized that individuals were habituating to the noise and that the simulated construction noise would have no significant effect on site fidelity or territory location. Using data obtained from the impact assessment, our final objective was to evaluate responses to playback and simulated construction noise in relation to reproductive success.

Methods

Study Area

We conducted our experiments during the breeding seasons of 2008 and 2009 in Real and Uvalde counties in central Texas. Study sites were located on Big Springs Ranch and at Garner State Park. Big Springs Ranch was a 2,800-ha private ranch that included a significant area of oak (*Quercus*)–juniper (*Juniperus*) woodland that served as warbler habitat. A 9-km stretch of U.S. Highway 83, adjacent to Big Springs Ranch, was used for construction-noise sites and was the only such area available in the region. This length of highway was being widened from two lanes to four lanes to improve traffic flow, but not because of increased traffic. Activities included, but were not limited to, road grading, excavation, paving, and pilot-car operation. Garner State Park was located ~32 km south of the construction zone; because most of the region is privately owned, Garner State Park was the closest appropriate location where we could gain access. The portion of Garner State Park adjacent to Highway 83 was used for road-noise-only sites. Reijnen et al. (1997) estimated a disturbance zone of ~300 m in woodlands adjacent to roads with a vehicle load of 10,000 vehicles day^{-1}; the vehicle load adjacent to the study area was <2,000 vehicles day^{-1}, so we considered areas ≥400 m from Highway 83 to be no-disturbance sites (see also Fig. 1).

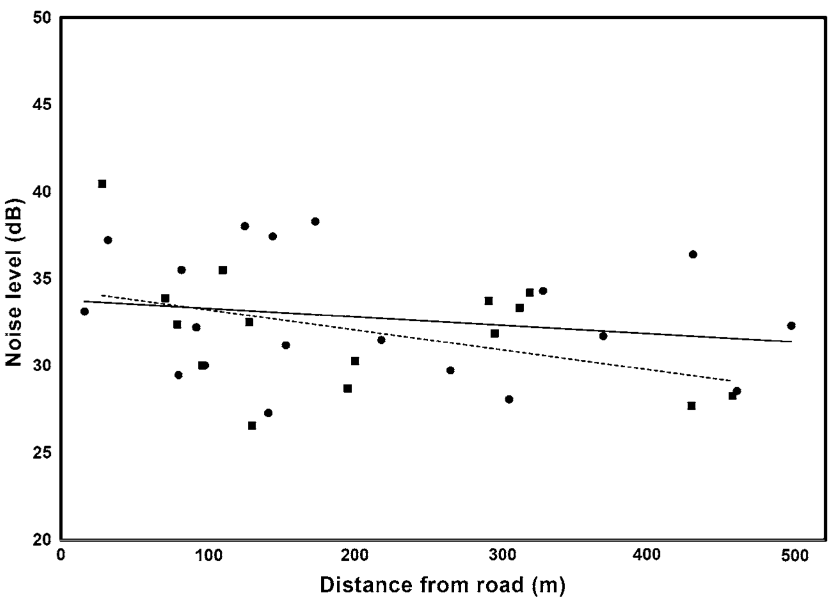

Fig. 1. Average ambient noise levels (dB) in relation to distance from road within road-construction and road-noise-only sites adjacent to Highway 83 in Real and Uvalde counties, central Texas, 2007–2009. Circles are construction, and squares are the road-noise-only site. Solid line is construction, and dashed line is the road-noise-only site.

Study Design

We designed our study as an impact assessment because of a lack of opportunity to collect specific pre-treatment data for treated (construction) or control sites and a lack of replication of treatment. Under such a design, impact (positive or negative) is determined in relation to conditions on associated control sites (Morrison et al. 2008). Thus, we followed the basic after-only design (Wiens and Parker 1995, Morrison et al. 2008:247). We located controls in the same general region as the disturbed site and gathered data on all sites simultaneously to ensure comparability (Parker and Wiens 2005).

We used two types of study sites for our experiments: (1) an impact (construction) site adjacent to the road that was undergoing construction activities, which was exposed to both construction noise and road noise (vehicle traffic); and (2) a control site with road noise only, where traffic noise and disturbance existed but no construction activity occurred. We conducted all surveys using the same methods in each site and determined potential effects of construction and road noise on behavior and productivity of warblers by evaluating results as a function of distance from road.

Territory Identification

We conducted line-transect surveys from 12 to 24 March each year to determine the presence and location of warblers. In the construction and road-noise site, we placed six transects perpendicular to the road along the construction route. Transects varied in length depending on the extent of suitable habitat (one transect at 400 m, three transects at 500 m, and two transects at 600 m). In the road-noise-only site, we placed four transects perpendicular to the road in suitable warbler habitat at Garner State Park (three transects 600 m in length, and one 500 m in length).

Surveyors began transect surveys at sunrise and completed surveying within 60–90 min, depending on transect length. Upon detection of a male warbler, the surveyor marked his or her location using a handheld global positioning system (GPS) and recorded approximate distance and direction to the bird. Territories for all warblers recorded during transect surveys were spot-mapped using a GPS. Observers located and followed each singing male for 60 min or until 10 GPS waypoints were recorded during each visit. After 24 March, we monitored presence and territory location through productivity surveys as described below.

Reproductive Success

We determined reproductive success of warbler territories using a reproductive index (Vickery et. al 1992). Use of this index allows a reliable measure of success for species whose nests are hard to locate while avoiding nest disturbance (Christoferson and Morrison 2001, Rivers et al. 2003). The rankings we used were as follows: 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, and female observed laying or incubating eggs; 4 = female observed carrying food to presumed nestlings, and male observed feeding nestlings; and 5 = one or more fledglings of the same species as the parent observed with the pair. For this study, we considered territories where fledglings were observed to be successful, and territories where a female but no fledglings were observed to be unsuccessful. Our territorial visits were of sufficient frequency to ensure that fledglings had not dispersed.

We conducted productivity surveys on each territory approximately once every 7 days, from 24 March until 18 June. Surveys lasted 60 min to allow sufficient time to follow birds moving long distances and to obtain sufficient time to observe breeding behaviors. If the bird was not located within 30 min, observers moved on to the next territory. Birds that were not located during a visit were surveyed first during the next visit. Observers recorded GPS waypoints of the birds' locations and behaviors throughout the productivity survey. We trained two or three observers to assist with surveys at the beginning of each season and monitored quality of work throughout the season; two observers assisted in both years. We rotated observers among study sites and territories to balance observer bias.

Behavioral Response

We experimentally examined birds' initial behavioral responses to an audio cue, specifically recordings of construction noise. Responses served as an indicator of the birds' immediate response to loud, erratic construction and road noise. We evaluated occurrence and types of behavioral change as a function of distance from the roadway and compared the results with those for individuals in the no-disturbance area.

Construction noise on Highway 83 is intermittent and includes multiple sounds, all of which have different frequencies and amplitudes (Lackey 2010). Using a Sennheiser shotgun microphone and iRiver H300 with Rockbox 1.28J, we created a recording of the variable construction noises prior to the field season. The primary noises recorded were back-up warning beepers, excavating, diesel engine noise, loading dump trucks, and human voices. Current research suggests that birds hear no better than humans (Dooling 2002); thus, we played construction-noise recordings at 80 dB(A) (measured at ~5 m), a level known to be annoying to humans but that could not cause hearing damage (Legris and Poulin 1998, Ristovska et al. 2009, Lackey 2010); individuals may have experienced lower levels of sound, depending on distance from speaker and sound attenuation in the environment.

After we established the location of territorial males, we randomly chose territories for treatment at varying distances from the roadway on construction sites and road-noise-only sites. We conducted playback surveys on both days with active and non-active construction from 15 March until 17 June in 2008 and 2009. We chose territories at random to receive treatment at no-disturbance sites. Playback surveys occurred throughout the season, but no more than once every 10 days on a given territory, to detect whether there was a temporal aspect of the birds' reactions and to avoid habituating birds to playback recordings. No individual was exposed to playback >5 times per season, and the same noise clip was used for all surveys. We conducted surveys from sunrise until 5 h after sunrise. To minimize surveyor influence, we approached a territorial male and remained at a distance of ~20 m. We recorded behavior for 2 min before playback. We then broadcast construction noise with a handheld speaker for 1–5 s. Each 1- to 5-s bout of playback ceased as soon as the bird's behavior changed. We documented after-playback behavior every minute for 10 min, or until the bird was unable to be located by the surveyor. We recorded the time and initial behavior as well as subsequent behavioral changes with the corresponding time. We did not play other types of noise to warblers (e.g., barking dog or airplane) because we were interested only in construction-related activities, and such a procedure would have substantially reduced our sample size for testing our primary objective.

Table 1. Distance from Highway 83 of Golden-cheeked Warbler territories used in broadcast-unit experiments in Real and Uvalde counties, central Texas, 2008–2009.

Broadcast unit territory	2008	2009
1	440	551
2	343	381
3	216	445

We chose territories for control surveys using the same methods as described for treatment territories. We conducted control surveys in the same manner but without playback to detect response caused by surveyor presence. We recorded behavior according to the following categories: type of vocalization, if any; foraging; preening; and short (<2 s) or long (≥2 s) flight (see Table 1). In addition to the behavioral categories, observers estimated distances moved and number and types of songs or calls (A song, B song, or chipping) during the before-, during-, and after-playback observations. The short duration of each experimental playback (≤5 s) and infrequent experimental treatment (once every 10 days) enabled us to observe the birds' behavioral responses while ensuring that the surveys did not cause undue risk to the birds.

Habituation to Construction Noise

From the recordings made of construction noise in the previously described methods, we established broadcast units that simulated appropriate volume and duration of construction activities. Construction noise was broadcast on weekdays only, between 0700 and 1400 hours, which matched actual construction activities. Broadcast units played at 80 dB(A), the level of a typical road-construction site (Legris and Poulin 1998, Ristovska et al. 2009). Noise was intermittent and played at random intervals and durations in order to mimic the actual construction noise. Each unit broadcast noise at least once every hour, and each bout lasted between 5 and 30 min.

Broadcast unit locations were identified by randomly selecting transects in the construction site and placing units on the edge of territories well removed from Highway 83 in the previous year (Table 1). In 2008, we placed broadcast units on the edges of territories identified during the 2007 field season. We chose territories for 2009 on the basis of 2008 data (M. A. Lackey unpubl. data). The units were established prior to 15 March, the approximate arrival time of the birds. We were able to use warbler territories in this experiment as long as we displaced (i.e., made the area unsuitable for warblers' use) no more than three birds, in accordance with U.S. Fish and Wildlife Service permitting.

We surveyed broadcast-unit territories at least once every 7 days in order to accurately map territory boundaries and determine reproductive success. If no territory was identified near a broadcast unit prior to 24 March, we systematically searched the previous year's territory for 1 h or until a bird was located. Upon locating a bird, we spot mapped the territory using a handheld GPS unit and afterward conducted surveys in the territory until 18 June. Broadcast units remained in the same locations throughout the season, regardless of new territory boundaries.

Analysis

Behavioral response.—We considered a behavioral response to playback to be (1) the bird ceasing singing, (2) the bird flying from its previous perch and out of the surveyor's view (≥10 m), and (3) the bird changing behavior before or exactly at the end of hearing 5 s of construction noise. Because we had 6 positive responses and 81 negative responses (one survey was confounded and not used for analysis) and a preliminary logistic model predicted no effect, we descriptively compared response to playback as a function of distance from the roadway to no-disturbance territory results as well as control survey results. We used a chi-square test to determine whether construction-noise playback altered bird response. We also determined whether a gradient effect was occurring as a result of distance from road to test our hypothesis that birds found closest to the construction activity would have the least behavioral response to recordings of construction noise and that responses would increase with increasing territory distance from construction activity. We evaluated response in relation to both distance from road and productivity.

We used custom-made automatic recording units (ARUs; for unit description, see Rognan et al. 2009) to assess ambient noise in each study site. Each ARU was programmed to record from 0600 to 1200 hours daily, from 15 March until 15 June, 2007–2009. The ARUs were located 30–460 m from Highway 83 at points identified as preferred warbler song posts in order to best capture the localized noise exposure to focal vocal males. From the recordings, long-term noise exposure levels at each location were established using SONOBIRD acoustic analysis software, version 1.0.0 (DNDesign, Arcata, California). The negative correlation between distance and noise level was not significant for either location type or overall (construction: $P = 0.31$; road-noise only: $P = 0.09$). Sound reflection and uneven absorption due to topography and the sporadic timing and uneven distribution of noise sources in the construction zone may account for the low correlation. Linear regression showed ambient noise on Highway 83 to be loudest within 200 m of the road (Lackey 2010; Fig. 1); thus, we used three distance categories for analysis: 0 to 200 m (loudest), 200 to 400 m (intermediate), and ≥400 m (no-disturbance) from the road.

Habituation.—To address habituation, we used productivity data to establish site occupancy over the three seasons for territories in each site type. We created minimum convex polygons using ARCMAP, version 9.2 (ESRI, Redlands, California), to identify territory boundaries. Extreme outliers were removed because those points may be measurement error or represent rare instances of movement events that were outside of the primary territory-use area. We considered outliers to be points in which the bird was located well outside of the primary use area on only one occasion during the breeding season. We determined whether any temporal or spatial effects on site fidelity and territory location were created by the introduction of simulated construction noise by documenting distance and direction of shifts in territory location using center points of the minimum convex polygons. Because all broadcast units were located in the construction site, we used a t-test to compare shifts in broadcast-unit territory locations with shifts of six randomly chosen non-broadcast territories in the same site for each year.

Results

Behavioral response.—We conducted 33 playback surveys for warblers in 2008 and 55 in 2009. Three warblers responded to construction-noise playback in 2008, and three responded in 2009. All birds that responded were vocalizing prior to playback, and all ceased to vocalize in response to playback. Four birds immediately left the immediate area of the observer, whereas two left the area after 5 s of playback. Only one bird was relocated after responding to playback; this bird was found 145 m from the initial survey point (Table 2). Types of behavioral response did not vary according to distance from the roadway. Surveys ranged from 10 to 640 m from the road, and all warblers that responded were located ≥150 m from the road. Forty-four surveys were conducted in the construction site and 44 surveys were conducted in the road-noise-only site (21 surveys from 0 to 400 m; 19 surveys ≥400 m). Three birds reacted to playback in the construction site (150 m, 210 m, and 218 m from roadway), and three reacted to playback in the road-noise-only site (377 m, 444 m, and 508 m from roadway; Table 2). Overall, in the no-disturbance area (≥400 m from Highway 83), 11% of warblers reacted to playback (n = 19), whereas 3% (n = 36) reacted in the loudest area from 0 to 200 m (Lackey 2010), and 9% (n = 32) reacted in the intermediate area, 200 to 400 m from the roadway. We observed too few responses to determine whether responses varied temporally.

Mean territory distance from road was similar for all territories, paired territories, and successful territories in all study sites (Lackey 2010). Mean distance from road was similar between successful ($\bar{x}$ = 236 m, n = 50) and unsuccessful ($\bar{x}$ = 247 m, n = 18) male warblers that did not react to playback; successful males that reacted to playback were located farther from the roadway ($\bar{x}$ = 370 m, n = 4) than unsuccessful males that reacted to playback ($\bar{x}$ = 214 m, n = 2) (Table 3). Of the successful males (n = 54), 20% (n = 12) reacted to playback in the no-disturbance area (≥400 m from Highway 83), whereas 4% (n = 28) reacted to playback in the loudest area from 0 to 200 m, and 7% (n = 14) reacted in the intermediate area, 200 to 400 m from the roadway. Twenty percent of the unsuccessful males (n = 20) reacted from 200 to 400 m from the roadway, whereas none reacted in the other areas. Unpaired males and territories with unknown outcomes (territories not fully monitored throughout the breeding season) were excluded from this analysis.

We conducted 18 control surveys to control for surveyor presence and observed one (~6%) behavioral response. Using this as the expected percentage of bird response, we did not find that the addition of construction-noise broadcast significantly altered bird response (χ^2 = 0.212, df = 1, P = 0.65). Control surveys ranged from 32 to 581 m from the road. The bird that responded was located 359 m from the roadway in the construction site and immediately fled the area; however, the territory successfully fledged young.

Habituation.—In 2008, two territory centers shifted away from the broadcast unit (27 m and 71 m) whereas the remaining territory center shifted 89 m toward the broadcast unit. In 2009, we located territories only near two of the three broadcast units. One territory center shifted 14 m parallel to the broadcast unit, and one territory center shifted 105 m away. Of the six randomly chosen territories in 2007, the average shift between years was 46.6 ± 19.5 m; in one location, a territory was not established in 2008. Four of the six randomly chosen territories from 2008 were occupied in 2009, with an average territory shift

TABLE 2. Initial behavior and types of behavioral response of the six Golden-cheeked Warblers (n = 88) that responded to construction-noise playback in Real and Uvalde counties, central Texas, 2008–2009.

Distance from road (m)	Initial behavior[a]	Response	Success[b]
150	V, SF	Immediate LF	Y
210	V, S	Immediate LF	N
218	V, F	LF at end of 5 second playback; returned after 3 min	N
359	V, C	Immediate LF [c]	Y
377	V, S	Immediately ceased V; LF 145 m	Y
444	V, G	Immediately ceased V; SF 15 m to middle of tree	Y
508	V, S	LF at end of 5 second playback	Y

[a]V = vocalizing, SF = short flight, S = scanning, F = foraging, C = courtship behaviors, G = grooming, SF = short flight, LF = long flight.
[b]Y = successfully fledged young; N = paired but unsuccessful; U = unpaired.
[c]Control survey; bird reacted when speaker was raised.

Table 3. Golden-cheeked Warbler response to playback in relation to reproductive success and distance from Highway 83 in Real and Uvalde counties, central Texas, 2007–2009.

Reaction to playback	Distance from road			
	0–200 m	200–400 m	>400 m	Total
Successful	1	1	2	4
Unsuccessful	0	2	0	2
No reaction to playback				
Successful	27	13	10	50
Unsuccessful	8	8	2	18

of 70.5 ± 27.7 m. There was not a significant difference in mean territory shifts for broadcast-unit and non-broadcast-unit territories ($\bar{x}_{broadcast}$ = 61.2 ± 31.3 m; $\bar{x}_{non\text{-}broadcast}$ = 57.2 ± 25.2 m; P = 0.95). Territory shifts did not show patterns in directionality.

Of the six territories with broadcast units, two successfully fledged young after being successful in the previous year and one was successful after being unsuccessful in the previous year; one was paired but unsuccessful in both years, and one was paired but unsuccessful after being unpaired in the previous year. An unpaired male occupied the territory in 2008 that was not re-established in 2009. Similarly, there were no patterns in reproductive success from one year to the next in the 12 randomly chosen non-broadcast-unit territories (Lackey 2010: table 10).

Discussion

Our experimental approach allowed us to isolate the effects of the noise disturbance present in a typical construction site from other factors, such as the visual disturbance of active construction work. Our results suggest that most birds located in the noisiest areas have habituated to construction noise, as evidenced by behavioral responses from a higher proportion of birds occupying territories in areas not previously subjected to road noise, which is consistent with findings in other parts of the species' range (Benson 1995). Additionally, we conducted control playback surveys to control for responses elicited by surveyor presence, and found that only perhaps ~6% of the responses by birds were due to surveyor presence. Although human presence is often reported as a disturbance to wildlife (Bélanger and Bédard 1990, Burger and Gochfeld 1998, González et al. 2006), most warblers did not react to surveyors. As a constraint of working with endangered species, construction noise was played to individual birds for only a short duration of time in order to prevent any unnecessary threat to the birds. Although the noise level and types of noises were similar to those of the actual construction, playback duration and daily frequency of the disturbance could not be accurately reproduced. As a result, birds may have been less likely to respond as they would to the actual disturbance—a common limitation of studies that address biological effects of noise on wildlife (Pater et al. 2009).

The broadcast-unit experiment showed that territories located near broadcast units had similar year-to-year shifts in territory locations as a random sample of territories not located near broadcast units. In addition, there appeared to be no differences in reproductive success between broadcast-unit and non-broadcast-unit territories, or a higher incidence of territory abandonment in broadcast-unit territories. A potential limitation of our approach was the fact that we did not rely on marked (i.e., banded) individuals. Thus, we accepted the assumption that individuals observed across the 2 years experienced similar road construction noises in both years; in other words, either the same adult(s) returned to the territory location between years or, if different birds used the location in the second year, they had the same experience with road and construction noise as the previous occupants of the location. In our study, the construction-noise disturbance was short-term and there were no apparent biological effects on warblers; longer periods of disturbance may lead to changes in the population over time and should be studied accordingly (Bejder et al. 2006, Holmes et al. 2006, Madsen and Boertmann 2008, Francis et al. 2009).

Because our study sites were located in rural counties with vehicle loads of <2,000 vehicles day^{-1}, our results are most applicable to similar situations elsewhere in the species' range. Previous studies that reported negative effects of road noise on songbird populations have been located near roads with 10,000–60,000 vehicles day^{-1} and have shown biological effects from 40 m to 3 km away from roadways (Reijnen et al. 1995, 1997; Federal Highway Administration 2004). Given the difference in vehicle loads, it is conceivable that warblers may react differently to road noise in louder areas with higher traffic volume than warblers in rural areas. Further studies of the effects of road construction on warblers are ongoing in an urban area along Highway 71 in Travis County, Texas (M. L. Morrison unpubl. data), where populations may be exposed to louder anthropogenic noise.

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