AVIAN RESPONSE TO ROAD CONSTRUCTION NOISE WITH EMPHASIS ON THE ENDANGERED GOLDEN-CHEEKED WARBLER

A Thesis

by

MELISSA ANNE LACKEY

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2010

Major Subject: Wildlife and Fisheries Sciences

AVIAN RESPONSE TO ROAD CONSTRUCTION NOISE WITH EMPHASIS

ON THE ENDANGERED GOLDEN-CHEEKED WARBLER

A Thesis

by

MELISSA ANNE LACKEY

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Approved by:

Chair of Committee,	Michael L. Morrison
Committee Members,	Bret A. Collier
	William E. Rogers
Head of Department,	Thomas E. Lacher

May 2010

Major Subject: Wildlife and Fisheries Sciences

ABSTRACT

Avian Response to Road Construction Noise with Emphasis on the Endangered Golden-cheeked Warbler. (May 2010)

Melissa Anne Lackey, B.S., Ohio Northern University

Chair of Advisory Committee: Dr. Michael L. Morrison

Noise pollution can mask or distort bird songs, which inhibits mating success, predator detection, and parental response to begging calls. Road noise can cause lowered density and reproductive success in songbirds. I examined the impact of construction noise on reproductive success and territory selection of golden-cheeked warblers (*Dendroica chrysoparia)* at 3 sites: adjacent to road construction, adjacent to road-noise only, and a control with no noise or construction activity. I also examined birds' responses to experimental playback of construction noise to determine if warblers alter behavior in the presence of introduced road construction noise, if they have habituated to construction noise, and whether habituation is hindering their reproductive success. I used the Vickery reproductive index to evaluate productivity and automatic recording units to assess the levels of ambient noise in each site. From 2007–2009, productivity was stable in the road-noise only site and showed more annual variation in the construction and control sites; productivity was nearly identical in the latter 2 sites in 2008 and 2009. There was no significant difference in productive territory locations based on distance from road. Ambient noise was similar in the construction and road-noise only sites but significantly different from the control. To examine habituation and territory placement, I (1) used construction noise playback to individual birds and evaluated occurrence of behavioral response as a function of distance from the roadway, and (2) established broadcast stations that simulate construction noise to determine impacts on territory selection. Of 88 surveys, 6 birds responded to construction noise playback. I conducted 18 control surveys and observed 1 behavioral response. All birds that responded were located ≥140 m from the road. I established 3 broadcast stations per season in 2008 and 2009. In each year I placed broadcast units on the edges of randomly chosen territories identified during the previous field season. There was not a significant difference in mean territory shifts for broadcast and non-broadcast unit territories, and territory shifts did not show patterns in directionality or in reproductive success. Results suggest that construction noise does not appear to affect behavior or reproductive success of golden-cheeked warblers.

ACKNOWLEDGEMENTS

I would like to thank my committee chair, Dr. Michael L. Morrison, and my committee members, Dr. Bret A. Collier and Dr. William E. Rogers, for their guidance and support throughout the course of my graduate studies. I would like to thank the Texas Department of Transportation for funding this project and the Institute of Renewable Natural Resources for providing logistical support. Thanks go to Michael Priour at Big Springs Ranch for allowing me to work and live on his property and to Texas Parks and Wildlife for allowing me to work at Garner State Park. I would also like to thank Dr. Joseph Szewczak and Zachary Loman for their collaboration with the acoustic portion of this research project, and Zac for his assistance in the field. I would like to thank Jill Loman for her work as a field technician throughout the project, as well as field technicians A. Corso, A. Renteria, and A. Sabella. Thanks also go to my lab mates for their advice during the course of my graduate studies. Finally, thanks to my friends and family for their love and encouragement.

TABLE OF CONTENTS

		Page
ABSTRACT		iii
ACKNOWLEDGEMENTS		v
TABLE OF CONTENTS		vi
LIST OF FIGURES		vii
LIST OF TABLES		ix
CHAPTER		
I	INTRODUCTION	1
II	REPRODUCTIVE SUCCESS OF THE GOLDEN-CHEEKED WARBLER IN RESPONSE TO CONSTRUCTION ACTIVITIES	4
	Methods	7
	Analysis	13
	Results	17
	Discussion	27
III	EXPERIMENTAL DETERMINATION OF AVIAN RESPONSE TO CONSTRUCTION ACTIVITIES	31
	Methods	35
	Analysis	43
	Results	45
	Discussion	51
IV	SUMMARY	55
LITERATURE CITED		59
VITA		65

LIST OF FIGURES

		Page
Figure 1	Location of transects used to determine the presence and location of golden-cheeked warblers in the construction and control sites in Real County, Texas, USA, 2007–2009	10
Figure 2	Location of transects used to determine the presence and location of golden-cheeked warblers in the road-noise only site in Uvalde County, Texas, USA, 2007–2009	11
Figure 3	Minimum convex polygons used to determine distance from road of golden-cheeked warblers in the construction site in Real County, Texas, USA, 2009	15
Figure 4	Percentage of successful pairs in construction, road-noise only, and control sites in Real and Uvalde Counties, Texas, USA, 2007–2009	19
Figure 5	Mean distance from road of all territories, paired territories, and successful territories of golden-cheeked warblers in construction, road-noise only, and control sites in Real and Uvalde Counties, Texas, USA, 2007–2009	22
Figure 6	Density of golden-cheeked warbler territories in construction, road-noise only, and control sites in Real and Uvalde Counties, Texas, USA, 2007–2009	24
Figure 7	Average ambient noise levels (dB) at ARU locations in road construction, road-noise only, and control sites adjacent to Highway 83 in Real and Uvalde Counties, Texas, USA 2007–2009	26
Figure 8	Average ambient noise levels (dB) in relation to distance from road at ARU locations within construction and road-noise only sites adjacent to Highway 83 in Real and Uvalde Counties, Texas, USA 2007–2009	27
Figure 9	Golden-cheeked warbler response to playback and control surveys in relation to distance from Highway 83 in Real and Uvalde Counties, Texas, USA, 2007–2009	48

		Page
Figure 10	Golden-cheeked warbler response to playback in relation to productivity and distance from Highway 83 in Real and Uvalde Counties, Texas, USA, 2007–2009	48
Figure 11	Black-and-white warbler response to playback in relation to distance from Highway 83 in Real and Uvalde Counties, Texas, USA, 2007–2009	49

LIST OF TABLES

Page

Table 1 Vickery reproductive index used to determine reproductive success of golden-cheeked warblers in the road construction, road-noise only, and control sites adjacent to Highway 83 in Real and Uvalde Counties, Texas, USA 2007–2009 (Vickery et. al 1992).................. 12

Table 2 Percentage of unpaired, paired but unsuccessful, and successful golden-cheeked warbler males in construction, road-noise only, and control sites in Real and Uvalde Counties, Texas, USA, 2007–2009.. 18

Table 3 Minimum, maximum, mean and standard error of the distance 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 21

Table 4 Density of golden-cheeked warbler territories in construction, road-noise only, and control sites in Real and Uvalde Counties, Texas, USA, 2007–2009 23

Table 5 Vickery reproductive index used to determine reproductive success of golden-cheeked warblers in the road construction, road-noise only, and control sites adjacent to Highway 83 in Real and Uvalde Counties, Texas, USA 2007–2009 (Vickery et. al 1992).................. 38

Table 6 Average noise levels (dB) produced by typical activities; the apparent loudness of the noise level compared to the baseline (suburban area with medium traffic) and the typical human perception (Harrington 2000)... 40

Table 7 Behavior categories used to document golden-cheeked warbler behavior before, during, and after playback surveys to individual males.. 41

Table 8 Initial behavior and types of behavioral response of the 6 golden-cheeked warblers (n = 88) and 4 black-and-white warblers (n = 14) that responded to construction noise playback, based on behavior categories (Table 7).. 47

Page

Table 9 Golden-cheeked warbler territory shifts between 2007 and 2008, and 2008 and 2009 for broadcast unit and non-broadcast unit territories 50

Table 10 Golden-cheeked warbler reproductive success between 2007 and 2008, and 2008 and 2009 for broadcast unit and non-broadcast unit territories 51

CHAPTER I

INTRODUCTION

Birds may be particularly sensitive to noise resulting from human disturbance because they frequently use auditory signals for communication. Noise that distorts or masks the birds' 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 2005, Habib et al. 2007). Noise may require birds to sing at higher frequencies, at higher energetic cost (Slabbekoom and Peet 2003, Wood and Yezerinac 2006).

Noise can affect bird community structure by favoring certain species (Stone 2000). Studies have found that densities of birds that sing at higher frequencies are unaffected by noise pollution (Rheindt 2003, Francis et al. 2009). Francis et al. (2009) showed that noisy environments can alter community composition by interfering with predator-prey interactions. They concluded that altered species interactions may be contributing to the success of species well-adapted to noisy environments and to the decline of species more sensitive to noise. Habib et al. (2007) found a reduction in pairing success and a higher proportion of inexperienced ovenbirds (*Seiurus aurocapilla*) at industrial well compressor stations compared with control sites

---

This thesis follows the style of Journal of Wildlife Management.

surrounding habitat-disturbed but noiseless stations. Habib et al. (2007) concluded that noise disturbance interferes with male songs, causing females to be unable to hear or judge song quality as lower due to distortion. In a study evaluating habitat quality for the willow warbler (*Phylloscopus trochilus*) along a highway with dense traffic, Reijnen and Foppen (1994) found a lower density of birds in the road zone.

Anthropogenic disturbance affects wildlife in a variety of ways, and can be permanently detrimental to a species' population. Recent studies (Thompson and Henderson 1998, Conomy et al. 1998, Stolen 2003) have found increasing evidence of wildlife habituation to anthropogenic disturbance. Habituation is an animal ceasing to respond to repeated activities that have neither positive nor negative reinforcement, and is considered an adaptive behavioral strategy (Thompson and Henderson 1998). Some evidence suggests that habituation to anthropogenic disturbance is species-specific, and that short-term effects may not accurately represent long-term effects. In a study on Spanish imperial eagles (*Aquila adalberti*), birds showing signs of habituation to human disturbance had lower breeding success than those not exposed to human activity (González et al. 2006). However, a study of gentoo penguins (*Pygoscelis papua*) found that breeding success appeared to be unaffected in populations exposed to human disturbance (Holmes et al. 2006).

The golden-cheeked warbler (*Dendroica chrysoparia),* the focal species for my research, was placed on the federal endangered species list in 1990 due to habitat destruction and fragmentation. As urbanization increases, roads are being built and modified throughout the golden-cheeked warbler's range. The warbler uses 2 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. My goal was to compare reproductive success of birds exposed to construction noise, exposed to road-noise only, and not exposed to noise or activity; and to evaluate reproductive success in relation to distance from road. My impact assessment evaluated whether (1) road noise affected the warblers, (2) construction activity exacerbated these effects, and (3) construction noise affected the warblers differently than road noise.

I conducted 2 experiments to assess whether golden-cheeked warblers are habituating to construction noise. My first objective was to document behavioral responses to recordings of construction noise played to birds that were: (1) already exposed to road and construction noise, (2) only exposed to road noise, and (3) exposed to neither road noise nor construction noise. I hypothesized that birds found closest to the construction activity would have the least behavioral response to recordings of construction noise, and responses would steadily increase with increasing territory distance from construction activity. The black-and-white warbler *(Mniotilta varia*) was a secondary study species in the construction noise playback experiment. My second objective was to examine site fidelity and territory location in response to simulated construction noise. I 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. My final objective was to evaluate responses to playback and simulated construction noise in relation to reproductive success.

CHAPTER II

REPRODUCTIVE SUCCESS OF THE GOLDEN-CHEEKED WARBLER IN RESPONSE TO CONSTRUCTION ACTIVITIES

Birds may be particularly sensitive to noise resulting from human disturbance because they frequently use auditory signals for communication. Noise that distorts or masks the birds' communication signals can influence population density, mating behavior, and breeding success; ambient noise may reduce male to female communication, drown out begging calls, or inhibit predator detection (Benson 1995, Habib et al. 2007). Noise may require birds to sing at higher frequencies, at higher energetic cost (Slabbekoom and Peet 2003, Wood and Yezerinac 2006). The Lombard effect, or birds raising song amplitude to compensate for higher ambient noise, is an example of a short-term vocal adjustment that birds exhibit in noisy environments (Patricelli and Blickley 2006). In addition, birds may have to increase redundancy of songs in noisy environments in order to communicate effectively (Brumm and Slater 2005).

Noise can affect bird community structure by favoring certain species (Stone 2000). Loud ambient noise gives an advantage to birds that sing at higher frequencies; studies have found that densities of these birds such as house finches (*Carpodacus mexicanus*), black-chinned hummingbirds (*Archilochus alexandri*), blue tits (*Parus caeruleus*) and chaffinches (*Fringilla coelebs*) are unaffected by noise pollution (Rheindt 2003, Francis et al. 2009). Francis et al. (2009) showed that noisy environments can alter community composition by interfering with predator-prey interactions. Birds in noisy areas had higher reproductive success than those in control areas due to a decrease in predation, in this case a result of western scrub-jays' (*Aphelocoma californica*) avoidance of the noisy areas. Francis et al. (2009) concluded that altered species interactions may be contributing to the success of species well-adapted to noisy environments and to the decline of species more sensitive to noise.

Another recent study assessed the effects of chronic industrial noise on age distribution and pairing success among ovenbirds (*Seiurus aurocapilla*) (Habib et al. 2007). Impact study sites surrounded noise-generating compressor stations with control sites surrounding habitat-disturbed but noiseless well stations. Results of the study showed a reduction in pairing success and a higher proportion of inexperienced birds at compressor stations. Habib et al. (2007) concluded that noise disturbance interferes with male songs, causing females to be unable to hear or judge song quality as lower due to distortion. Ovenbirds have a high amplitude song compared to most wood warblers, suggesting similar effects on species with quieter songs.

In a study evaluating habitat quality for the willow warbler (*Phylloscopus trochilus*) along a highway with dense traffic, Reijnen and Foppen (1994) found that presence of the highway negatively influenced the species population. Reijnen and Foppen (1994) divided the habitat into 3 zones beginning at the highway. The road zone was 0–200 m away from the road, the intermediate zone was 200–400 m from the road, and ≥400 m away was considered a control zone. Reijnen and Foppen (1994) found a lower density of birds in the road zone than in comparable habitat in the intermediate and control zones, and suggested density might have been lower in the road zone because of song distortion due to noise, and increased stress.

The golden-cheeked warbler (*Dendroica chrysoparia*), the focal species for my project, is a medium-sized wood-warbler that breeds exclusively in the oak-juniper woodlands of central Texas. Females build nests using strips of bark pulled from Ashe juniper (*Juniperus ashei*); this nesting behavior is the most likely reason for the species' restricted range (Pulich 1976). Golden-cheeked warblers are early migrants, arriving on the breeding grounds in early March and departing in mid-June. They are complete neotropical migrants and winter in the highlands of southern Mexico, Guatemala, Honduras, and Nicaragua (Ladd and Gass 1999).

The golden-cheeked warbler was placed on the federal endangered species list in 1990 due to habitat destruction and fragmentation. As urbanization increases, roads are continually being built and modified throughout the warbler's range. Golden-cheeked warblers use 2 different songs to communicate during the breeding season (Bolsinger 2000); anthropogenic noise that masks or distorts these songs could impact an already endangered population.

My goal was to compare reproductive success of birds exposed to construction noise, exposed to road-noise only, and not exposed to noise or activity; and to evaluate reproductive success in relation to distance from road. Construction activities in Real County, Texas provided the opportunity to carry out my research objectives through an impact assessment study which examined whether construction noise was affecting the density, breeding success, and singing behaviors of golden-cheeked warblers. My impact assessment evaluated whether (1) road noise affected the warblers, (2) construction activity exacerbated these effects, and (3) if construction noise affected the warblers differently than road noise.

METHODS

Study Design

My basic study design was that of an impact assessment due to lack of specific pre-treatment data for treated (construction) or reference sites and lack of replication of treatment. I used 3 types of study sites in my research:

1. Impact (construction): a site adjacent to the road that was undergoing construction activities; this site was exposed to both construction activity and road noise (vehicle traffic).
2. Reference, road-noise only: a site where traffic noise and disturbance existed but no construction activity occurred. The road-noise only site separated the potential effects of road noise from construction activity on golden-cheeked warblers.
3. Reference, no noise or activity (control): a site well removed from the highway, thus eliminating road noise, disturbance, and construction activity as factors that potentially influenced birds. The control site separated the effects of road noise and disturbance on golden-cheeked warblers.

I conducted all surveys using the same methods in each site and determined potential impacts of construction noise and activity on the productivity of golden-cheeked warblers by comparing results in each site type. In addition, I assessed potential impacts by evaluating productivity as a function of distance from road in the construction and road-noise only sites.

Study Areas

I conducted productivity surveys on golden-cheeked warblers during the breeding seasons of 2007, 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 where much of the land remained unaltered golden-cheeked warbler habitat (oak-juniper woodland) in accordance with the benefactor's will. A 9-km stretch of U.S. Highway 83, adjacent to Big Springs Ranch, was used for construction noise sites and was the only "impact" area available in the region. This length of highway was being widened from 2 lanes to 4 lanes to improve traffic flow and safety, but not due to increased traffic. Activities included, but were not limited to: road grading, excavation, paving, and pilot car operation. 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 my study area was <2,000 vehicles/day, and I used areas on Big Springs Ranch ≥1,000 m from the roadway for control sites. Garner State Park was located approximately 32 km south of the construction zone. The portion of Garner State Park adjacent to Highway 83 was used for road-noise only sites; because most of the region is privately owned, Garner State Park was the closest appropriate location where I could gain access.

Territory Identification

I conducted line transect surveys from 12–24 March to determine the presence and location of golden-cheeked warblers. I conducted the surveys as follows:

1. Construction and road noise site: 6 transects ran 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, 2 transects at 600 m) (Fig. 1).
2. Road-noise only site: 4 transects ran perpendicular to the road in suitable golden-cheeked warbler habitat at Garner State Park. Three of these transects were 600 m in length and 1 was 500 m in length (Fig. 2).
3. Control site: 4 transects were located ≥1,000 m from the highway within suitable warbler habitat. Three of these transects were 600 m in length and 1 was 500 m in length (Fig. 1).

Surveyors began transect surveys at sunrise and completed surveying within 60–90 minutes, depending on transect length. Upon detection of a male golden-cheeked 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 golden-cheeked warblers recorded during transect surveys were spot-mapped using a GPS (International Bird Census Committee 1969). Observers located and followed each singing male for 60 minutes or until 10 GPS waypoints were recorded for each bird. After 24 March, I monitored presence and territory location through productivity surveys as described below.

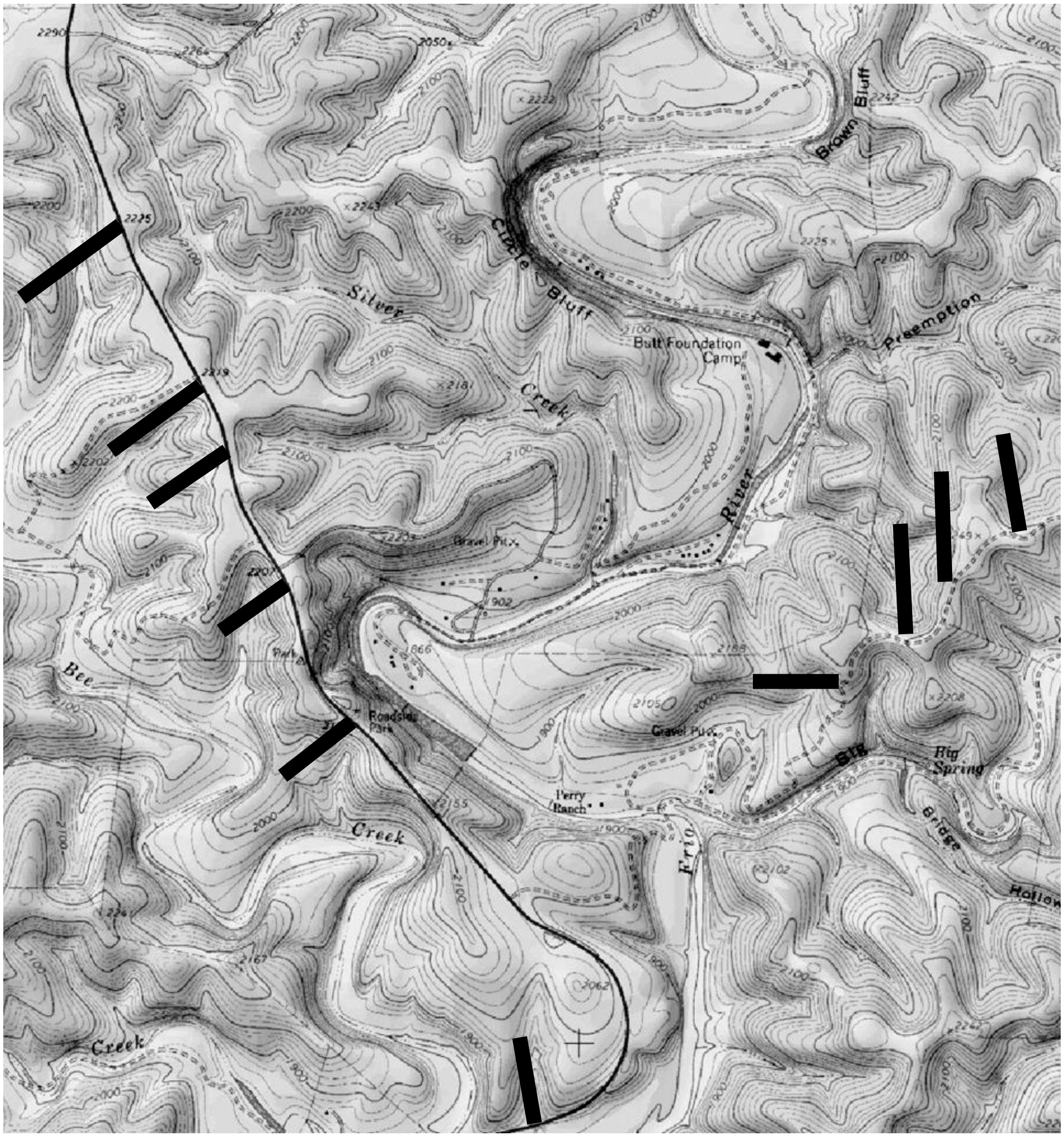

Figure 1. Location of transects used to determine the presence and location of golden-cheeked warblers in the construction and control sites in Real County, Texas, USA, 2007–2009.

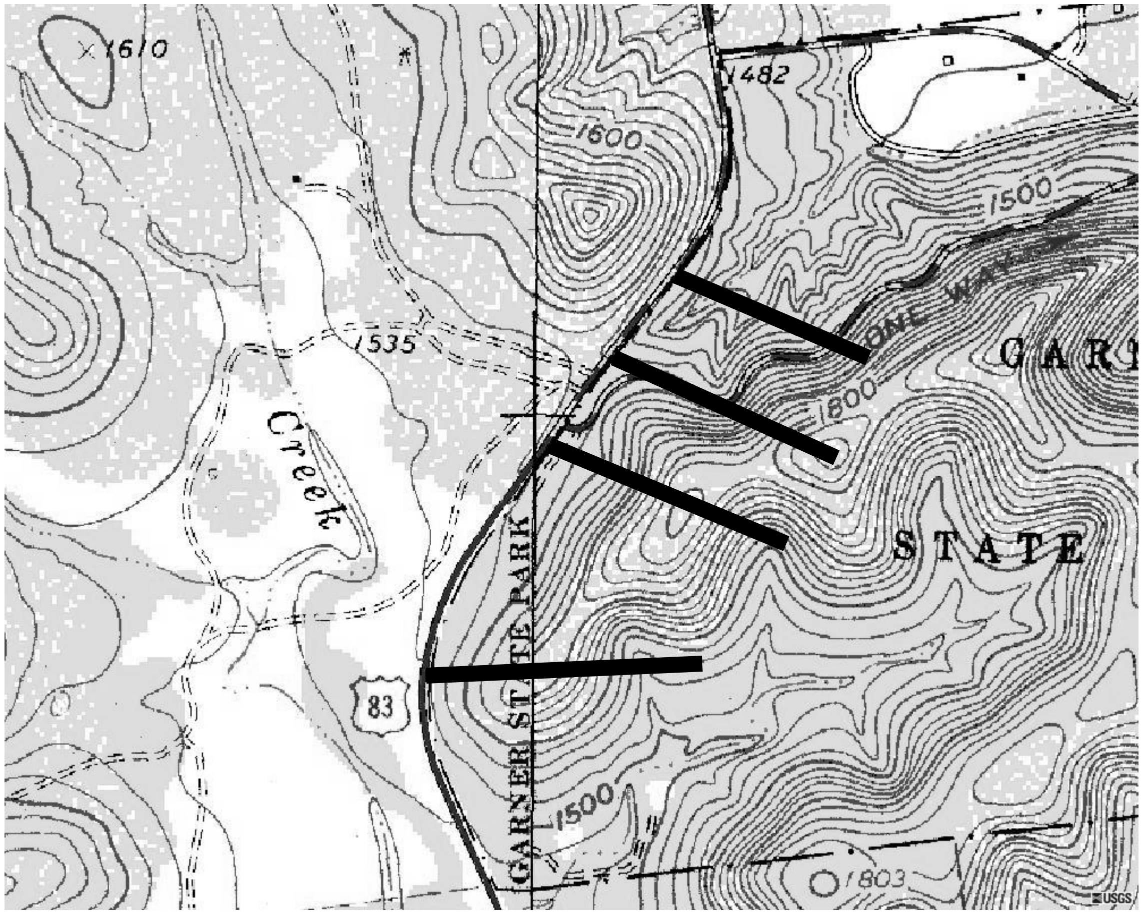

Figure 2. Location of transects used to determine the presence and location of golden-cheeked warblers in the road-noise only site in Uvalde County, Texas, USA, 2007–2009.

Productivity

I determined territorial reproductive success of golden-cheeked warblers using the Vickery reproductive index (Vickery et. al 1992). The Vickery method was useful because it does not disrupt nests of rare or endangered species and is a reliable measure of success rates of species whose nests are hard to locate. Both advantages overcome difficulties that researchers face when assessing reproductive success of the golden-cheeked warbler. Previous studies have successfully employed the Vickery method (Christoferson and Morrison 2001, Rivers et al. 2003) to show which birds successfully fledged young, which birds were paired but unsuccessful, and which birds remained unpaired throughout the breeding season (Table 1).

Table 1. Vickery reproductive index used to determine reproductive success of golden-cheeked warblers in the road construction, road-noise only, and control sites adjacent to Highway 83 in Real and Uvalde Counties, Texas, USA 2007–2009 (Vickery et. al 1992).

Vickery Rank	**Description**
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 was 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

I conducted productivity surveys on each territory approximately once every 7 days, from 24 March until 18 June. Surveys lasted 60 minutes 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 minutes, 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. I trained 2–3 observers to assist with surveys at the beginning of each season and monitored quality of work throughout the season; 1 observer assisted all 3 years. I rotated observers among study sites and territories to reduce observer bias.

Ambient Noise

I used automatic recording units (ARUs) to assess the levels of ambient noise in the construction, road-noise only, and control sites. The ARUs were programmed to record from 06:00 to 12:00 daily from 15 March until 15 June 2007–2009, at 44 total locations within known warbler territories. I deployed ARUs at varying distances from 30 to 460 m from Highway 83 in the construction and road-noise only sites, and at randomly chosen locations in the control site.

ANALYSIS

Reproductive Success

I graphically compared percentages of reproductive success in all sites for each year. I considered territories successful if adults were seen with fledglings at least 1 time, and unsuccessful if the male was observed with a female at least 1 time but I did not find fledglings in the territory. I considered males unpaired if they were never observed with a female and excluded them from productivity analyses. I used a factorial analysis of variance (ANOVA) to determine whether there were significant differences in productivity between sites and years (Zar 2010: 265–269).

Distance from Road

I graphically compared pairing success and reproductive success in the construction and road-noise only sites in relation to distance from road in each year. I created minimum convex polygons using ArcMap™ 9.2 software to identify territory boundaries (Fig. 3). 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. I considered outliers to be points in which the bird was located well outside of the primary use area on only 1 occasion during the breeding season. I used center points of the minimum convex polygons to obtain distance from road, and conducted Mann-Whitney tests to compare territory distances from road between the construction and road-noise only sites in each year (Zar 2010: 163–172). I used Mann-Whitney tests due to low sample sizes within each site ($n \leq 26$). I used one-way ANOVAs to compare differences in territory distances between years (Zar 2010: 190–206).

Figure 3. Minimum convex polygons used to determine distance from road of golden-cheeked warblers in the construction site in Real County, Texas, USA, 2009.

Density

To determine density I used minimum convex polygons in ArcMap™ 9.2 to determine the area surveyed in each study site. Extreme outliers were removed because those points may be measurement error or represent rare instances of movement events that were outside of the primary survey area. I considered outliers to be points in which a bird was located well outside of the primary survey area on only 1 occasion during the breeding season. I calculated area surveyed separately for each year because survey effort increased from 2007 to 2009. I divided total number of birds by total area surveyed to determine birds/ha for each of the study sites in all years.

Ambient Noise

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

RESULTS

Reproductive Success

In 2009, the number of unpaired males was 31% higher in the road-noise only site and 20% higher in the control site than in 2008; I did not observe unpaired males at either site in 2007. In the construction site, 13% of males were unpaired in 2007 compared with 4% in 2008 and 2009 (Table 2).

From 2007 to 2009, productivity was stable (88–93%) in the road-noise only site and showed more yearly variation in the construction (62–90%) and control (62–78%) sites; productivity was 21% lower in the control site than the road-noise only site over all 3 years. Reproductive success in the construction site was similar to the road-noise only site in 2007 but decreased and was nearly identical to success rates in the control site in 2008 and 2009. Productivity of golden-cheeked warblers differed significantly between sites ($F_{8,136}$ = 2.190, P = 0.035) but there was not a significant interaction between site and year ($F_{4,136}$ = 0.719, P = 0.528). A Tukey HSD post-hoc comparison showed that productivity in the construction and control sites were both significantly different from the road-noise only site (P = 0.012; P = 0.017) but were not significantly different from each other (P = 0.947) (Fig. 4).

Table 2. Percentage of unpaired, paired but unsuccessful, and successful golden-cheeked warbler males in construction, road-noise only, and control sites in Real and Uvalde Counties, Texas, USA, 2007–2009.

	Road Construction	**Road-noise Only**	**Control**	**Total**
2007				
Unpaired[1]	13.0%	0	0	6.8%
Paired but Unsuccessful[2]	10.0%	8.3%	22.2%	12.2%
Successful[3]	90.0%	91.7%	77.8%	87.8%
2008				
Unpaired	3.8%	1.9%	1.9%	7.5%
Paired but Unsuccessful	38.1%	6.25%	38.5%	28.0%
Successful	61.9%	93.3%	61.5%	71.4%
2009				
Unpaired	3.8%	33.3%	22.2%	19.1%
Paired but Unsuccessful	28.0%	12.5%	28.6%	23.6%
Successful	72.0%	87.5%	71.4%	76.3%

[1] Males never observed with a female/total number of birds
[2] Males observed with a female during ≥1 survey and no fledglings observed/total number of paired birds
[3] Number of successful territories/total number of paired males

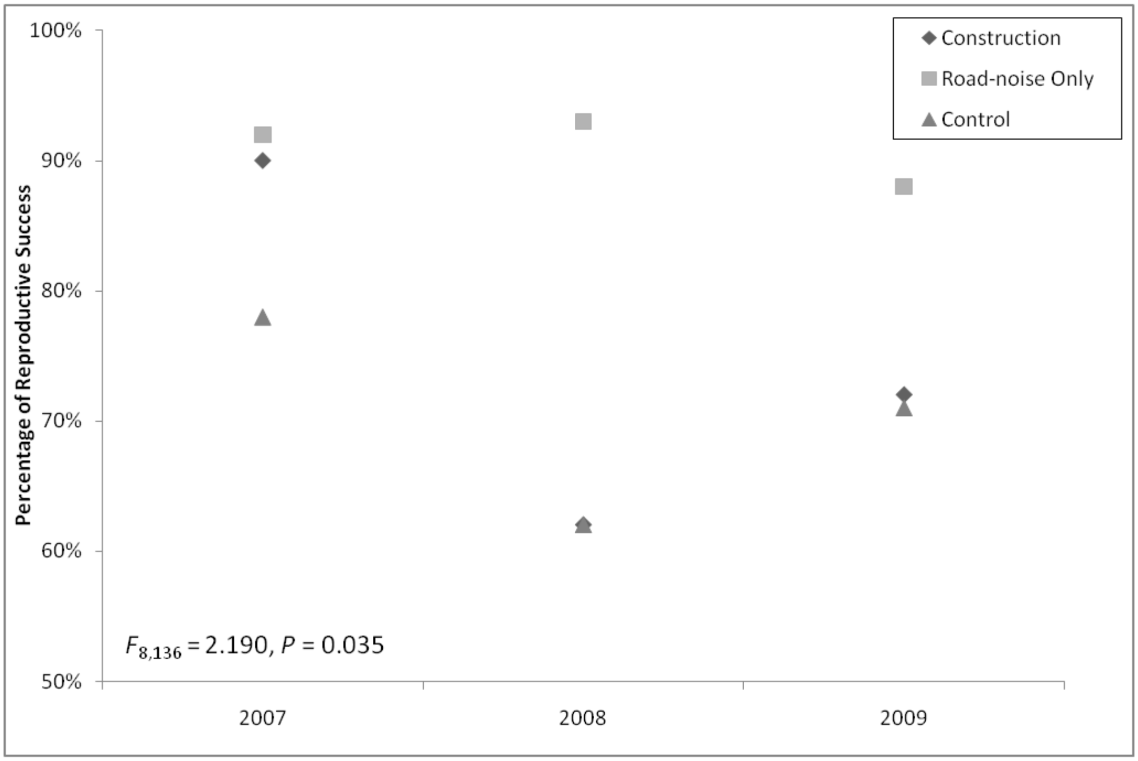

Figure 4. Percentage of successful pairs in construction, road-noise only, and control sites in Real and Uvalde Counties, Texas, USA, 2007–2009.

Distance from Road

Territory distances from road were not significantly different between years in either the construction site ($F_{2,69}$ = 1.052, P = 0.355) or the road-noise only site ($F_{2,49}$ = 0.024, P = 0.976). Distance from road was not significantly different between sites in 2007 (P = 0.281), 2008 (P = 0.549), or 2009 (P = 0.816). Distance from road was not significantly different between years in paired territories (construction: $F_{2,63}$ = 0.983, P = 0.380; road-noise only: $F_{2,40}$ = 0.019, P = 0.981) or successful territories (construction: $F_{2,46}$ = 0.745, P = 0.481; road-noise only: $F_{2,36}$ = 0.070, P = 0.932)(Table 3). Distance of successful territories was not significantly different from all territories in the construction site (P = 0.283) or the road-noise only site (P = 0.764), or between sites (P = 0.194).

Distance from road of paired territories was not significantly different from unpaired territories in the construction site (P = 0.121) or the road-noise only site (P = 0.271). Distance of successful territories was close to significantly different from unsuccessful territories in the construction site (P = 0.054) but was not significantly different in the road-noise only site (P = 0.920).

From 2007 to 2008 the minimum distance from road increased from 37 m to 72 m in the road construction site and from 26 m to 49 m in the road-noise only site. In 2009 the minimum distance from road decreased to 57 m in the road construction site and 44 m in the road-noise only site (Table 3). Means were similar across the 3 years in both sites for all territories, paired territories, and successful territories (Fig. 5).

Table 3. Minimum, maximum, mean and standard error of the distance 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	Minimum	Maximum	Mean	Std. Error
Construction					
All, 2007	23	37	472	235	25
Paired, 2007	20	37	472	230	28
Successful, 2007	18	37	440	209	26
All, 2008	23	72	643	270	33
Paired, 2008	21	72	643	257	35
Successful, 2008	13	72	643	253	48
All, 2009	26	57	655	297	33
Paired, 2009	25	57	655	293	34
Successful, 2009	18	57	608	267	38
Paired, All Years	66	37	655	263	19
Unpaired, All Years	6	203	445	334	35
Successful, All Years	49	37	643	243	21
Unsuccessful, All Years	17	131	655	323	38
Road-noise only					
All, 2007	12	26	523	294	48
Paired, 2007	12	26	523	294	48
Successful, 2007	11	26	523	308	51
All, 2008	16	49	606	302	43
Paired, 2008	15	49	606	294	45
Successful, 2008	14	49	606	283	47
All, 2009	24	45	568	307	32
Paired, 2009	16	45	544	284	43
Successful, 2009	14	45	544	286	46
Paired, All Years	43	26	606	291	26
Unpaired, All Years	9	203	569	363	40
Successful, All Years	39	27	607	292	27
Unsuccessful, All Years	4	112	446	284	88

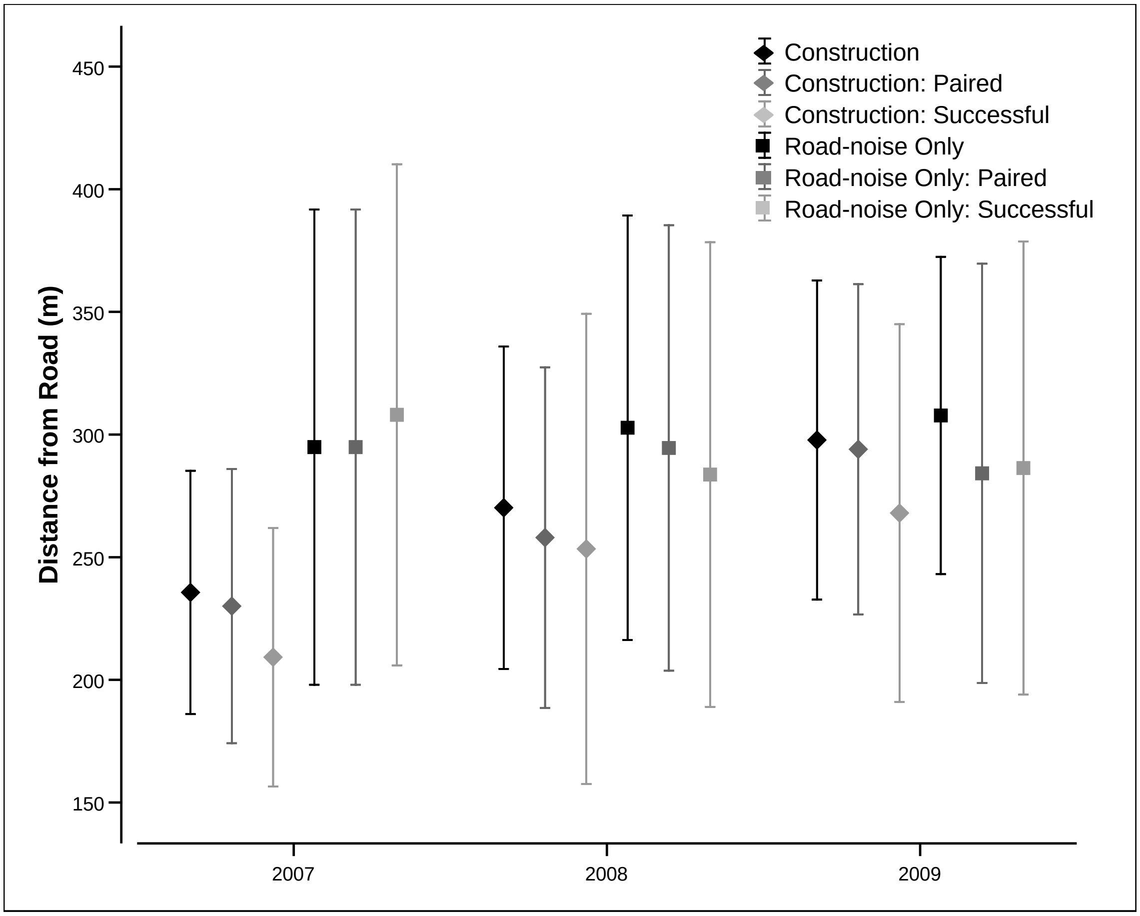

Figure 5. Mean distance from road of all territories, paired territories, and successful territories of golden-cheeked warblers in construction, road-noise only, and control sites in Real and Uvalde Counties, Texas, USA, 2007–2009.

Density of Golden-cheeked Warbler Territories

I used minimum convex polygons to determine area surveyed and density (Table 4). In the construction site, density decreased 5% from 2007 to 2008, and decreased 6% from 2008 to 2009. Density increased 9% in the road-noise only site from 2007 to 2008 and increased 20% from 2008 to 2009. In the control site, density increased 23% from 2007 to 2008 but decreased 6% from 2008 to 2009. Overall density increased 10% from 2007 to 2009 (Fig. 6). Density of golden-cheeked warblers did not differ significantly between sites ($F_{2,9}$ = 1.003, P = 0.421) or between years ($F_{2,9}$ = 0.939, P = 0.442).

Table 4. Density of golden-cheeked warbler territories in construction, road-noise only, and control sites in Real and Uvalde Counties, Texas, USA, 2007–2009.

	Area Surveyed (ha)	**Total Number of Territories**	**Density[1] (birds per ha)**
2007			
Road construction	71.59	23	0.3213
Road-noise only	39.15	12	0.3065
Control	32.16	9	0.2798
Total	142.90	44	0.3079
2008			
Road construction	75.01	23	0.3066
Road-noise only	47.25	16	0.3386
Control	38.46	14	0.3640
Total	160.72	53	0.3298
2009			
Road construction	90.13	26	0.2885
Road-noise only	56.42	24	0.4254
Control	52.82	18	0.3408
Total	199.37	68	0.3411

[1]Density= total number of birds/area surveyed (ha)

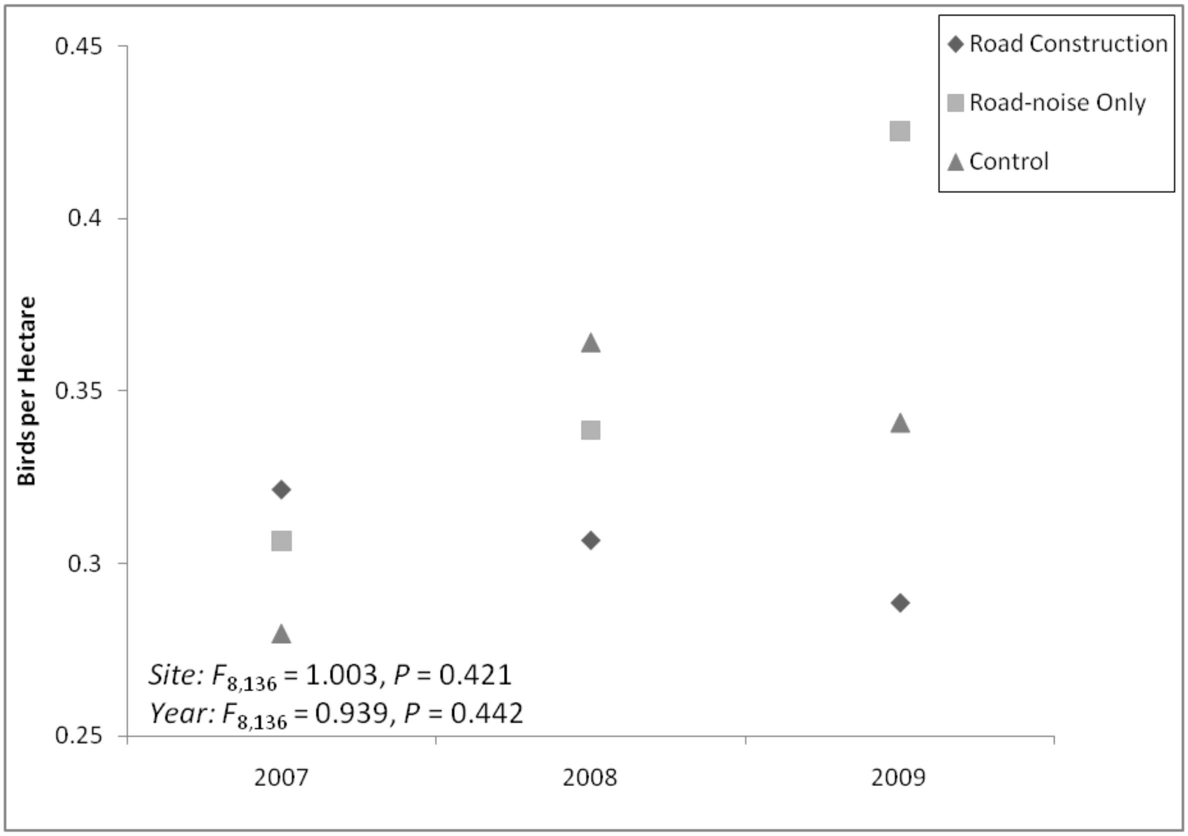

Figure 6. Density of golden-cheeked warbler territories in construction, road-noise only, and control sites in Real and Uvalde Counties, Texas, USA, 2007–2009.

Ambient Noise

Ambient noise levels (dB) differed significantly between sites ($F_{8,35}$ = 2.663, P = 0.021) but there was not a significant interaction between site and year ($F_{4,35}$ = 1.382, P = 0.260). A Tukey HSD post-hoc comparison showed that ambient noise in the construction and road-noise only sites were both significantly different from the control site (P = 0.001; P = 0.010) but were not significantly different from each other (P = 0.790) (Fig. 7). The linear regression showed a negative correlation between distance and noise level (Fig. 8) but was not significant for either the construction site ($F_{1,18}$ = 0.715, P = 0.409), the road-noise only site ($F_{1,14}$= 2.967, P = 0.109), or both sites combined ($F_{1,33}$ = 3.009, P = 0.092) and had low explanatory power (R^2 = 0.086). 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.

Within approximately 200 m of the highway, there is an increase in noise with decreasing distance to the road (Fig. 8). However, productivity data showed no significant differences in reproductive success between territories in each site located from 0 to 200 m from the road and from 200 to 500 m from the road. A factorial ANOVA showed no significant differences between success in each distance category in the construction site (F = 1.133, P = 0.354) and there was not a significant interaction between year and distance category (F = 0.493, P = 0.614). In the road-noise only site, there was also no significant difference between success in the 2 distance categories (F = 0.495, P = 0.778) or a significant interaction between year and distance category (F = 1.087, P = 0.349). Overall, there was no significant difference in productivity in all birds located 0 to 200 m from the road and those located 200–500 m from the road (F = 0.623, P = 0.682), or a significant interaction between distance category and year (F = 0.102, P = 0.903).

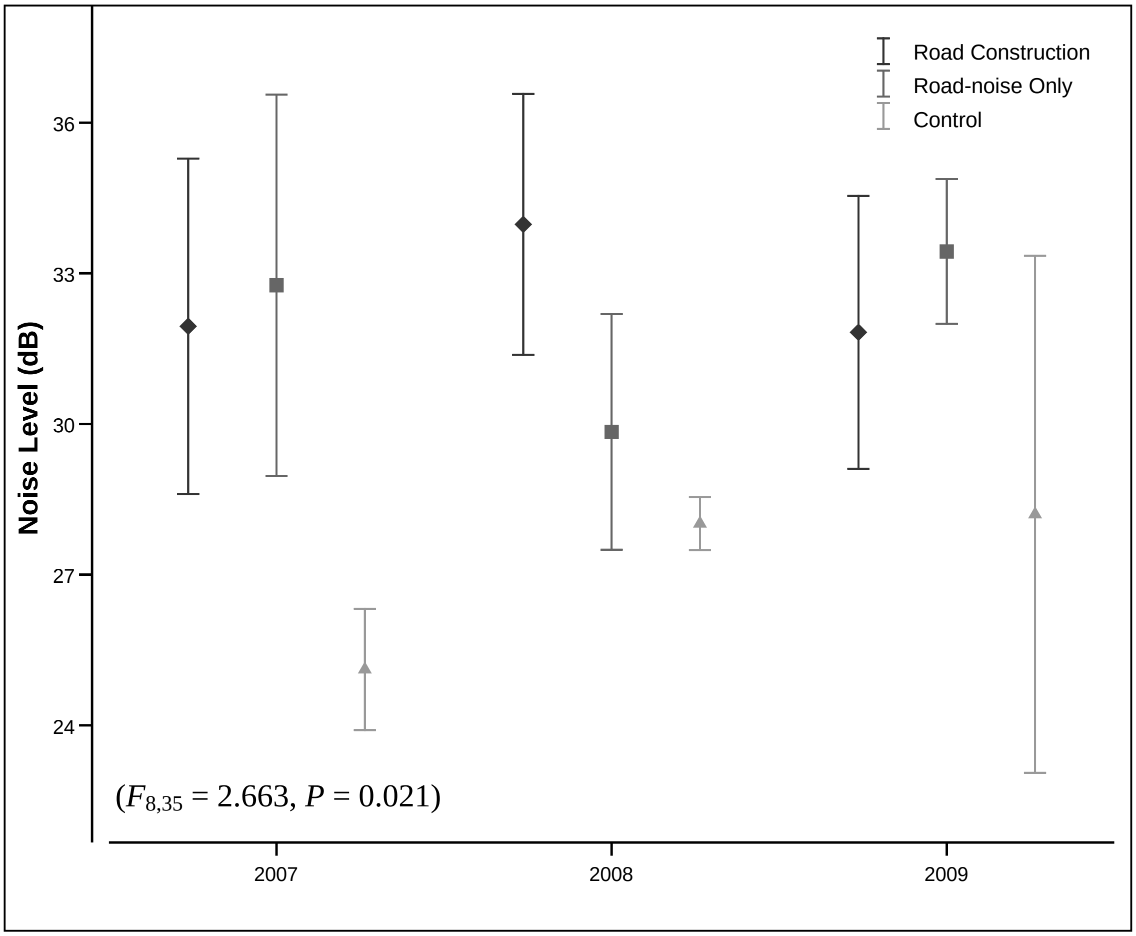

Figure 7. Average ambient noise levels (dB) at ARU locations in road construction, road-noise only, and control sites adjacent to Highway 83 in Real and Uvalde Counties, Texas, USA 2007–2009.

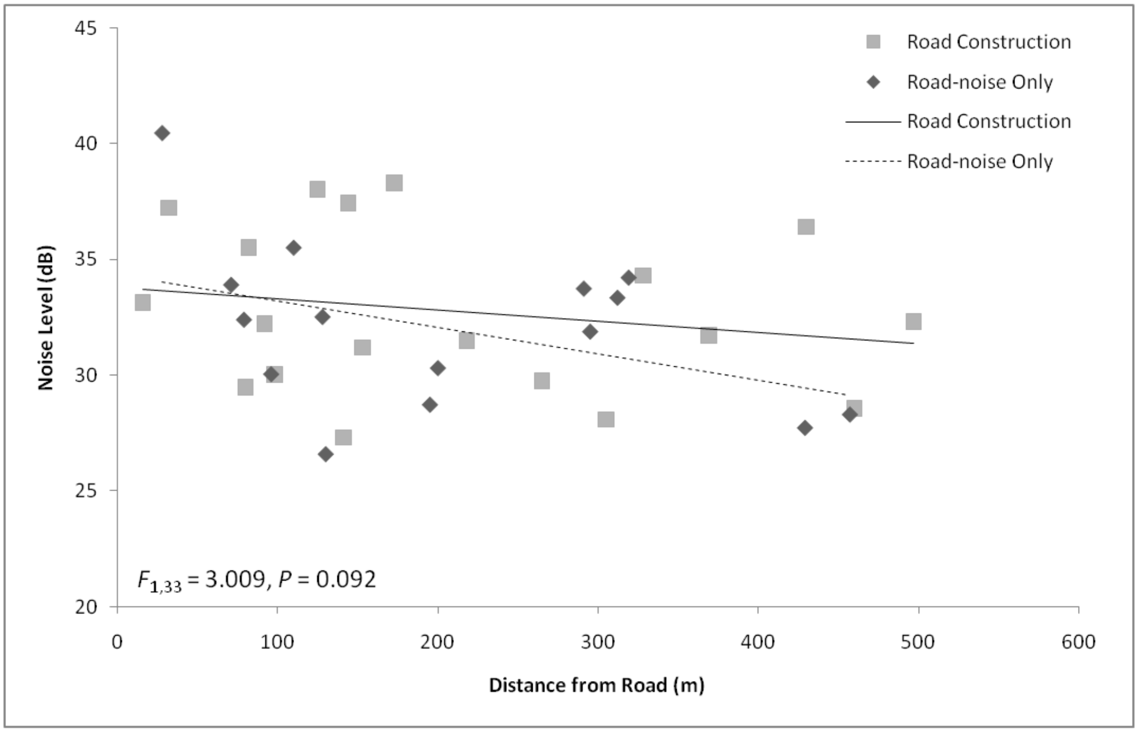

Figure 8. Average ambient noise levels (dB) in relation to distance from road at ARU locations within construction and road-noise only sites adjacent to Highway 83 in Real and Uvalde Counties, Texas, USA 2007–2009.

DISCUSSION

I found that reproductive success of golden-cheeked warblers in the road construction site was significantly different from warblers in the road-noise only site, but similar to reproductive success in the control site with no noise or activity. Productivity differed in the road construction site after the first year of the study, but distance from road and density did not differ; average territory distance in the construction site was closer to Highway 83 than average territory distance in the road-noise only site, but was not a statistically significant difference. Results suggest that construction noise was not affecting reproductive success of golden-cheeked warblers along Highway 83 and that proximity to the road did not influence reproductive success. The results of my study are consistent with previous work that found no significant difference between golden-cheeked warbler presence at high-noise and low-noise song posts near a highway (Benson 1995).

The significantly higher reproductive success, percentage of unpaired males, further average distance from road, and increase in density in the road-noise only site indicates road noise is not influencing golden-cheeked warblers in the area, but does suggest the possibility that a factor unrelated to road noise is creating population differences in the 3 study sites. Geographically, the road-noise only site was located at Garner State Park and was approximately 32 km south of Big Springs Ranch where both the construction and control sites were located. Differences in maximum territory distance from road is likely due to varying survey effort among years and differences in extent of habitat between the 2 sites. The number and experience of surveyors increased from 2007 to 2009, which increased efficiency and allowed time to monitor a greater number of territories each year. Additionally, golden-cheeked warbler habitat in the construction site only extended past 1 of 6 transects (400–600 m transects; habitat extended 400 m past 1 600-m transect) while 3 of 4 transects in the road-noise only site (500–600 m) had habitat extending 800–1000 m beyond the length of the transect.

I did not evaluate edge effects for my study, though previous studies of golden-cheeked warblers have reported higher nest success in areas with less forest edge (Peak 2007, Reidy et al. 2009). Other research has found that golden-cheeked warblers prefer landscape compositions of high percentages of woodland cover (Magness et al. 2006).

Territories in the road-noise only site were located primarily in 1 contiguous 743-ha patch with 72% woodland cover, while 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 (Texas A&M University, unpublished data). In the construction site, successful territories were closer to the road than unsuccessful territories, and there were fewer unpaired males, suggesting further evidence that edge effects and landscape composition may be playing a role in this area. Similarly, the difference in productivity in the construction site after the first year of study may be attributed to the patchier habitat.

The level of noise produced from the road construction on Highway 83 did not fundamentally represent a different (louder) noise regime in the study site than from highway noise alone. However, noise exposure in the construction site and road-noise only site was significantly different from noise in the control site. The similarity in ambient noise in the construction and road-noise only sites also suggests that construction noise is not affecting the warblers differently than road noise or exacerbating any effects of road noise. While there is an increase in noise levels within 200 m of the highway, productivity was similar between territories from 0 to 200 m from the road and those located 200–500 m from the road. Furthermore, the similarity of reproductive success in the significantly louder construction site to the control site indicates that noise is not affecting warbler populations in these 3 areas.

Some studies have addressed differences in golden-cheeked warbler populations in urban and rural areas (Reidy et al. 2008, Reidy et al. 2009) but have not looked at road or construction noise as specific disturbance factors. As urbanization increases, road and construction noise will be persistent disturbance factors near golden-cheeked warbler habitat. My 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 (Federal Highway Administration 2004, Reijnen et al. 1995, Reijnen et al. 1997). Given the difference in vehicle loads, it is conceivable that golden-cheeked warblers may react differently to road noise in louder areas with higher traffic volume than warblers in rural areas. Further study of the effects of road construction noise on golden-cheeked warblers is on-going in an urban area along Highway 71 in Travis County, Texas (Texas A&M University, unpublished data), where populations may be exposed to louder anthropogenic noise.

CHAPTER III

EXPERIMENTAL DETERMINATION OF AVIAN RESPONSE TO CONSTRUCTION ACTIVITIES

Anthropogenic disturbance affects wildlife in a variety of ways, and can be permanently detrimental to a species' population. The 3 major classes of wildlife responses to human disturbance are attraction, habituation, and avoidance (Whittaker and Knight 1998). Habituation is an animal ceasing to respond to repeated activities that have neither positive nor negative reinforcement, and is considered an adaptive behavioral strategy (Thompson and Henderson 1998). Recent studies (Thompson and Henderson 1998, Conomy et al. 1998, Stolen 2003) have found increasing evidence of wildlife habituation to anthropogenic disturbance.

Keller and Bender (2007) assessed the degree of disturbance caused by a road separating bighorn sheep (*Ovis canadensis*) from lakes containing mineral licks used by the sheep. Proximity to traffic and degree of road traffic increased bighorn sheep's avoidance of the lakes; the sheep were sensitive enough to the road that they gave up necessary resources in favor of avoiding disturbance.

Some evidence suggests that habituation to anthropogenic disturbance is species-specific, and that short-term effects may not accurately represent long-term effects (Bejder et al. 2006, Holmes et al. 2006). In a study on Spanish imperial eagles (*Aquila adalberti*), birds showing signs of habituation to human disturbance had lower breeding success than those not exposed to human activity (González et al. 2006). However, a study of gentoo penguins (*Pygoscelis papua*) found that breeding success appeared to be unaffected in populations exposed to human disturbance (Holmes et al. 2006).

In a study designed to determine whether aircraft overflight activities adversely affect waterfowl, Conomy et al. (1998) found evidence to suggest that habituation is species-specific. Researchers exposed a group of captive American black ducks (*Anas rubripes*) and a group of captive wood ducks (*Aix sponsa*) to (1) aircraft overflight activity and (2) noise recordings of aircraft at the same volume and intensity as actual occurrences. In American black ducks, they found the response rates to be similar between the group exposed to aircraft activity and the group exposed only to the sound. American black duck responses significantly decreased over time and eventually stabilized, while the wood duck responses did not suggest habituation.

The golden-cheeked warbler (*Dendroica chrysoparia*), the focal species for my project, is a medium-sized wood-warbler that breeds exclusively in the oak-juniper woodlands of central Texas. Females build nests using strips of bark pulled from Ashe juniper (*Juniperus ashei*); this nesting behavior is the most likely reason for the species' restricted range (Pulich 1976). Golden-cheeked warblers are early migrants, arriving on the breeding grounds in early March and departing in mid-June. They are complete neotropical migrants and winter in the highlands of southern Mexico, Guatemala, Honduras, and Nicaragua (Ladd and Gass 1999).

The golden-cheeked warbler was placed on the federal endangered species list in 1990 due to habitat destruction and fragmentation. As urbanization increases, roads are continually being built and modified throughout the warbler's range. Golden-cheeked warblers use 2 different songs to communicate during the breeding season (Bolsinger 2000); anthropogenic noise that masks or distorts these songs could impact an already endangered population.

The black-and-white warbler (*Mniotilta varia*) was a secondary study species in my research. Black-and-white warblers have similar breeding habitat requirements and foraging behaviors as the golden-cheeked warbler. Research suggests that body size may predict behavioral responses of wildlife to anthropogenic disturbance (Blumstein et al. 2005). The black-and-white warbler is a similar-sized migrant warbler, which minimized the effect of body size in evaluating differences between the 2 species.

Construction activities in Real County, Texas provided the opportunity to carry out my research objectives. My research served as an experimental component of an impact assessment determining the effect of road construction noise on the golden-cheeked warbler. My impact assessment examined whether the construction noise affected density, breeding success, and singing behaviors of golden-cheeked warblers. I evaluated whether (1) road noise affected the warblers, (2) construction activity exacerbated these effects, and (3) if construction noise affected the warblers differently than road noise.

While conducting the impact assessment in 2007 (see chapter II), I observed golden-cheeked warblers in close proximity to construction noise and activities. However, I did not know whether these birds had a behavioral response at the onset of construction, or if the disturbance displaced certain individuals. Previous work evaluating effects of traffic noise on golden-cheeked warbler territory selection, Benson

(1995), found no evidence that the warblers select territories based on 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. Recently, Pater et al. (2009) also suggested techniques to improve the assessment of noise impacts on wildlife. My research in 2008 and 2009 experimentally determined the immediate and temporal response of golden-cheeked and black-and-white warblers to road construction noise. My information supplemented the impact assessment and resulted in more complete understanding of the effects of road construction noise on the warblers.

My first goal was to document behavioral responses to recordings of construction noise played to birds that were: (1) already exposed to road and construction noise, (2) only exposed to road noise, and (3) exposed to neither road noise nor construction noise. I evaluated occurrence of behavioral response and types of behavioral change as a function of distance from the roadway and compared results to birds not exposed to construction noise playback. I hypothesized that birds found closest to the construction activity would have the least behavioral response to recordings of construction noise, and responses would steadily increase with increasing territory distance from construction activity. My second goal was to examine site fidelity and territory location in response to simulated construction noise. The experiment assessed whether golden-cheeked warblers are habituating to construction noise. I 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, my final objective was to evaluate responses to playback and simulated construction noise in relation to reproductive success.

METHODS

Study Design

I conducted my experiments concurrently with the impact assessment study. The basic study design was that of an impact assessment due to lack of specific pre-treatment data for treated (construction) or reference sites and lack of replication of treatment. I conducted experiments within 3 types of study sites:

1. Impact (construction): a site adjacent to the road that was undergoing construction activities; this site was exposed to both construction activity and road noise (vehicle traffic).
2. Reference, road-noise only: a site where traffic noise and disturbance existed but no construction activity occurred.
3. No-noise: I considered areas ≥400 m from Highway 83 in both the impact and reference sites to be no-noise sites, thus eliminating road noise, disturbance, and construction activity as factors that potentially influenced birds.

I conducted all surveys and experiments using the same methods in each site, and evaluated results as a function of distance from road in order to determine whether golden-cheeked and black-and-white warblers are habituating to construction and road noise.

Study Area

I conducted my 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-hectare private ranch where much of the land remained unaltered golden-cheeked warbler habitat (oak-juniper woodland) in accordance with the benefactor's will. A 9-km stretch of U.S. Highway 83, adjacent to Big Springs Ranch, was used for construction noise sites and was the only "impact" area available in the region. This length of highway was being widened from 2 lanes to 4 lanes to improve traffic flow, but not due to increased traffic. Activities included, but were not limited to: road grading, excavation, paving, and pilot car operation. Garner State Park was located approximately 32 km south of the construction zone; because most of the region is privately owned, Garner State Park was the closest appropriate location where I 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 approximately 300 m in woodlands adjacent to roads with a vehicle load of 10,000 vehicles/day; the vehicle load adjacent to my study area was <2,000 vehicles/day, and so I considered areas ≥400 m from Highway 83 to be no-noise sites.

Territory Identification

I conducted line transect surveys from 12–24 March to determine the presence and location of golden-cheeked warblers. I conducted the surveys as follows:

1. Construction and road noise site: 6 transects ran 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, 2 transects at 600 m).
2. Road-noise only site: 4 transects ran perpendicular to the road in suitable golden-cheeked warbler habitat at Garner State Park. Three of these transects were 600 m in length and 1 was 500 m in length.

Surveyors began transect surveys at sunrise and completed surveying within 60–90 minutes, depending on transect length. Upon detection of a male golden-cheeked 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 golden-cheeked warblers recorded during transect surveys were spot-mapped using a GPS (International Bird Census Committee 1969). Observers located and followed each singing male for 60 minutes or until 10 GPS waypoints were recorded for each bird. After 24 March, I monitored presence and territory location through productivity surveys as described below.

Productivity

I determined territorial reproductive success of golden-cheeked warblers using the Vickery reproductive index (Vickery et. al 1992). The Vickery method was useful because it does not disrupt nests of rare or endangered species, and is a reliable measure of success rates of species whose nests are hard to locate. Both advantages overcome difficulties that researchers face when assessing reproductive success of the golden-cheeked warbler. Previous studies have successfully employed the Vickery method (Christoferson and Morrison 2001, Rivers et al. 2003) to show which birds successfully fledged young, which birds were paired but unsuccessful, and which birds remained unpaired throughout the breeding season (Table 5).

Table 5. Vickery reproductive index used to determine reproductive success of golden-cheeked warblers in the road construction, road-noise only, and control sites adjacent to Highway 83 in Real and Uvalde Counties, Texas, USA 2007–2009 (Vickery et. al 1992).

Vickery Rank	**Description**
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 was 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

I conducted productivity surveys on each territory approximately once every 7 days, from 24 March until 18 June. Surveys lasted 60 minutes 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 minutes, 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. I trained 2–3 observers to assist with surveys at the beginning of each season and monitored quality of work throughout the season; 1 observer assisted all 3 years. I rotated observers among study sites and territories to reduce observer bias.

Determination of Behavioral Response

I 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. I evaluated occurrence and types of behavioral change as a function of distance from the roadway and compared results to individuals in the no-noise area.

Playback.— Construction noise on Highway 83 is intermittent and includes multiple sounds, all of which have different frequencies and amplitudes (M. A. Lackey, Texas A&M University, unpublished data). Using a Sennheiser shotgun microphone and iRiver H300 with rockbox v.1.28J, I created a recording of the variable construction activity noises prior to the field season. The primary noises recorded were: backup 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, I played the construction noise recordings at 80 dB, a level known to be annoying to humans but that could not cause hearing damage (Table 6; Harrington 2000).

Table 6. Average noise levels (dB) produced by typical activities; the apparent loudness of the noise level compared to the baseline (suburban area with medium traffic) and the typical human perception (Harrington 2000).

Activity	**Noise Level (dB(A))**	**Apparent Loudness**	**Typical Human Perception**
Sand blasting	110-115	>128 times as loud	Can damage hearing after 15 min
Heavy truck at 15 m; busy city street	90	32 times as loud	Can damage hearing after 8 hr
Road construction site; busy intersection	80	16 times as loud	Annoying
Roadway traffic at 15 m	70	8 times as loud	Telephone use difficult
Light car traffic at 15 m; city or commercial areas	60	4 times as loud	Intrusive
Suburban area with medium traffic	40	Baseline level	Quiet

Response determination.— After I established the location of territorial males, I randomly chose territories for treatment at varying distances from the roadway on construction sites and road-noise only sites. In addition, I randomly chose territories to receive treatment at no-noise sites (≥400 m from Highway 83). I conducted playback surveys on both days with active and non-active construction from 15 March until 17 June in 2008 and 2009. Surveys included both golden-cheeked and black-and-white warblers.

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. I conducted surveys from sunrise until 5 hours after sunrise. To minimize surveyor influence, I approached a territorial male and remained at a distance of approximately 20 m. I recorded behavior for 2 minutes before playback. I then broadcast construction noise with a hand-held speaker for 1–5 seconds. Each 1–5 second bout of playback ceased as soon as the bird's behavior changed. I documented after-playback behavior every minute for 10 minutes, or until the bird was unable to be located by the surveyor. I recorded the time and initial behavior as well as subsequent behavior changes with the corresponding time. I chose territories for control surveys using the same methods as described for treatment territories. I conducted control surveys in the same manner but without playback to detect response caused by surveyor presence. I recorded behavior according to categories (Table 7). In addition to the behavioral categories, observers estimated distances moved and number and types of songs or calls (A song, B song, chipping) during the before, during, and after playback observations.

Table 7. Behavior categories used to document golden-cheeked warbler behavior before, during, and after playback surveys to individual males.

Code	**Description**
T	Intraspecific interactions; males exhibiting territorial behavior
A	Interspecific interactions; males interacting with competitors or predators
V	Vocalizing, singing, calling
VC	Change in vocalization type; singing to calling, A song to B song, etc.
C	Courtship interactions: displays, copulation, male feeding female
B	Nest building; pulling at bark strips, carrying material, nest construction
LF	Long flight: >2 seconds
SF	Short flight: <2 seconds
S	Scanning, vigilant
F	Feeding, gleaning
G	Grooming, preening
FN	Food carries to nest
FC	Food carries to fledglings

Determination of Habituation to Construction Noise

Dearborn and Sanchez (2001) suggested that territory selection is more important than nest-site selection for breeding success in golden-cheeked warblers. Additionally, studies have documented males exhibiting varying degrees of participation in nest-site selection (Graber et al. 2006). Because of these factors, noise disturbance has a high potential to influence territory location and nest-site selection for the golden-cheeked warbler.

Experimental Broadcasts.— From the recordings made of construction noise in the previously described methods, I established broadcast stations that simulated appropriate volume and duration of construction activities. Construction noise was broadcast on weekdays only, between 07:00 and 14:00. Broadcast stations played at 80 dB, the level of a typical road construction site (Harrington 2000). Noise was intermittent and played at random intervals and durations in order to mimic the actual construction noise. Each station broadcasted noise at least once every hour and each bout lasted between 5 and 30 minutes.

In 2008 I placed broadcast stations on the edges of randomly chosen territories identified during the 2007 field season. I chose territories for 2009 based on 2008 data. The stations were established prior to 15 March, the estimated arrival time of the birds. I was able to use golden-cheeked warbler territories in this experiment as long as I displaced (i.e., made the area unsuitable for golden-cheeked warblers' use) no more than 3 birds in accordance with U.S. Fish and Wildlife Service permitting.

Territory Location.— I surveyed broadcast station 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 station prior to 24 March, I systematically searched the previous year's territory for 1 hour or until a bird was located. Upon locating a bird, I spot-mapped the territory using a handheld GPS unit and afterward conducted surveys in the territory until 18 June. Broadcast stations remained in the same locations throughout the season, regardless of new territory boundaries.

ANALYSIS

Behavioral Response

I considered a behavioral response to playback to be (1) the bird ceased singing, (2) the bird flew from its previous perch and out of the surveyor's view (≥10m), and (3) the bird changed behavior before or exactly at the end of hearing 5 seconds of construction noise. Because I had very few responses, I graphically evaluated response to playback as a function of distance from the roadway and descriptively compared to no-noise territory results as well as control survey results. I also determined whether a gradient effect is occurring as a result of distance from road to test my hypothesis that birds found closest to the construction activity would have the least behavioral response to recordings of construction noise, and responses would increase with increasing territory distance from construction activity. I evaluated response in relation to both distance from road and productivity for golden-cheeked warblers and evaluated black-and-white warbler response in relation to distance from road only; I did not obtain productivity data for black-and-white warblers due to time constraints.

Habituation

To address habituation, I used productivity data to establish site fidelity over the 3 seasons for territories in each site type. I created minimum convex polygons using ArcMap™ 9.2 software 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. I considered outliers to be points in which the bird was located well outside of the primary use area on only 1 occasion during the breeding season. I determined whether there were any temporal or spatial impacts on site fidelity and territory location 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, I compared shifts in broadcast station territory locations to shifts of 6 randomly chosen non-broadcast territories in the same site for each year.

RESULTS

Behavioral Response

I conducted 33 playback surveys for golden-cheeked warblers in 2008 and 55 in 2009; one survey was omitted from analysis in 2009 due to noisy hikers walking by during the survey. In 2008, 3 golden-cheeked warblers responded to construction noise playback and 3 golden-cheeked warblers responded in 2009. All birds that responded were vocalizing prior to playback, and all ceased to vocalize in response to playback. Four birds immediately fled the area, while 2 fled the area after 5 seconds of playback. Only 1 bird was relocated after responding to playback; this bird was found 145 m from the initial survey point (Table 7). 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 birds that responded were located ≥150 m from the road. In the no-noise area (≥400 m from Highway 83), 10.5% of golden-cheeked warblers reacted to playback (n = 19), while 2.8% reacted in the loudest area from 0 to 200 m (see chapter II), and 9.4% reacted in the intermediate area, 200 to 400 m from the roadway (Fig. 9).

Medians were similar between successful and unsuccessful male golden-cheeked warblers that did not react to playback. Successful males that reacted to playback (n = 4) were located farther from the roadway than males that did not react to playback; unsuccessful males that reacted to playback (n = 2) were located at a similar distance from the roadway as males that did not react to playback. Of the successful males (n = 54), 20% reacted to playback in the no-noise area (≥400 m from Highway 83), while

3.6% reacted to playback in the loudest area from 0 to 200 m, and 7.1% reacted in the intermediate area, 200 to 400 m from the roadway (Fig. 10). Twenty percent of the unsuccessful males (*n* = 20) reacted from 200 to 400 m from the roadway while none reacted in the other areas. Unpaired males and territories with unknown outcomes were excluded from this analysis.

All golden-cheeked warblers that reacted to playback were located ≥150 m from the highway (Table 8). However, productivity data showed no significant differences in reproductive success between territories in each site located from 0 to 150 m from the road and ≥150 m from the road. A factorial ANOVA showed no significant differences between success in each distance category ($F = 0.703$, $P = 0.622$) and there was not a significant interaction between year and distance category ($F = 0.166$, $P = 0.847$).

I conducted 18 control surveys to control for surveyor presence and observed 1 behavioral response. Surveys ranged from 32 to 581 m from the road. The bird that responded was located 359 m from the roadway and immediately fled the area; the territory successfully fledged young (Fig. 9).

I conducted 8 surveys for black-and-white warblers in 2008 and 6 surveys in 2009. I did not use the construction noise recording for 1 black-and-white warbler survey in 2009 because comparable construction activity began during the survey. In 2008, 2 black-and-white warblers responded to construction noise playback and in 2009 I observed 2 responses of black-and-white warblers from the same individual. All birds that responded were vocalizing prior to playback, and all ceased to vocalize in response to playback. Three birds immediately fled the area, while 1 fled the area after 3 seconds of playback (Table 8). Types of behavioral response did not vary according to distance from the roadway. Surveys ranged from 95 to 585 m from the road and all birds that responded were located ≥140 m from the road. In the no-noise area (≥400 m from Highway 83), 50% of black-and-white warblers reacted to playback (*n* = 4), while 25% reacted to playback from in the loudest area from 0 to 200 m, and none reacted in the intermediate area, 200 to 400 m from the roadway (Fig. 11).

Table 8. Initial behavior and types of behavioral response of the 6 golden-cheeked warblers (*n* = 88) and 4 black-and-white warblers (*n* = 14) that responded to construction noise playback, based on behavior categories (Table 7).

	Distance (m)	Initial Behavior[1]	Response
Golden-cheeked Warbler			
	150	V, SF	Immediate LF
	210	V, S	Immediate LF
	218	V, F	LF at end of 5 second playback; returned after 3 min
	359	V, C	Immediate LF[2]
	377	V, S	Immediately ceased V; LF 145 m
	444	V, G	Immediately ceased V; SF 15 m to middle of tree
	508	V, S	LF at end of 5 second playback
Black-and-white Warbler			
	140	V, S	Immediate LF when construction began[3]
	142	V	LF after 3 seconds of playback
	521	V, F	Immediately ceased V; SF 20 m
	585	V, F	Immediate LF

[1]V=vocalizing, SF=short flight, S=scanning, F=forgaging, C=courtship behaviors, G=grooming, SF=short flight, LF=long flight
[2]Control survey; bird reacted when speaker was raised
[3]Recording not used; bird reacted to road construction activity that began when speaker was raised

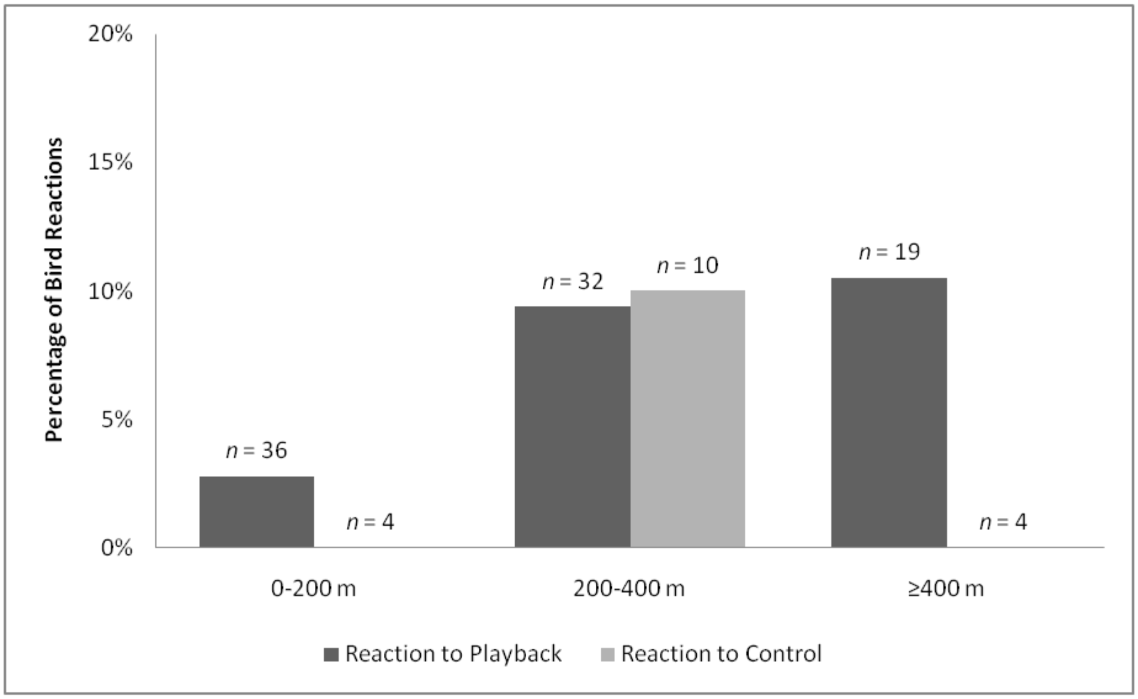

Figure 9. Golden-cheeked warbler response to playback and control surveys in relation to distance from Highway 83 in Real and Uvalde Counties, Texas, USA, 2007–2009.

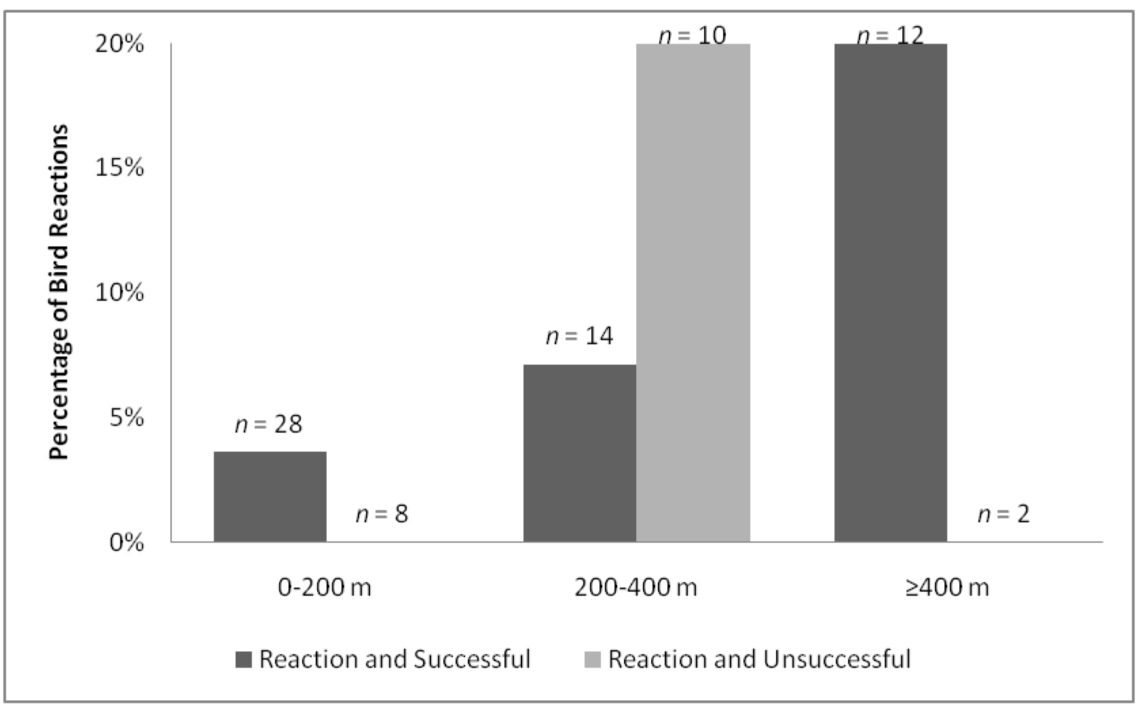

Figure 10. Golden-cheeked warbler response to playback in relation to productivity and distance from Highway 83 in Real and Uvalde Counties, Texas, USA, 2007–2009.

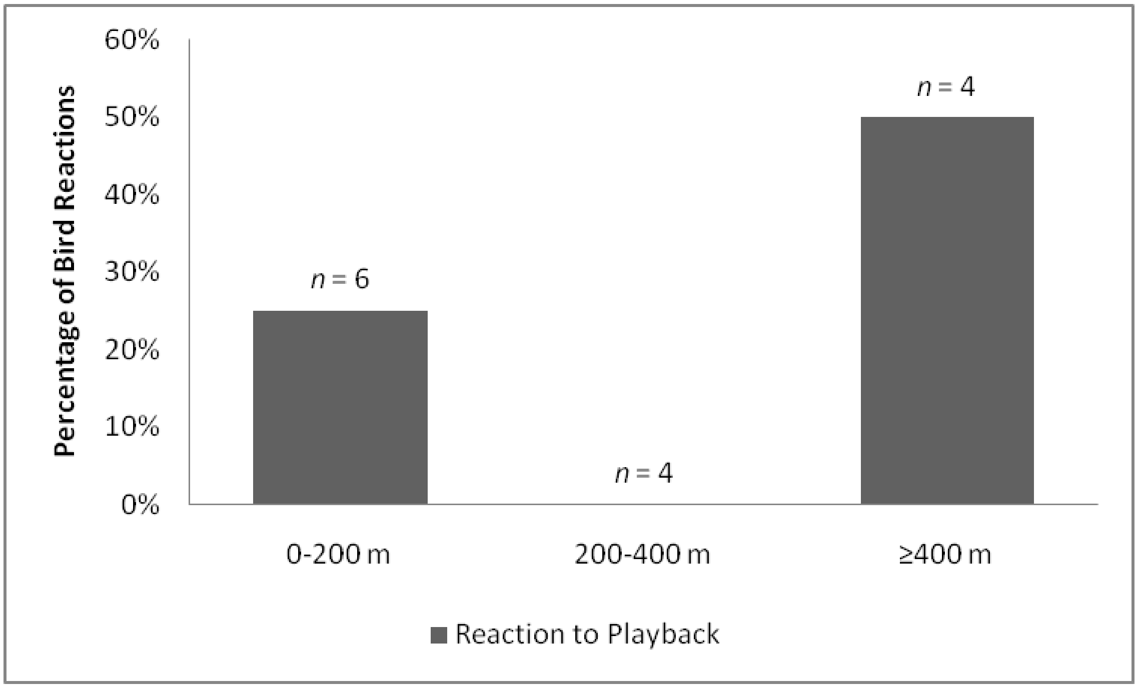

Figure 11. Black-and-white warbler response to playback in relation to distance from Highway 83 in Real and Uvalde Counties, Texas, USA, 2007–2009.

Habituation

In 2008, 2 territory centers shifted away from the broadcast unit (27 m and 71 m) while the remaining territory center shifted 89 m towards the broadcast unit. In 2009, I only located territories near 2 of the 3 broadcast units. One territory center shifted 14 m parallel to the broadcast unit and 1 territory center shifted 105 m away. Of the 6 randomly chosen territories in 2007, the average shift between years was 47 m; in 1 location, a territory was not established in 2008. Four of the 6 randomly chosen territories from 2008 were occupied in 2009 with an average territory shift of 71 m. There was not a significant difference in mean territory shifts for broadcast and non-broadcast unit territories ($\bar{x}_{broadcast}$ = 61 m ± 31; $\bar{x}_{non\text{-}broadcast}$ = 57 m ± 25; P = 0.947) (Table 9). Territory shifts did not show patterns in directionality.

Table 9. Golden-cheeked warbler territory shifts between 2007 and 2008, and 2008 and 2009 for broadcast unit and non-broadcast unit territories. I established 3 broadcast units each year and randomly chose 6 non-broadcast unit territories for comparison.

	Shift in Territory Center Location (m)		
	2007-2008	**2008-2009**	**Combined Years**
Broadcast Unit Territories			
1	71	105	
2	29	14	
3	87	X[1]	
Mean	62.33 ± 31.90	59.50 ± 64.35	61.2 ± 31.32
Non-Broadcast Unit Territories			
1	30	63	
2	29	109	
3	42	67	
4	75	43	
5	57	X	
6	X	X	
Mean	46.60 ± 19.50	70.50 ± 27.73	57.2 ± 25.24

[1]Territory not established in chosen territory location from previous year

Of the 6 territories with broadcast units, 2 successfully fledged young after being successful in the previous year and 1 was successful after being unsuccessful in the previous year; 1 was paired but unsuccessful in both years, and 1 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 (Table 10).

Table 10. Golden-cheeked warbler reproductive success between 2007 and 2008, and 2008 and 2009 for broadcast unit and non-broadcast unit territories. I established 3 broadcast units each year and randomly chose 6 non-broadcast unit territories for comparison.

	Reproductive Success[1]			
	2007-2008		2008-2009	
Broadcast Unit Territories				
1	Y	Y	N	N
2	Y	Y	N	Y
3	U	N	U	N
Non-broadcast Unit Territories				
1	U	Y	U	N
2	N	N	Y	Y
3	Y	U	N	Y
4	Y	Y	Y	Y
5	Y	Y	N	X
6	Y	X	Y	X

[1]Y = successfully fledged young; N = paired but unsuccessful; U = unpaired; X = no territory established

DISCUSSION

I observed very few behavioral responses of golden-cheeked warblers to construction noise playback. All birds that responded were located ≥150 m from the roadway and there was no pattern in types of behavioral response with distance from the roadway; successful males that reacted to playback were located farther from the roadway than unsuccessful males that reacted to playback. I found ambient noise on Highway 83 to be loudest within 200 m of the road. My results suggest that most birds located in the noisiest areas have habituated to construction noise, while a higher percentage of birds in the quietest areas have not habituated. However, reproductive success was not different between birds located within 150 m of the road and those located ≥150 m, nor those located within 200 m of the road and those ≥200 m. Lack of difference in productivity and the very low number of observed responses indicates the majority of golden-cheeked warblers near Highway 83 have habituated to road and construction noise, consistent with findings in other parts of its range (Benson 1995).

I observed a higher percentage of behavioral responses of black-and-white warblers than golden-cheeked warblers, though I conducted fewer surveys. Similar to golden-cheeked warblers, black-and-white warblers responding to construction noise playback were located ≥140 m from the roadway. Some research suggests body size may be used as a predictor for responses to anthropogenic disturbance (Blumstein et al. 2005), and other wildlife habituation studies have found species-specific responses unrelated to body size (Conomy et al. 1998, Stolen 2003). Though black-and-white warblers have a similar body size as golden-cheeked warblers, further study on black-and-white warblers is needed to fully evaluate whether they have habituated to construction noise in this area.

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. My results indicate that construction noise does not impact golden-cheeked warbler site fidelity or territory location, and that proximity of a territory to construction noise does not influence reproductive success. In my study the construction noise disturbance was short-term and there were no apparent biological impacts on golden-cheeked or black-and-white 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, Masden and Boertmann 2008).

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). While my construction noise recordings simulated approximate volume and types of noises present in the construction site, other factors could not be exactly reproduced such as the visual disturbance of active construction work. However, I did conduct control playback surveys to control for responses elicited by surveyor presence. I observed 1 behavioral response during control playback surveys, indicating that a factor unrelated to noise was a potential influence in some of the observed behavioral responses to construction noise. While human presence is often reported as a disturbance to wildlife (Bélanger and Bédard 1990, Burger and Gochfeld 1998, González 2006), most golden-cheeked warblers did not react to surveyors.

Some studies have addressed differences in golden-cheeked warbler populations in urban and rural areas (Reidy et al. 2008, Reidy et al. 2009) but have not looked at road or construction noise as specific disturbance factors. As urbanization increases, road and construction noise will be persistent disturbance factors near golden-cheeked warbler habitat. My study sites were located in rural counties with vehicle loads of <2,000 vehicles/day. Previous studies reporting negative effects 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 (Federal Highway Administration 2004, Reijnen et al. 1995, Reijnen et al. 1997). Given the difference in vehicle loads, it is conceivable that golden-cheeked warblers may react differently to road noise in louder areas with higher traffic volume than warblers in rural areas. Further study of the effects of road construction noise on golden-cheeked warblers is on-going in an urban area along Highway 71 in Travis County, Texas (Texas A&M University, unpublished data), where populations may be exposed to louder anthropogenic noise.

CHAPTER IV

SUMMARY

I found that reproductive success of golden-cheeked warblers in the road construction site was significantly different from warblers in the road-noise only site, but similar to reproductive success in the control site with no noise or activity. Productivity differed in the road construction site after the first year of the study, but distance from road and density did not differ; average territory distance in the construction site was closer to Highway 83 than average territory distance in the road-noise only site, but was not a statistically significant difference. Results suggest that construction noise was not affecting reproductive success of golden-cheeked warblers along Highway 83 and that proximity to the road did not influence reproductive success. The results of my study are consistent with previous work that found no significant difference between golden-cheeked warbler presence at high-noise and low-noise song posts near a highway (Benson 1995).

The significantly higher reproductive success, percentage of unpaired males, further average distance from road, and increase in density in the road-noise only site indicates road noise is not influencing golden-cheeked warblers in the area, but does suggest the possibility that a factor unrelated to road noise is creating population differences in the 3 study sites. I did not evaluate edge effects for my study, though previous studies of golden-cheeked warblers have reported higher nest success in areas with less forest edge (Peak 2007, Reidy et al. 2009). Other research has found that golden-cheeked warblers prefer landscape compositions of high percentages of woodland cover (Magness et al. 2006). Territories in the road-noise only site were located primarily in 1 contiguous 743-ha patch with 72% woodland cover, while 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 (Texas A&M University, unpublished data). In the construction site, successful territories were closer to the road than unsuccessful territories, and there were fewer unpaired males, suggesting further evidence that edge effects and landscape composition may be playing a role in this area.

The level of noise produced from the road construction on Highway 83 did not fundamentally represent a different (louder) noise regime in the study site than from highway noise alone. However, noise exposure in the construction site and road-noise only site was significantly different from noise in the control site. The similarity in ambient noise in the construction and road-noise only sites also suggests that construction noise is not affecting the warblers differently than road noise or exacerbating any effects of road noise. While there is an increase in noise levels within 200 m of the highway, productivity was similar between territories from 0 to 200 m from the road and those located 200–500 m from the road. Furthermore, the similarity of reproductive success in the significantly louder construction site to the control site indicates that noise is not affecting warbler populations in these 3 areas.

I observed very few behavioral responses of golden-cheeked warblers to construction noise playback. All birds that responded were located ≥150 m from the roadway and there was no pattern in types of behavioral response with distance from the roadway; successful males that reacted to playback were located farther from the roadway than unsuccessful males that reacted to playback. Because I found ambient noise adjacent to Highway 83 to be loudest within 200 m of the road, my results suggest that most birds located in the noisiest areas have habituated to construction noise, while a higher percentage of birds in the quietest areas have not habituated. However, reproductive success was not different between birds located within 150 m of the road and those located ≥150 m, nor those located within 200 m of the road and those ≥200 m. I observed a higher percentage of behavioral responses of black-and-white warblers than golden-cheeked warblers, though I conducted fewer surveys. Similar to golden-cheeked warblers, black-and-white warblers responding to construction noise playback were located ≥140 m from the roadway. Lack of difference productivity and the very low number of observed responses indicates the majority of warblers near Highway 83 have habituated to road and construction noise.

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. My results indicate that construction noise does not impact golden-cheeked warbler site fidelity or territory location, and that proximity of a territory to construction noise does not influence reproductive success. In my study the construction noise disturbance was short-term and there were no apparent biological impacts on golden-cheeked or black-and white 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, Masden and Boertmann 2008).

Some studies have addressed differences in golden-cheeked warbler populations in urban and rural areas (Reidy et al. 2008, Reidy et al. 2009) but have not looked at road or construction noise as specific disturbance factors. My 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 (Federal Highway Administration 2004, Reijnen et al. 1995, Reijnen et al. 1997). Given the difference in vehicle loads, it is conceivable that golden-cheeked warblers may react differently to road noise in louder areas with higher traffic volume than warblers in rural areas. Further study of the effects of road construction noise on golden-cheeked warblers is on-going in an urban area along Highway 71 in Travis County, Texas (Texas A&M University, unpublished data), where populations may be exposed to louder anthropogenic noise.

LITERATURE CITED

Bejder, L., A. Samuels, H. Whitehead, and N. Gales. 2006. Interpreting short-term behavioural responses to disturbance within a longitudinal perspective. Animal Behaviour 72:1149–1158.

Bélanger, L., and J. Bédard. 1990. Energetic cost of man-induced disturbance to staging snow geese. Journal of Wildlife Management 54:36–41.

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.

Blumstein, D. T., E. Fernández-Juricic, P. A. Zollner, and S. C. Garity. 2005. Inter-specific variation in avian responses to human disturbance. Journal of Applied Ecology 42:943–953.

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.

Burger, J., and M. Gochfeld. 1998. Effects of ecotourists on bird behaviour at Loxahatchee National Wildlife Refuge, Florida. Environmental Conservation 25:13–21.

Christoferson, L. L., and M. L. Morrison. 2001. Integrating methods to determine breeding and nesting status of 3 Western songbirds. Wildlife Society Bulletin 29:688–696.

Conomy, J. T., J. A. Dubovsky, J. A. Collazo, and W. J. Fleming. 1998. Do black ducks and wood ducks habituate to aircraft disturbance? Journal of Wildlife Management 62:1135–1142.

Dearborn, D. C., and L. L. Sanchez. 2001. Do golden-cheeked warblers select nest locations on the basis of patch vegetation? Auk 118:1052–1057.

Dooling, R. 2002. Avian hearing and the avoidance of wind turbines. National Renewable Energy Laboratory, Publication No. NREL/TP-500-30844, Golden, Colorado, USA.

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.

González, L. M., B. E. Arroyo, A. Margalida, R. Sánchez, and J. Oria. 2006. Effect of human activities on the behaviour of breeding Spanish imperial eagles (*Aquila adalberti*): management implications for the conservation of a threatened species. Animal Conservation 9:85–93.

Graber, A. E., C. A. Davis, and D. M. Leslie, Jr. 2006. Golden-cheeked warbler males participate in nest-site selection. Wilson Journal of Ornithology 118:246–251.

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.

Harrington, K. 2000. Decibel chart: How loud is loud? Josaka. <http://www.josaka.com/Content/2000/Decibel-Chart.htm>. Accessed 13 February 2008.

Holmes, N. D., M. Giese, H. Achurch, S. Robinson, and L. K. Kriwoken. 2006. Behaviour and breeding success of gentoo penguins *Pygoscelis papua* in areas of low and high human activity. Polar Biology 29:399–412.

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

Keller, B. J., and L. C. Bender. 2007. Bighorn sheep response to road-related disturbances in Rocky Mountain National Park, Colorado. Journal of Wildlife Management 71:2329–2337.

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

Masden, J. and D. Boertmann. 2008. Animal behavioral adaptation to changing landscapes: spring-staging geese habituate to wind farms. Landscape Ecology 23:1007–1011.

Pater, L. L, T. G Grubb, and D. K. Delaney. 2009. Recommendations for improved assessment of noise impacts on wildlife. Journal of Wildlife Management 73:788–795.

Patricelli, G. L., and J. L. Blickley. 2006. Avian communication in urban noise: causes and consequences of vocal adjustment. Auk 123:639–649.

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

Pulich, W. M. 1976. The golden-cheeked warbler: a bioecological study. Texas Parks and Wildlife Department, Austin, USA.

Reidy, J. L., M. M. Stake, and F. R. Thompson, III. 2008. Golden-cheeked warbler nest mortality and predators in urban and rural landscapes. Condor 110:458–466.

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.

Rivers, J. W., D. P. Althoff, P. S. Gipson, and J. S. Pontius. 2003. Evaluation of a reproductive index to estimate dickcissel reproductive success. Journal of Wildlife Management 67:136–143.

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

Stolen, E. D. 2003. The effects of vehicle passage on foraging behavior of wading birds. Waterbirds 26:429–436.

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.

Thompson, M. J., and R. E. Henderson. 1998. Elk habituation as a credibility challenge for wildlife professionals. Wildlife Society Bulletin 26:477–483.

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.

Whittaker, D., and R. L. Knight. 1998. Understanding wildlife responses to humans. Wildlife Society Bulletin 26:312–317.

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.

VITA

Name:	Melissa Anne Lackey
Address:	215 Old Heep Building 2258 TAMU College Station, TX 77843-2258
Email Address:	melissalackey@neo.tamu.edu
Education:	B.S., Environmental Studies and Spanish, Ohio Northern University, 2005 M.S., Wildlife and Fisheries Sciences, Texas A&M University, 2010