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Special Section

Using Impact Assessment Study Designs for Addressing Impacts to Species of Conservation Concern

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ABSTRACT Impact assessments are a valuable tool for investigating the effects of human-induced and natural perturbations on ecosystems and wildlife, including species of conservation concern. The breeding range of the golden-cheeked warbler (*Setophaga chrysoparia*), a federally endangered species, is located in a region with increasing development that includes housing, road construction and maintenance, and other land-use conversions; along with wildfire, oak wilt, and other disturbances. Although many of these actions are assumed to have deleterious effects on warbler occurrence or fitness, there is limited research directly investigating impacts of these activities to date. Many of these threats cannot be investigated within a fully manipulative study framework because it is rarely possible or even appropriate to replicate treatments. We conducted impact assessment studies investigating the effects of military training and highway construction on the warbler. We use these studies to provide examples that demonstrate how common challenges in investigating impacts can be addressed during planning and implementation by using alternative study design and sampling strategies to effectively assess the impact of perturbations on species of interest. © 2012 The Wildlife Society.

KEY WORDS endangered species, golden-cheeked warbler, highway construction, impact assessment, military training, mitigation, *Setophaga chrysoparia*, study design.

Quantification of impacts on ecological systems is essential for wildlife conservation; yet few studies of impacts can be conducted using optimal sampling-design methodology. Researchers are often tasked with ecological studies under conditions beyond their control, and research is constrained by several factors, including time, spatial scale, lack of pretreatment data, or limited replication and randomization (Parker and Weins 2005, Morrison et al. 2008). Although these issues may present challenges, it is still possible to gain reliable knowledge using strategic, alternative study designs under an impact assessment framework (Parker and Weins 2005, Morrison et al. 2008).

Anthropogenic actions are often assumed to have deleterious effects on endangered species and their habitat; this is of particular concern when habitat loss and fragmentation are the primary threat to a species' viability. The golden-cheeked warbler (*Setophaga chrysoparia*; hereafter, GCWA) was listed in 1990 as federally endangered, with habitat loss and fragmentation cited as the primary threats to the persistence of the species (USFWS 1992*a*). The breeding range of the GCWA occurs in a region with high rates of population growth and development, road construction and maintenance, land-use conversion (Texas Forest Service 2009, 2010; Wilkins et al. 2009), and other potential disturbances. As with many endangered species, current regulatory, mitigation, and management approaches have been based on incomplete information (USFWS 1992*b*, Tear et al. 1995) from limited available research, often composed of descriptive natural-history information (e.g., Pulich 1976, Wahl et al. 1990), from studies limited in spatial and temporal scope (e.g., Kroll 1980, Coldren 1998, Baccus et al. 2007), or from studies that report relationships between GCWA occurrence and environmental variables (DeBoer and Diamond 2006), which do not directly address habitat preference or fitness measures (van Horne 1983). Recent research on impacts (Reidy et al. 2008; Davis et al. 2010; Lackey et al. 2011, 2012) has begun to address potential effects of human activities on GCWA reproductive performance, but there remains limited information about activities such as road development, residential development, and other hu-

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man activities that are ongoing and increasing in frequency and spatial scope within the range of the GCWA.

Many potential impacts to GCWAs cannot be investigated within a fully manipulative study framework, which involves replicated and randomized treatments, for several reasons. It is rarely appropriate to replicate an impact, as one would an experimental treatment, because the outcome of these impacts on the species of concern and the ecosystem is likely deleterious. For example, it is unlikely that we can implement creation of additional housing subdivisions on roadways in randomly selected locations to study the impacts of the construction of housing subdivisions. Because the timing, duration, spatial location, and spatial extent of the potential impact are usually not in the control of the researcher (which makes replication and randomization unlikely), the scope of inference drawn from an impact study can be limited (Parker and Weins 2005, Morrison et al. 2008). However, because regulation, mitigation, and conservation and management actions are often applied and monitored at a local scale, limited inference is often a minor concern (Morrison et al. 2008). Access to sufficient study areas to investigate impacts can be a challenge, particularly for species like the GCWA for which much of the available habitat occurs on private land (Groce et al. 2010, Collier et al. 2012).

Our research group recently conducted impact assessments that address the effects of military operational development and training and highway construction on the GCWA. We used these studies to demonstrate how common challenges in investigating impacts can be addressed during planning and implementation by using alternative study design and sampling strategies to effectively assess the impact of perturbations on species of interest. Our impact assessments improve upon many impact studies in a number of respects, including 1) use of multiple control sites, 2) investigation of impacts under a variety of intensities, 3) use of multiple years of post-treatment data, and 4) actual measurement of, rather than assumption about, impacts such as noise and movement rates. We suggest that such study design techniques are a viable solution for balancing sound conservation with efficient and reasonable regulation, mitigation, and assessment of harm to wildlife, particularly for endangered species.

OVERVIEW OF IMPACT ASSESSMENT PROJECTS

Fort Hood Impact Assessment

Construction and maintenance of training areas on military instillations is essential to meet the military mission, but development and use of training areas may impact endangered species or their habitats (Gutzwiller and Hayden 1997, Tazik and Martin 2002, Boice 2006, Barron et al. 2012). Direct impacts to endangered species may include loss of habitat due to removal or manipulation of vegetation or wildfire associated with weapon fire, and direct mortality of individuals during training events. Indirect impacts are typically associated with increases in ambient noise levels, which may cause stress or mask communication signals among individuals (Patricelli and Blickley 2006, Kight and Swaddle 2011), but also include changes in predator assemblages and dynamics (Ambuel and Temple 1983), changes in food supply (Zanette et al. 2000), and increased parasitism from species such as brown-headed cowbirds (*Molthrus ater*) that result from changes in vegetation structure and composition (Ambuel and Temple 1983, Butcher et al. 2010) that can lead to decreased fitness in the short- or long-term.

In 2008, the Texas A&M Institute of Renewable Natural Resources was asked to assess impacts to GCWAs in new training areas developed on Fort Hood in Coryell and Bell counties, Texas, USA. Fort Hood has traditionally focused on mechanized tank and aviation training. But recently, the Fort has an increased need for training areas that accommodate dismounted soldiers moving through maneuver areas toward target objectives in conditions that replicate those on the battleground. Woodland areas, some of which comprise GCWA habitat, were identified as appropriate locations for dismounted training maneuvers, but these areas required removal of some understory vegetation to enable movement and visibility for soldiers. The potential impacts to GCWAs included both the modification of the vegetation and activity of soldiers using these new training areas.

Highway Construction Impact Assessment

Wildlife impacts due to transport infrastructure have received growing concern (Prillevitz 1997, Forman and Alexander 1998). With increasing spatial demands of road networks and their encroachment on the landscape, conflicts between land-use for transportation infrastructure and other components of the landscape have become inevitable (Coffin 2007). Potential ecological effects of road construction and subsequent traffic include increased nest mortality, loss and isolation of habitat, increased edge effects, and vocal adjustment (Loman 2010).

In 2008, the Institute of Renewable Natural Resources was asked to assess impacts to GCWAs due to road construction, along Highway 71 west of Austin in Travis County, Texas, and Highway 83 near Leakey in Uvalde County, Texas. Construction on these existing highways was designed to widen and straighten the roadways to improve vehicle flow and safety. The potential impacts to GCWAs included all aspects of construction activity, including noise, movement, dust, and human activity in the area of the construction activity.

Defining the impact and selection of study sites.—Many wildlife studies are observational, in that the researcher has limited ability to tie a response to a particular factor (Morrison et al. 2008). Observational studies often explore correlations or patterns without the ability to tie mechanisms back to one specific driver or variable. The goal of an impact assessment is to determine whether a specific treatment has an effect on the population of interest. Thus, a key difference between traditional observational studies and impact assessments is causality. In an observational study, a plethora of confounding factors (e.g., predators, weather, heterospecifics, etc.) limit plausible conjectures about causal mechanisms, whereas impact assessments, like ideal manipulative experiments, focus on controlling for these confounding factors to tie any effects to the impact of interest. Impact assessments can employ a variety of study design types (e.g., before–after/control–impact, matched pairs, impact–reference, response gradient, etc.) to estimate the impact of environmental perturbations or the effects of a treatment. Although impact assessments are often observational studies, careful selection of study sites, explicitly defining the impact(s) of interest, and adherence to fundamental statistical principles can lead to reliable knowledge concerning cause-and-effect relationships (Morrison et al. 2008).

Explicitly defining the impact of interest by type, and in time and space, is important for identifying the appropriate design, reference sites, and response variables that should be used to effectively assess the impact of interest. One event or action can introduce multiple disturbances (e.g., noise, movement, smoke, dust, heat, and chemicals) that can behave differently (e.g., discrete and localized, or mobile, and able to spread over space or persist over time). Careful selection of treatment and control sites and identification of appropriate response variables is also critical. Confounding variables, such as weather, food availability, or patch size may have ecological impacts to the species of concern, and if these are not addressed explicitly in the design, conclusions that can be drawn from the study will be limited. When possible, multiple control sites should be utilized (Morrison et al. 2008), and these control sites should be expected to undergo the same overall natural perturbations as the disturbed site(s).

In the Fort Hood impact assessment, we investigated the effects of 2 co-occurring impacts: understory thinning and subsequent troop training. The area affected by vegetation modification was easily identified because areas where understory vegetation removal occurred covered a discrete area mapped by land managers. The effect of vegetation removal was localized because, unlike in the case of a chemical spill, we did not expect the impact to spread. This impact was also discrete in time, with the modification occurring once, although the response by GCWAs could be delayed, extending over a period of time or increasing cumulatively. The impacts of troop training were not discrete in time, and intensity of use could vary in timing, location, duration, and spatial extent. Training events ranged from a few soldiers engaged in tracking exercises (low noise levels) to Combined Arms Live-Fire Exercises, in which hundreds of soldiers occupied the area and used a combination of infantry, mechanized, and aerial combat platforms (high noise). We worked closely with army personnel to obtain information on training event dates, the type of training that would occur, and how long the area would be occupied by soldiers to clearly define the type, time, and location of the impact. Because a noise impact is not fixed in a discrete unit of space but, like a chemical spill in a waterway, can perpetuate across space with expected attenuation with distance, we implemented a design that considered both temporal and spatial gradients. We used transects for surveying GCWAs, which extended away from the area where vegetation was modified and troop training was to occur, and conducted our study for 4 years following the treatments. Use of a gradient design allowed us to analyze the impacts along a scale using regression techniques to test for any associations between the level of impact and the response by GCWAs (Morrison et al. 2008). By using gradients, thresholds may be identified, which are a critical component of wildlife management (Denoel and Ficetola 2007). For example, there might be a threshold in ambient noise levels at which GCWAs do not pair successfully, and this threshold can be related to distance. Land managers at Fort Hood could use this information to aid in the construction of future training ranges to minimize the impact to GCWA productivity.

We identified appropriate control sites by locating areas nearby that were not exposed to understory vegetation modification or troop movements, and that extended in a gradient fashion (Morrison et al. 2008) to sufficient distances away from the impact area such that noise resulting from troop training would not be present. We considered other site-specific factors, such as vegetation species composition, that would otherwise limit our ability to attribute differences in response variables to the impact itself. Research by Marshall (2011) on Fort Hood showed GCWA abundance and productivity varied between vegetation types based on ecological sites (distinctive land types with specific physical characteristics, such as soil and geologic conditions, that influence the potential vegetation assemblages that can emerge there; Society for Range Management 1989, USDA 1997; Creque et al. 1999). We therefore assessed and determined that the treated area and both control sites had a similar proportion of ecological sites, to control for the potential effects of vegetation composition on GCWA reproductive success.

Intensity of impact, such as traffic density or vehicle load, is known to be an important factor in highway impact assessments (Reijnen et al. 1995). Previous studies have shown negative effects of road noise on bird populations when vehicle loads ranged between 10,000 and 60,000 vehicles/day (Reijnen et al. 1995). The study area at highway 83 was located in a rural area and represented a small vehicle load (<2,000 vehicles/day), while highway 71 was located near to Austin, Texas, and represented a relatively large vehicle load (>10,000 vehicles/day). Research reviewed by the Federal Highway Administration revealed that the distances at which deleterious effects could be observed varied from <100 m to approximately 3 km from the right-of-way, though most species were affected at distances between 100 m and 1,500 m from the right-of-way. Thus, study sites included construction sites, road-noise-only sites, and a control site, to allow us to separate effects of road-noise and construction activity on bird responses. Sites selected as road-noise-only and control sites were within 10 km of the impact site and similar in vegetative structure and composition. We sampled bird responses along transects perpendicular to the roadway to enable identification of any gradient patterns of response with distance from the roadway.

Construction schedules at both highway study sites changed multiple times. At highway 83, the construction schedule shifted such that an additional year of construction impacts occurred. At highway 71, construction occurred only within a segment of the treatment site, which required altering our analysis approach by dividing the area designated as the treatment (i.e., construction) into 2 areas: construction and pre-construction (the latter to receive construction later). By obtaining details about construction schedules and locations, we were able to clearly identify the type, time, and location of impacts and modify our sampling and analyses appropriately. Changes in construction plans are not unlike changes in natural conditions (e.g., flood, drought) that often confront researchers, which highlights the applicability of impact assessment designs to other disturbance situations.

Measuring variables that indicate levels of impact can confirm or test assumptions about impact intensity, duration, and extent, and confirm that control sites are appropriately excluded from the impact of concern. To confirm that areas were a sufficient distance from the impact sites to be excluded from noise related to the military and highway construction actions, and to account for ongoing background noise, we sampled ambient noise on all study sites with decibel meters. This allowed us to identify areas that were at a sufficient distance from the locus of noise origination to be considered controls with regard to the noise impact. At both highway construction sites, there were no differences in ambient noise levels between the construction and road-noise-only sites, and the noise in the control site was only slightly lower than the other sites (Lackey et al. 2011, D. Robinson, Texas A&M University, unpublished data 2011). On Fort Hood, ambient noise showed no pattern in relation to distance from the impact area. Noise was variable over space and time but was similar at increasing distances from the impact area and on control sites, which suggests that troop training activity did not generate noise that added to or differed from the existing ambient noise across the impact and control sites. Additionally, we were able to show that noise in the impact areas did not show an increase during days in which training events were taking place, in comparison to the days immediately before and after the training event. Measuring noise allowed us to test the assumption that noise would be greater at or near impact areas, decrease with distance from the impact areas and at control sites, and increase during training events. Consequently, we were able to determine that any responses observed with increasing distance from impact sites or that differed between impact and control sites, were not correlated with actual noise levels.

Identifying response variables.—For both the military training and highway construction impact studies, we identified GCWA occupancy, abundance, pairing success, and fledging success as the primary response variables of interest. These responses capture demographically relevant parameters for GCWA population status and recovery (USFWS 1992*a*) that reflect the ultimate outcome of many fine-scale metrics, including habitat use, food availability, and predator activity. Observers mapped territorial male GCWAs within the impact area and 2 control sites. We conducted behavioral observations at all territories across the season to determine reproductive status of the territory, including locating females and fledglings, and recording behavior associated with nesting (Vickery et al. 1992, Christoferson and Morrison 2001, Butcher et al. 2010, Lackey et al. 2011). At the highway study sites, we searched for GCWA nests and placed video cameras to record nesting behavior and predation events. We calculated pairing success as the proportion of territories that were occupied by both a male and a female. We calculated fledging success as the proportion of territories where ≥ 1 fledgling was observed. Measuring fledging success does not allow for assessment of specific components that contribute to fledging success, such as differences in clutch size, brood parasitism, parental nest-defense behavior, or nest predation due to the impact. However, it measures an important fitness outcome directly; differences in parental attentiveness or nest predation may occur due to the impact, but may not result in different outcomes for major fitness parameters such as fledgling production. As is common for impact assessment analyses, we compared measures for occupancy, abundance, pairing success, and fledging success between the impact and control sites, and among years (Morrison et al. 2008).

Because noise from troop training and roadway activities could have indirect effects on fitness outcomes, we also assessed song characteristics to investigate potential vocal adjustment to increases in noise that might result from military training, road construction, and general road-noise impacts. Increases in background noise can interfere or mask communication signals used in breeding and survival, which consequently could influence mating activity, population distributions, and detection of predators or prey (Patricelli and Blickley 2006). Many birds increase the amplitude (i.e., volume) of their vocalizations in response to increased ambient noise (Slabbekoorn and Peet 2003, Brumm 2004), but there can be fitness consequences (e.g., bio-energetics) associated with increasing the amplitude of vocalizations (Thomas 2002, Ward et al. 2003, Hu and Cardoso 2009). As such, many songbirds will change other characteristics of their songs to avoid the bio-energetic costs associated with singing louder (Hu and Cardoso 2009). Vocal adjustments in response to increased background noise could have long-term consequences not detected by short-term changes in abundance or fledging success. Accurate measures of amplitude are also often difficult to obtain in the field due to factors such as sound attenuation, variation in vegetation structure, distance, and orientation of the bird in relation to the recording device, and others. We therefore analyzed other song metrics that could be influenced by increased background noise from military training activity for roadway construction and vehicle activity, including minimum frequency, maximum frequency, and bandwidth (Hu and Cardoso 2009, Loman 2010).

Previous research has suggested that some avian species exhibit a decrease in breeding activity and abundance in proximity to highways (Reijnen and Foppen 1994, Federal Highway Administration 2004). In addition to background noise effects, roadway construction can lead to changes in predator assemblages or predator movement and activity patterns, or changes in prey availability along roadways (Reijnen et al. 1995, Federal Highway Administration 2004, Patricelli and Blickley 2006). Thus, we also examined behavioral responses of GCWAs to construction noise and activity across all study sites by experimentally testing behavioral responses of GCWAs to construction noises via playback experiments, and recording adult activity patterns at the nest using digital video recorders when possible (Lackey et al. 2011, 2012).

Timing and duration of sampling.—Ideally, researchers are able to plan and collect data before and after the impact of interest, on both the impact and control sites (i.e., before–after, control–impact design). However, unexpected effects, lack of planning, and logistical constraints can limit the ability to execute this ideal design. On Fort Hood, vegetation modification to the impact area occurred before pre-treatment data could be collected. Thus we had to rely on comparing responses on the impact site and control sites, and among years following the impact. Because troop training began in the same year, we were also unable to collect pre-treatment data on GCWA occupancy, abundance, pairing, and fledging success. However, we were able to collect data on bird song characteristics prior to military training events. Thus, for one set of response variables, we were able to implement a before–after, control–impact design.

Multiple years of post-treatment data can allow us to better understand the long-term effects of an impact. Some species may experience delayed or lag-effects in response to an impact (Cole and Landres 1995, Larson 1995). For example, avian species may not show a response to changes in breeding habitat conditions in the year immediate following the impact, due to other behaviors or influences such as site fidelity or predator community responses (Porneluzi 2003). Additionally, effects can last over a long-term, or can accumulate over time. Thus, even when researchers can gather data before and after the impact, studies should aim to sample for responses for a sufficient time after the impact to address delayed, long-term, or cumulative responses for the species of interest. At Fort Hood, vegetation modification occurred during a discrete period of time, but the effects of the disturbance could be delayed, continue, or accumulate over time. Golden-cheeked warbler abundance, pairing success, and fledging success may not show an observable response, or the response may not be limited to, the period immediately following the impact. Effects could potentially be observed in the first breeding season during which GCWAs were present in the study area following the vegetation thinning treatment. Alternatively, GCWAs could return to the impacted area due to influences such as site fidelity in the first breeding year following the treatment, but perform poorly and not return in year 2 or 3. By sampling over several years for GCWA presence, abundance, and productivity within the thinned area and adjacent control sites, we were able to investigate potential delayed or cumulative effects. Because GCWA site fidelity is relatively high (Jette et al. 1998) and life expectancy for songbirds is relatively short, with 4 years of data post-treatment indicating no negative impacts to abundance, pairing success, or fledging success, we could infer that neither an immediate, nor a time-lagged response, in habitat selection or productivity occurred.

Unexpected results.—Although we often assume that natural or anthropogenic perturbations will have deleterious effects on wildlife, positive responses to natural or human-induced impacts are also possible. For example, thinning of understory vegetation is assumed to have negative effects on GCWAs though no research has addressed this question directly. Current regulatory policies consider thinning of understory vegetation as loss or take of habitat (USFWS 2010). However, we observed that a higher proportion of territories in the vegetation-thinned area successfully fledged young than in control sites, which suggests that GCWAs may respond positively to thinning of understory vegetation (M. E. Marshall, unpublished data). Also, density of GCWAs was similar between the treated area and both control plots, which suggests that the pattern of higher productivity in the treated area was not a result of density dependence. Our results underline the importance of assessing actual impacts rather than resting on previous assumptions.

Activities that generate noise are assumed to disturb GCWAs during the breeding season, though research has not addressed this question directly. Research on other birds has indicated a strong effect of distance from roadways on presence, density, and productivity of many avian species (Reijnen et al. 1995, Forman et al. 2002), and these effects can be strongly influenced by vehicle load (i.e., vehicles/day) (Mumme et al. 2000, Forman et al. 2002, Lackey et al. 2011). As described above, we were able to sample at sites with both a low and high vehicle load. Contrary to the results of other studies (Mumme et al. 2000, Forman et al. 2002), we found that GCWA abundance, pairing success, and fledging success were similar between road-noise-only sites, road construction sites, and controls, and that there was no relationship between GCWA reproductive success and distance from road. Because of the use of our impact design, we could infer that highway construction along this route did not affect breeding GCWAs (Lackey et al. 2011). However, we were unable to provide any conclusions pertaining specifically to the effects of noise from highway construction because our data from ambient noise levels differed only slightly (approx. 4 dB) among the 3 site types (Lackey et al. 2011). Furthermore, results from our experimental playback suggested that GCWAs might be habituated to road-way noise, thus overcoming any behavioral consequences of noise associated with highway construction (Lackey et al. 2012).

Our initial assumption pertaining to noise levels generated from military troop maneuvers at Fort Hood also were not supported by our ambient noise-level data. There was no correlation between noise and distance from the training area, meaning GCWA territories within the training area and reference sites were subjected to similar levels of noise. This finding may be due to the location of the impact area. The impact area and both control sites are located immediately adjacent to an active live-artillery firing range. It is plausible that typical background noise in this area created by live-fire artillery training is louder, on average, than any infantry training that occurred within the impact area. We selected control sites that were subject to the same activity levels and proximity to the live-artillery fire ranges to control for pre-existing differences in noise levels (i.e., rather than selecting controls far from major training and artillery-fire areas, so it is unlikely that the treated site was quieter than the control sites pre-troop maneuvers). The similarity of ambient noise across our impacted and control sties at both the Real County highway project and the Fort Hood military training project demonstrate the necessity of testing assumptions of the specific disturbances that are associated with an impact. Without measuring ambient noise levels at these sites, the results of these projects could have led to incorrect conclusions of no impact of noise based on faulty assumptions.

CONCLUSION

Impact assessments are a means for investigating the effects of human-induced and natural perturbations on wildlife and wildlife habitat. Land managers and agencies should avoid readily accepting assumptions about the effects of actions on focal species, and researchers should assess the direct impacts on wildlife. When designing an impact study, care should be taken to define the type, time, and location of the impact of interest; to select suitable control sites; to identify appropriate response variables; and to test assumptions associated with the specific disturbances produced by the impact. Determining what design components are possible, including collection of pre-impact data and long-term, post-impact data, can help to clarify responses of the species of interest to the specific impact by allowing us to determine the effects of the impact with precision, and to detect delayed, ongoing, or cumulative effects of an impact. Although the scope of inference for impact assessments can be limited, it often matches the local scale at which management and monitoring is conducted, which makes this approach a useful tool to evaluate the effects (positive or negative) of various actions on wildlife.

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