Wildlife Society Bulletin; DOI: 10.1002/wsb.428

Tools and Technology

Using Audio Lures to Improve Golden-Winged Warbler (*Vermivora chrysoptera*) Detection During Point-Count Surveys

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ABSTRACT The golden-winged warbler (*Vermivora chrysoptera*) is a Neotropical migratory songbird listed as a "Bird of Conservation Concern" by the U.S. Fish and Wildlife Service. To manage golden-winged warblers, it is important to develop effective survey techniques for conservation research and monitoring. We conducted point counts in 1–8-year-old aspen (*Populus* sp.) stands in the northern Lower Peninsula of Michigan (USA), during 2011, to estimate detection probability of golden-winged warblers, with and without an electronic broadcast of a golden-winged warbler song (i.e., audio lure). We compared audio lure effectiveness for detecting golden-winged warblers during fixed- (50-m radius) and variable-radius point counts. Golden-winged warbler detection estimates were $\hat{P} = 0.84$ (95% CI = 0.39–0.98) and $\hat{P} = 0.22$ (0.11–0.40) for fixed-radius point counts, with and without audio lure, respectively. For variable-radius point counts, golden-winged warbler detection estimates were $\hat{P} = 0.79$ (CI = 0.51–0.93) and $\hat{P} = 0.57$ (0.42–0.71), with and without audio lure, respectively. We also estimated the number of 3-minute sub-counts required to achieve detection probability $\geq$95% for both radii, with and without audio lures. We found that 2 sub-counts with audio lure resulted in >95% detection probability for golden-winged warblers at both radii. Without audio lure, 12 and 4 sub-counts were required for fixed and variable radii, respectively. Regardless of survey technique, golden-winged warbler detection probability was always <1.0, which highlights the importance of accounting for imperfect detection of golden-winged warblers. Our results indicate that the use of an audio lure is an effective design technique for improving detectability of golden-winged warblers.

KEY WORDS audio lure, detection probability, golden-winged warbler, Michigan observation error, point counts, presence, sampling, *Vermivora chrysoptera*.

The golden-winged warbler (*Vermivora chrysoptera*) is a Neotropical migratory songbird with a breeding range that extends throughout the eastern United States (Buehler et al. 2007, Payne 2011). Throughout the breeding range, golden-winged warblers have experienced an average decline of 2.3% each year (USGS 2009) primarily due to habitat loss, hybridization with blue-winged warblers (*V. cyanoptera*), and brood parasitism by brown-headed cowbirds (*Molothrus ater*; Gill 1980, Confer and Knapp 1981, Confer et al. 2003). As a result, the U.S. Fish and Wildlife Service designated the golden-winged warbler as a Bird of Conservation Concern (USFWS 2008) and the Golden-winged Warbler Working Group was formed in 2003 to improve conservation efforts through science, education, and management (Buehler et al. 2007). In Michigan, USA, the Department of Natural Resources has designated the golden-winged warbler as a Featured Species—a rank used for those wildlife species selected for strategic management and whose primary limiting factor is habitat (MDNR 2012).

Developing effective research and monitoring programs for rare or declining species such as golden-winged warblers is important for describing population trends and determining species responses to management (e.g., Yoccoz et al. 2001). However, the true state of a wildlife population is often obscured to researchers and managers because of limited detectability (MacKenzie et al. 2005). Failure to account for imperfect detection has been cited as a leading source of bias in wildlife research and monitoring programs because a species may go undetected at a site, even though it is present (MacKenzie 2005, Kéry and Schmidt 2008). Thus, developing research and monitoring programs that employ both design- and model-based approaches for minimizing bias caused by imperfect detection is of primary interest to researchers and wildlife managers.

Perhaps one of the most common methods of estimating songbird occurrence and abundance is the point count (Fuller and Langslow 1983). When conducting point counts, audio lures may increase the ability of observers to detect focal

Received: 22 April 2013; Accepted: 5 December 2013

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species. Often these audio lures consist of an amplified broadcast of a singing or calling conspecific (Johnson and Searcy 1996, Conway and Gibbs 2005). Some audio lures simulate a rival male intruding on a resident male territory, thereby initiating a territorial response (Highsmith 1989).

Although audio lures are often utilized in avian research and monitoring programs (Highsmith 1989, Legare et al. 1999, Turcotte and Desrochers 2002, Conway and Gibbs 2005), few studies have empirically evaluated how well these devices reduce bias caused by false-absences of the target species. Kubel and Yahner (2007) showed that golden-winged warblers responded positively to audio lures, but cautioned that 3-minute surveys with audio lure were too short to reliably estimate population size. We used single-season occupancy models (MacKenzie et al. 2002) to determine whether golden-winged warbler detection probability increased with the addition of an auditory lure, during both fixed- (50-m radius) and variable-radius point counts. We subsequently used estimates from this analysis to determine the number of 3-minute, consecutive sub-counts required to achieve a 0.95 detection probability of golden-winged warblers, with and without the use of an audio lure. Our analysis highlights the benefit of combining design- and model-based solutions for minimizing false absences of golden-winged warblers sampled during point counts.

STUDY AREA

Our study occurred on state-owned lands within a 4-county area (Grand Traverse, Kalkaska, Mesaukee, and Wexford) in the northern Lower Peninsula of Michigan. State forest lands in this area were actively managed for aspen (*Populus* sp.) production. This area occurred along a glacial outwash plain and had porous, sandy soils (Albert 1995). Primary vegetation cover was mixed northern hardwoods and conifer forests 1–100 years old (Barnes and Wagner 2004). We focused our sampling on early successional (1–8 yr post-harvest) aspen patches (>8 ha in size) with dense understory vegetation consisting of quaking (*P. tremuloides*) and bigtooth aspen (*P. grandidentata*) intermixed with cherry (*Prunus* spp.), red maple (*Acer rubrum*), white oak (*Quercus alba*), and brambles (*Rubus* spp.; Barnes and Wagner 2004). Early successional habitats with dense understories are known habitats for golden-winged warblers (Klaus and Buehler 2001, Payne 2011). Additional study area information can be found in Otto and Roloff (2012).

METHODS

Male golden-winged warblers arrive on northern breeding grounds in May and establish territories within 2–3 days (Buehler et al. 2007). In Michigan, the first nests are typically constructed from 21 May to 1 June in scrub–shrub habitat and early successional woodlands, which possess an abundance of understory vegetation (Payne 2011). On the breeding grounds, male golden-winged warblers sing most actively from May through June (Highsmith 1989). Throughout much of the northern range of golden-winged warblers timber harvesting, and subsequent forest regeneration, plays an important role in providing habitat (Klaus and Buehler 2001). Nests are built by the female and constructed on the ground amongst thick understory cover (Ficken and Ficken 1967, Hunter et al. 2001).

To select potential survey sites, we used HAWTH'S TOOLS (Hawth's Tools, version 3.27, http://www.spatialecology.com/htools/, accessed 1 Feb 2009) in a Geographic Information System (GIS) to overlay each regenerating patch of aspen with a 60×60-m lattice. All lattice cells whose borders intersected or encompassed an unharvested forest edge, active logging road, off-road recreational vehicle trail, or wetland that appeared on 2005 National Agricultural Imagery Program imagery were discarded from the candidate set. From the remaining lattice cells we randomly selected 49 lattice cells, calculated the cell center in GIS, and used that location for our point counts (i.e., sites). Point-centers for all selected lattice cells were >250 m apart and >75 m from the harvest unit boundary. We eliminated 7 sites from our candidate pool because initial field visits revealed that the dominant forest type was not aspen. Our final sample size was 42 sites.

A single observer (D. J. McNeil) visited each site once from 1 June to 24 June 2011, between 0.5 and 3.5 hours after sunrise. The June surveys were consistent with other golden-winged warbler monitoring programs such as the Cornell Lab of Ornithology's golden-winged warbler Atlas Project. Surveys were not conducted during high winds or rain. At each site we conducted a 12-minute point count consisting of 4 3-minute sub-counts. During each sub-count we noted whether a golden-winged warbler was heard or seen within a fixed (50 m from the point-count center) or variable-radius sampling distance. The first 3 sub-counts were performed without an audio lure. During the fourth sub-count, we broadcast a digital recording of a male golden-winged warbler song in all directions. The recording consisted of golden-winged warbler songs played at approximately 3-second intervals. Songs were broadcast from a portable music speaker connected to an MP3 player that contained the 3-minute audio lure recording. Songs were played at a volume we believed was comparable to songs of male golden-winged warblers in the study area. The audio lure simulated an intruding male golden-winged warbler.

We used single-season occupancy models (MacKenzie et al. 2002) in Program PRESENCE (Version 3.1; J. E. Hines, Patuxent Wildlife Research Center, Laurel, MD) to estimate detection and occupancy probabilities for golden-winged warblers. We created a detection history for each study site, noting whether ≥1 golden-winged warbler was detected during each sub-count. For example, a detection history for 2 sites may appear as

Site A: 1001
Site B: 0000

where 1 represents detection of ≥1 golden-winged warbler during a 3-minute sub-count and 0 represents non-detection of golden-winged warblers. For Site A, ≥1 golden-winged warblers were detected during sub-counts 1 and 4, but not 2 and 3, indicating that golden-winged warblers were present at the site but were undetected during 2 of the 3-minute sub-counts. At Site B, golden-winged warblers were not detected during any of the 4 sub-counts. We constructed data sets for fixed- and variable-radius point counts and analyzed each separately.

We constructed a candidate set of 2 models to estimate golden-winged warbler detection and occupancy probabilities for fixed- and variable-radius data sets. We kept our candidate models focused on the objective of quantifying audio lure effects and therefore held occupancy constant and did not consider the effects of additional environmental factors on detection. First, we considered a model where golden-winged warbler detection probability was held constant across all sub-counts ($\psi(.)$, $p(.)$), representing our null hypothesis that use of an audio lure did not increase golden-winged warbler detection probability. Our second model was structured to allow detection probability during the fourth sub-count (i.e., audio lure period) to be different than the first 3 sub-counts ($\psi(.)$, p(Audio Lure)). Support for this model would suggest that the addition of an audio lure influenced golden-winged warbler detection probability.

We used Akaike's Information Criterion, adjusted for small sample size (AIC_c), to rank models (Burnham and Anderson 2002). We used cumulative AIC weights (w_+) and evaluation of 95% confidence intervals to determine relative importance of covariates and model parameters. We report model-averaged estimates and unconditional confidence intervals (95% CI) for all real parameters (Burnham and Anderson 2002:149–205).

We used model-averaged detection estimates to calculate the number of 3-minute sub-counts required to produce a 0.95 probability of detecting golden-winged warblers at least once. Cumulative detection probability was calculated as $1-(1-\hat{\bar{P}})^n$, where $\hat{\bar{P}}$ is the estimated probability (determined from our analysis) of detecting golden-winged warbler during a sub-count and n is the cumulative number of sub-counts. We calculated this value for fixed- and variable-radius point counts, with and without an audio lure.

RESULTS

For fixed-radius point counts, we observed golden-winged warblers at 11 of our 42 sites (naïve occupancy = 0.26). Estimated golden-winged warbler occupancy was 0.28 (95% CI = 0.16–0.45) after accounting for imperfect detection. Golden-winged warbler detection probability was higher during the audio-lure survey period ($\hat{\bar{P}} = 0.84$, 95% CI = 0.39–0.98) than it was during the non-audio-lure periods ($\hat{\bar{P}} = 0.22$, 95% CI = 0.11–0.40). Weight of evidence for the model containing the audio-lure parameterization for fixed-radius point counts was 1.0 (Table 1).

For variable-radius point counts, we observed golden-winged warblers at 14 sites (naïve occupancy = 0.33). Estimated occupancy probability was 0.36 (95% CI = 0.23–0.52). Golden-winged warbler detection probability was higher during the audio-lure period ($\hat{\bar{P}} = 0.79$, 95% CI = 0.51–0.93) than it was during the non-audio-lure periods ($\hat{\bar{P}} = 0.57$, 95% CI = 0.42–0.71); however, the 95% confidence intervals overlapped. Weight of evidence for the model containing the audio-lure parameterization for variable-radius point counts was 0.56 (Table 1).

For fixed-radius point counts, two 3-minute sub-counts with an audio lure and 12 sub-counts without an audio lure were required to achieved >95% detection probability (Fig. 1). For variable-radius point counts, 2 sub-counts with an audio lure and 4 sub-counts without an audio lure were required to achieved >95% detection probability (Fig. 1).

DISCUSSION

Our study shows that use of an audio lure increases golden-winged warbler detection probability during fixed-radius point counts, thereby reducing detection error when estimating golden-winged warbler occurrence within a 50-m sampling radius. This finding is consistent with other studies that highlighted the utility of audio lures for improving sampling effectiveness during point counts for birds (Highsmith 1989, Conway and Gibbs 2005, Kubel and Yahner 2007). Audio lures apparently elicit a territorial response in males; this is the mechanism that results in higher detection probabilities (Highsmith 1989, Kubel and Yahner 2007).

Although use of an audio lure increased detection probability for golden-winged warblers during fixed-radius point counts, the relative effectiveness of the audio lure was greatly reduced at the larger spatial scale (i.e., variable radius). Our detection estimates suggested a relatively weak, positive effect of the audio lure on golden-winged warbler detection probability during variable-radius point

Table 1. Ranking of candidate detection models for fixed- (50-m) and variable-radius point counts for golden-winged warblers), with and without audio lure, in northern Michigan, USA, 2011. ΔAIC_c = Akaike's Information Criterion adjusted for small sample size, AIC_c wt = the weight of evidence in favor of model i as being the actual best model in the candidate set. K = no. of parameters. $-2L = -2 \times$ Log Likelihood. $\hat{\beta}_{\text{Audiolure}}$(SE) represent parameter estimates (±1 SE) for the influence of audio lure on golden-winged warbler detection probability during point counts.

Model	ΔAIC_c	AIC_c wt	K	−2L	$\hat{\beta}_{\text{Audiolure}}$(SE)
Fixed-radius					
ψ(.), p(Audio lure)	0	1.00	3	90.36	2.91 (1.06)
ψ(.), p(.)	11.72	0.00	2	104.08	
Variable-radius					
ψ(.), p(Audio lure)	0	0.56	3	130.56	1.03 (0.70)
ψ(.), p(.)	0.46	0.44	2	133.02	

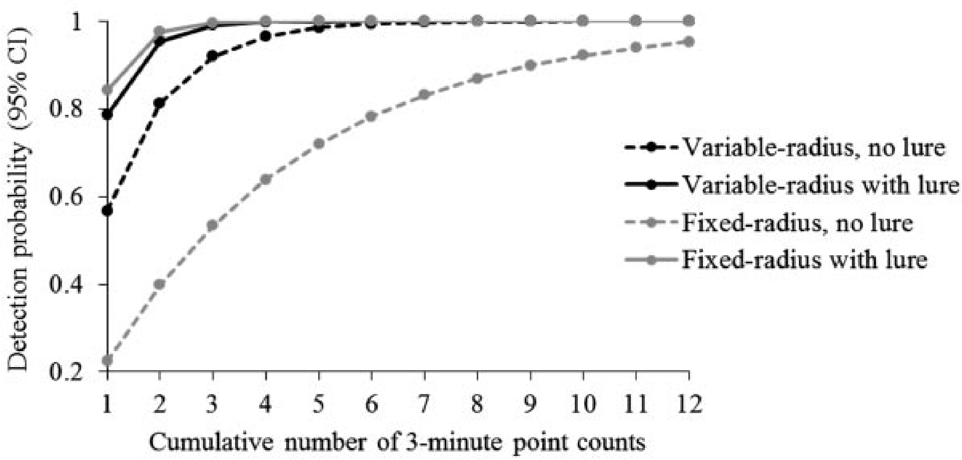

Figure 1. Cumulative detection probability of golden-winged warblers, based on the number of 3-minute point-count surveys conducted with (solid) and without (dashed) audio lure in the northern Lower Peninsula of Michigan, 2011. Cumulative detection probability was calculated for fixed- and variable-radius surveys as $1-(1-\hat{\hat{P}})^n$, where $\hat{\hat{P}}$ is the estimated probability of detecting golden-winged warblers during a 3-minute survey (determined from our original analysis) and n is the cumulative number of surveys.

counts. The ΔAIC_c for the model that did not include the audio lure covariate was 0.46 (Table 1), which suggests that evidence in support of $\psi(.)$, $p(.)$ and $\psi(.)$, p(Audio Lure) was almost equal (Burnham and Anderson 2002). Collectively, our results provide weak evidence of a positive effect of audio lure on golden-winged warbler detection probability during variable-radius point counts. The reduced effect size of the audio lure for the variable-radius point counts was likely caused by a higher detection probability during the period with no audio lure. Higher baseline detection probability for variable-radius point counts seems intuitive, because a larger area is sampled and hence more golden-winged warblers are available for sampling. Rosenberg and Blancher (2005) reported that the maximum distance for detecting golden-winged warblers was 200 m. Thus, our sampling area for variable-radius point counts could be as high as ≈12.5 ha, as compared with the ≈0.8 ha for our fixed sampling radius. This larger sampling area likely encompassed or overlapped more golden-winged warbler territories, which are between 1.4 ha and 5.2 ha in size (Murray and Gill 1976). If each bird within a territory has some chance of being detected during a point count, then it is clear that variable-radius point counts should yield higher detection probabilities during non–audio-lure periods when compared with fixed-radius surveys, because a greater number of birds were available for sampling over a larger site area.

Our study shows that the effectiveness of audio lures is maximized when conducting point counts within a fixed sampling radius. Indeed, golden-winged warbler detection estimates where ≈280% higher when using an audio lure. Conducting fixed-radius point counts is often necessary when studying avian use of small-scale habitat features (Merrill et al. 1998, Confer et al. 2003, Otto and Roloff 2012). Hence, the option to conduct variable-radius point counts, which yielded higher baseline detection probabilities in our study, may not always be practical from a research design perspective. Our study highlights the utility of audio lure for reducing false absences of golden-winged warblers during fixed-radius point counts.

Although our study suggests that detection probability of golden-winged warblers increased with an audio lure, it is also possible that part of the observed increase in detection probability was caused by violation of the closure assumption (MacKenzie et al. 2002). Because we conducted an observational study of unmarked golden-winged warblers, we do not know how much of the observed positive effect of the audio lure can be attributed to increased detection of golden-winged warblers at occupied sites within the survey area. An alternate explanation could be that the audio lure caused temporary immigration of golden-winged warblers into previously unoccupied sites during the 3-minute audio-lure sub-count. Immigration into the survey area would represent a violation of the closure assumption because golden-winged warbler attraction to the audio lure caused individuals to move into unoccupied sites. We suspect that part of the observed increase in detection probability during the audio lure sub-count was due to violation of closure, particularly during fixed-radius point counts because birds were observed numerous times flying directly toward the observer from unknown locations within the stand. To our knowledge, no studies have addressed potential bias resulting from violations of closure in avian research that use audio lures for collecting occupancy or abundance information. This is problematic considering that audio lures are commonly used when gathering avian occupancy and abundance data (Legare et al. 1999, Turcotte and Desrochers 2002, Conway and Gibbs 2005, Kubel and Yahner 2007). Our study provides a cautionary note to surveyors who use audio lures within limited sampling radii and emphasizes that research is needed to determine whether audio lures result in a positive bias in occupancy or abundance estimates. We note that potential positive bias caused by audio lures should be viewed as a study design limitation and not as a flaw of occupancy models (MacKenzie et al. 2002).

One aspect of our study that we did not quantify was the increased ability to see golden-winged warblers by playing audio lure, rather than detecting them via song or call. Although bird vocalizations were our primary method of detecting golden-winged warblers, the addition of audio lure often brought birds within 5 m of the observer. This is an important observation considering many studies in the past have relied on visual identification of individual birds or species during surveys (Ficken and Ficken 1967, Gill 1980, Kubel and Yahner 2007). Furthermore, golden-winged–blue-winged warbler hybrids often sing the songs of either species (Ficken and Ficken 1967), which may lead to species misidentifications if documented by vocalization alone (i.e., false positives). Future studies should determine whether audio lures are indeed effective for increasing visual detections of birds for the purposes of confirming sex, identifying marked individuals, or identifying golden-winged–blue-winged warbler hybrids.

MANAGEMENT IMPLICATIONS

Our results suggest that detection probability of golden-winged warblers during fixed-radius point counts can be increased through the use of an audio lure. This finding has important implications for golden-winged warbler research and monitoring efforts that track changes in golden-winged warbler occurrence or abundance over space and time. We recommend that when using audio lures, surveyors conduct 2 3-minute sub-counts for golden-winged warblers at both fixed and variable radii to achieve a 95% probability of detection. If audio lures are not used, we recommend that 12 and 4 sub-counts be conducted for fixed and variable radii, respectively. Our study highlights the strength of using both design- and model-based approaches for reducing false absences of golden-winged warblers during point counts and provides a cautionary note of potential bias resulting from the use of audio lures.

ACKNOWLEDGMENTS

We thank M. Kuczynski for his assistance with digitization of the golden-winged warbler audio lure. E. Linderman provided insightful comments. Support for this project was provided by the Michigan Department of Natural Resources Wildlife Division with funds from the federal Pittman–Robertson Wildlife Restoration Act grant administered by the U.S. Fish and Wildlife Service (W-147-R: Michigan's Statewide Wildlife Research and Restoration Program) and the Rachana Rajendra Fellowship.

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Associate Editor: Koper.