Influence of Audio Lures on Capture Rates of Passerines During Spring Migration in Veracruz, Mexico

(La Influencia del Uso de Atrayentes Auditivos Sobre Niveles de Captura de Paserinas Durante la Migración de Primavera en Veracruz, México)

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ABSTRACT

We studied the effect of audio luring on a selection of passerine birds during spring migration at Minatitlán, Veracruz, Mexico, in 2013. At our MIGRA2 site we broadcast an audio lure daily over a period of one month, while at our CONTA3 site the same audio lure was broadcast every second day. Of the five species broadcast throughout the study period, three were significantly more numerous at CONTA3 on audio lure days (Swainson's Thrush, Yellow-breasted Chat, and Painted Bunting), and Yellow Warbler, numbers were non-significantly higher, whereas Common Yellowthroat was marginally more numerous on silent days. Six other common species (≥ 25 individuals banded) were also more numerous on audio lure days although their calls were not part of the broadcast. Among the five species on the audio lure throughout the study period, capture frequencies varied by age and sex, although not consistently across species. Stopover frequency and duration were both very low. Use of audio lures may be particularly valuable where higher capture rates can increase the power of trend estimation. Further studies should explore additional target species to improve our understanding of audio lure effectiveness, and replicating this work in different locations would help assess variability in response of individual species.

RESUMEN

Se estudió el efecto de atrayentes auditivos en una selección de aves paserinas durante la migración de primavera de 2013, en Minatitlán, Veracruz, México. En nuestro sitio de monitoreo MIGRA2, emitimos un atrayente auditivo diariamente durante un periodo de un mes, mientras que en nuestro sitio CONTA3 el mismo atrayente fue transmitido cada dos días. De las cinco especies cuyos cantos y llamados fueron transmitidos en todo el período de estudio, tres fueron significativamente más numerosas en CONTA3 (Zorzal de Swainson's, Buscabreña y Siete Colores), en tanto que los Chipes amarillos no fueron significativamente más altos, y los Chipes garganta amarilla fueron marginalmente más abundantes en días silenciosos. Otras seis especies comunes (≥ 25 individuos anillados)también fueron más numerosas durante los días de emisión a pesar de que sus cantos no formaron parte de lo transmitido. En las cinco especies que formaron parte del atrayente auditivo durante el período de estudio, las frecuencias de captura variaron según la edad y sexo, aunque no de manera consistente en todas estas especies. La duración y frecuencia de las "paradas" fueron muy bajas. El uso de atrayentes auditivos puede ser particularmente valioso en donde las tasas altas de captura pueden aumentar

el poder de la estimación de tendencia. Nuevos estudios deberían explorar en otras especies con el fin de mejorar nuestro entendimiento sobre la efectividad del uso de atrayentes auditivos, y su replicación en diversas localidades ayudaría a evaluar la variabilidad en la respuesta de especies individuales.

INTRODUCTION

Most bird banding for migration monitoring in North America uses passive capture techniques, without any lures to draw in birds. A notable exception is the capture of Northern Saw-whet Owls (*Aegolius acadicus*), for which most researchers play the species' territorial call, as it greatly increases capture rate (Erdman and Brinker 1997, Whalen and Watts 1999). Kearns et al. (1998) also used an audio lure to study migrating Sora (*Porzana carolina*) and Virginia Rail (*Rallus limicola*). While Alessi et al. (2010) targeted Yellow-breasted Chat (*Icteria virens*) during one spring migration, the use of audio lures for studying migrating passerines is very recent in North America and results have not yet been published (Ralph 2013). Studies using audio lures have more commonly involved attracting a single target species during the breeding and/or non-breeding season: e.g., Swainson's Thrush (*Catharus ustulatus*) (Delmore and Irwin 2014), Black-throated Blue Warbler (*Setophaga caerulescens*) (Sillett and Holmes 2002), and Yellow-rumped Warbler (*Setophaga coronata*) (Toews et al. 2013).

In Europe, the use of audio lures is more established and commonly applied to attracting migrant songbirds (e.g., Schaub et al. 1999, Lecoq and Catry 2003). It may be particularly useful for studying rare or threatened species, which typically are recorded in small numbers during passive migration monitoring (e.g., Julliard et al. 2006). To increase the statistical power for detecting a significant trend requires either more data in the same period of time, or collecting data for a longer period of time (Steidl et al. 1997). Many analyses of banding data are limited by small sample sizes (e.g., Crewe et al. 2008). Since migration monitoring may be important for estimating population trends for species of conservation concern, the use of audio lures to augment capture rates could have potential to improve confidence in these estimates.

While there is general agreement that audio lures increase capture rates, there has been little research published on the magnitude of this influence, and the degree to which it varies among species. Our objectives, therefore, were to 1) evaluate the responsiveness of a suite of passerines to audio lures, 2) assess the degree to which non-target species are influenced by an audio lure, and 3) assess whether the audio lure biased capture frequency by age or sex.

METHODS

Study site. We conducted our research at the Santa Alejandrina Bird Observatory (Observatorio de Aves del Pantano de Santa Alejandrina - OAPSA), 5 km east of Minatitlán, Veracruz, Mexico (17°59'N, 94°30'W) in the Santa Alejandrina Marsh, adjacent to the Coatzacoalcos River (Fig. 1), from 10 Apr to 10 May 2013. OAPSA was established as a migration monitoring observatory in 2008 by Pemex Refinación, in coordination with Instituto Politécnico Nacional, and run by Tierra de Aves A.C. to take advantage of its location on a coastal flyway (18 km inland from the Gulf of Mexico) at the northern end of the Isthmus of Tehuantepec. This is the narrowest point of the land migration route between North America and Central America. The MIGRA2 banding site has been operated almost continuously since 2010 and consists of 13 nets adjacent and perpendicular to a lightly used gravel road. MIGRA2 has a mix of shrubs and trees up to five m high with a small marsh immediately to the north. The CONTA3 banding site is 2.5 km to the south (Fig. 1, inset) and had not previously been used for migration monitoring. CONTA3 was selected for this study to provide an experimental site in the same general habitat and area as MIGRA2, but far enough away that birds were unlikely to be attracted by the audio lure at MIGRA2, considering that Mukhin et al. (2008) estimated the reach of audio lures to generally be 1 km or less. There were 10 nets at CONTA3, arranged in a rough semi-circle off the same

gravel road, and mostly set near tall shrubs and scattered trees up to seven m in height. The landscape did not permit for two identical study sites, but differences in habitat and layout between MIGRA2 and CONTA3 were considered inconsequential, given that the primary objective was to compare between audio lure and non-audio lure days at CONTA3, with constant-effort data from MIGRA2 primarily used to monitor for pulses in migration that could confound analysis of audio lure effects.

Study team. MIGRA2 was operated by an OAPSA team, comprising of the same two banders and two

cast machine malfunctioned. At MIGRA2, the audio lure was played daily, to allow for detection of any variability among days that might be attributable to pulses in migration. Two playback units were used at MIGRA2, one at each end of the linear site, while at CONTA3 there was one unit central to the net array. Each playback unit was identical, consisting of an MP3 player and a 60W amplifier, broadcasting through a trumpet-style speaker. The same playback recording was used at both sites and broadcasted at the same volume. At both sites, the audio lure was turned on at 0200 nightly and run continuously until the nets were
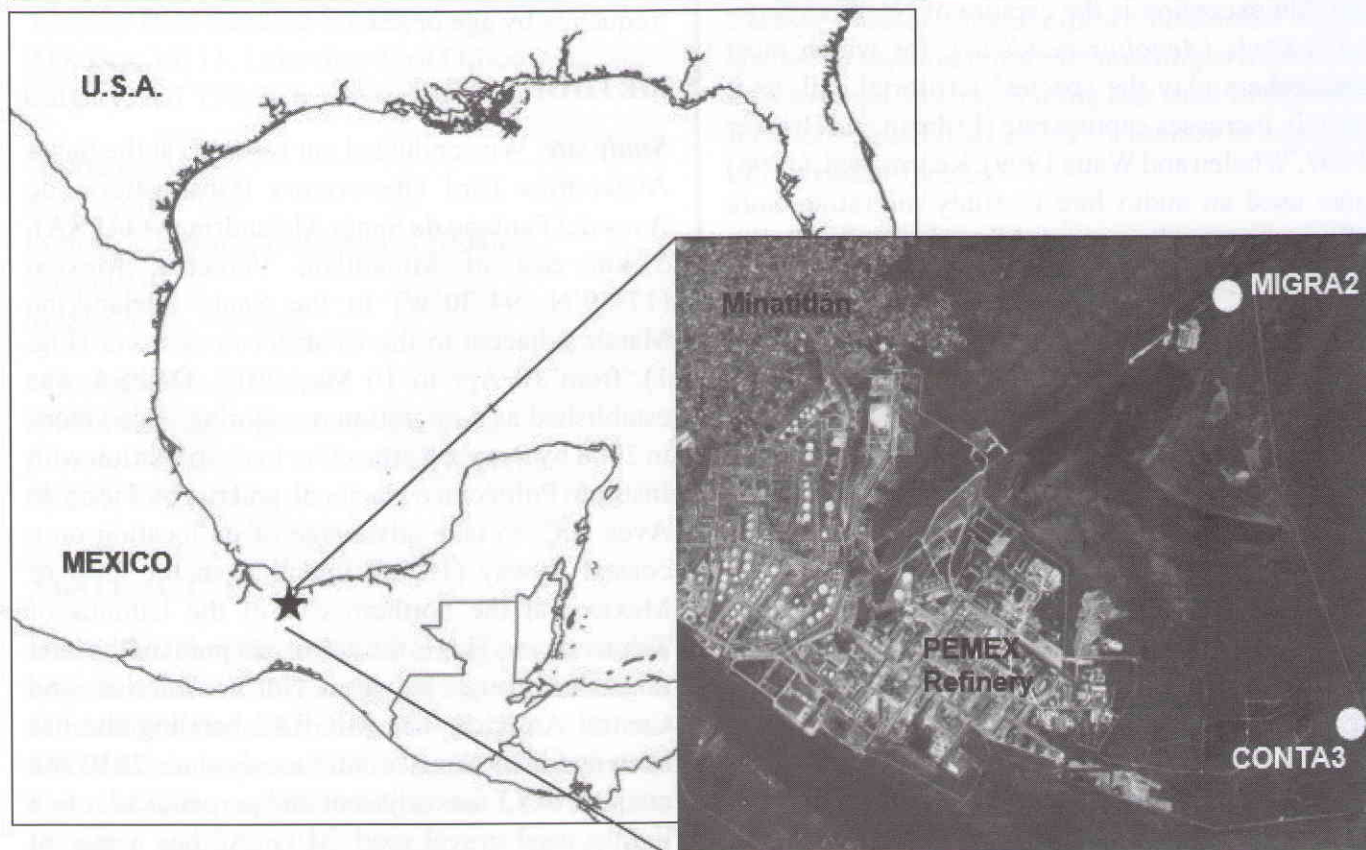
Fig. 1. Location of the two study sites (inset)near Minatitlan, Veracruz,Mexico

extractors throughout the study period. CONTA3 was operated by volunteers from the Calgary Bird Banding Society (CBBS), with three or four crew members at a time, covering shifts of 10-11 days each over the course of the study. At all times there was a bander-in-charge with a minimum of 15 years of experience banding North American passerines.

Audio lure. The audio lure was played at CONTA3 on alternate mornings, except for one day when the brod-

closed at the end of each banding session (at approximately 1000). Five species were featured on the audio lure throughout the study period (10 Apr to 10 May): Swainson's Thrush, Common Yellowthroat (*Geothlypis trichas*), Yellow Warbler (*Setophaga petechia*), Yellow-breasted Chat, and Painted Bunting (*Passerina ciris*). From 11 Apr to 26 Apr, Lincoln's Sparrow (*Melospiza lincolnii*) was also included in the broadcast whereas; from 27 Apr to 10 May, Hooded Warbler (*Setophaga citrina*),

Indigo Bunting (*Passerina cyanea*), and Orchard Oriole (*Icterus spurius*) were included. The selection of target species and timing was based on experience from previous years at OAPSA. Both versions of the audio lure were approximately two minutes long, looped continuously, and included the song and call notes of each species interspersed throughout. They were compiled by OAPSA in 2010 from a variety of commercially available CDs and online resources recorded in North America.

Banding. At both stations, birds were captured with mist nets 2.4 m high and 12 m long with a mesh size of 30 mm, open for four hours beginning 30 min before sunrise. All nets were operated daily at MIGRA2 (52 net hours/day of effort). At CONTA3 all nets were usually operated on days without the audio lure (full coverage of 40 net hours/day), but on most days with playback only four to eight nets were opened (16 to 32 net hours/day; mean 25). This was to ensure captures were safely managed, given that the CBBS crews had less experience with high bird volumes and with many of the species captured than the OAPSA team. Nets were checked at least every 40 min at both locations, and birds were placed in individual bags to be brought to a central location at each site for processing. Each bird was fitted with an uniquely numbered metal band (Porzana Ltd, East Sussex, UK) with the number preceded by "www.tierradeaves.com", to facilitate reporting of recoveries. In most cases each bird was aged and/or sexed (Howell and Webb 1995, Pyle 1997).

Data analysis. For standardization, all capture rates were calculated as number of birds per 100 net hours (b/100nh). For evaluation of audio lure effect at CONTA3, the nine species on the audio lure were tested, plus six others with at least 25 captures. Although the audio lure was used daily at MIGRA2, days were still classified as audio lure or silent, reflecting the treatment at CONTA3, to allow the site to be used to investigate any systematic differences between the days. Our data were not normally distributed; therefore, differences in capture rate by treatment (audio lure/silent) and between sites (MIGRA2/CONTA3) were tested using the non-parametric two-tailed Wilcoxon's signed-rank statistic for matched pairs (Fowler and Cohen 1996). A chi-squared statistic and Yates' correction for continuity (Fowler and Cohen 1996) were used to compare frequencies of captures among the categorical variables of age (second year vs. after-second year) and sex (male vs. female). Sample sizes differed in these comparisons because individuals of unknown age or sex were removed from the dataset. The results are considered significant if $p < 0.05$. The summary data for capture rates are presented as means ± 1 SD.

Minimum stopover duration was calculated as the difference (in days) between the initial capture date and the date that the bird was last recaptured in the study area (Kaiser 1999, Arizaga et al. 2008).

RESULTS

Between 10 Apr and 10 May 2013, 2,735 birds representing 71 species were banded at CONTA3, and 7,328 birds representing 89 species were banded at MIGRA2. Swainson's Thrush accounted for 50% of all birds banded at CONTA3, and 47% at MIGRA2. At CONTA3, 78% of all birds were banded on the 14 days (45%) with the audio lure playing. On average, the capture rate at CONTA3 was seven times higher on days when the audio lure was playing than on silent days, whereas at MIGRA2 where the audio lure was broadcast every day, the difference between the two sets of dates was negligible (<4%; Fig. 2). Overall, the 13 most frequently banded species at CONTA3 (each with at least 25 individuals; Table 1) comprised 88% of the total; the same species accounted for 85% of birds banded at MIGRA2. Table 1 also shows that there was some variability in migration that cannot be attributed to the audio lure; e.g., even though the audio lure was broadcast daily at MIGRA2, far more many Wilson's Warblers and Indigo Buntings were banded on days that were silent at CONTA3.

At CONTA3, capture rate was significantly higher on audio lure days for three species: 68 times higher for Swainson's Thrush ($z = -3.180, p = 0.002$), eight times higher for Yellow-breasted Chat ($z = -2.934, p = 0.003$) and 18 times higher for Painted Bunting ($z = -2.934, p = 0.003$; Fig. 3). Yellow Warbler numbers
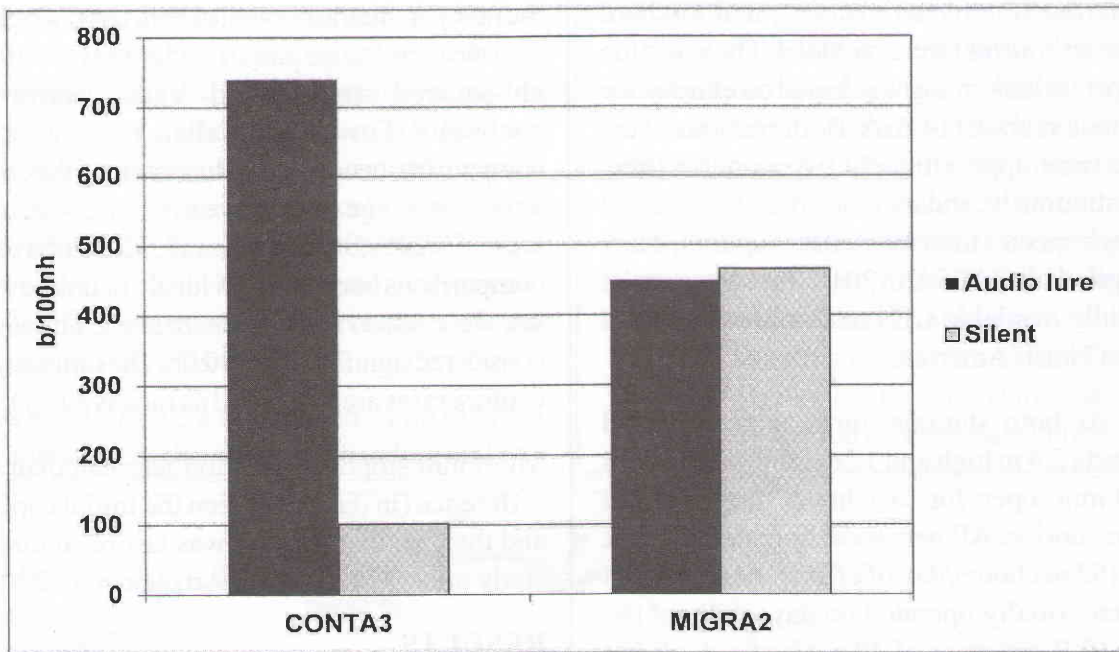
Fig. 2. The capture rate of birds at CONTA3 was seven times higher on days when the audio lure was broadcast, while there was no difference at MIGRA2 between the same set of days. (An audio lure was played on all days at MIGRA2, but the data were aligned to match the same days as CONTA3.)

Table 1. The 13 species with at least 25 individuals banded at CONTA3 were also among the most numerous species at MIGRA2.

Species	Number of Birds Banded					
	CONTA3			MIGRA2		
	Audio Lure	Silent	*Total*	Audio Lure	Silent [a]	*Total*
Swainson's Thrush [b]	1336	33	*1369*	1624	1829	*3453*
Yellow-breasted Chat [b]	163	33	*196*	254	397	*651*
Common Yellowthroat [b]	65	122	*187*	97	126	*223*
Yellow Warbler [b]	84	52	*136*	262	321	*583*
Mourning Warbler	70	46	*116*	96	143	*239*
Northern Waterthrush	42	63	*105*	65	99	*164*
Painted Bunting [b]	66	6	*72*	79	123	*202*
Gray Catbird	49	20	*69*	89	130	*219*
Wilson's Warbler	21	24	*45*	37	74	*111*
Least Flycatcher	19	23	*42*	59	65	*124*
Indigo Bunting [c]	19	13	*32*	16	67	*83*
Lincoln's Sparrow [c]	17	9	*26*	32	55	*87*
Chestnut-sided Warbler	14	11	*25*	53	61	*114*
Other Species	178	137	*315*	448	627	*1075*
Total	*2143*	*592*	*2735*	*3211*	*4117*	*7328*

[a] An audio lure was played on all days at MIGRA2, but the data were categorized to match the same days as CONTA3.
[b] Species broadcast on the audio lure throughout the study period.
[c] Species broadcast on the audio lure for only part of the study period.

were somewhat greater on audio lure days ($z = -1.817$, $p = 0.069$), while Common Yellowthroat numbers were higher on silent days ($z = -0.944, p = 0.347$), but neither difference was significant. For the four species that were included for only part of the broadcast period, sample sizes were small and with too many tied values ($n = 0$) to permit a reliable calculation of the Wilcoxon signed-rank statistic. However, three of the four species (Lincoln's Sparrow, Indigo Bunting, and Orchard Oriole) were banded in greater numbers on audio lure days, while Hooded Warbler was banded in slightly greater numbers on silent days during the broadcast period (Fig. 4). None of the nine species broadcasted showed any significant difference in capture rate at MIGRA2 between defined audio lure vs. silent days.

Among the 13 species with at least 25 individuals banded at CONTA3, six were not on the audio lure: Least Flycatcher (*Empidonax minimus*), Gray Catbird (*Dumetella carolinensis*), Northern Waterthrush (*Parkesia noveboracensis*), Mourning Warbler (*Geothlypis philadelphia*), Chestnut-sided Warbler (*Setophaga pensylvanica*), and Wilson's Warbler (*Cardellina pusilla*). All of them were captured more frequently on audio lure days (Fig. 5), although the difference was close to significant only for Gray Catbird ($p = 0.059$) and Mourning Warbler ($p = 0.052$). At MIGRA2, only two of these species (Least Flycatcher and Chestnut-sided Warbler) were slightly more numerous on defined audio lure days than on silent days, but no differences were significant.
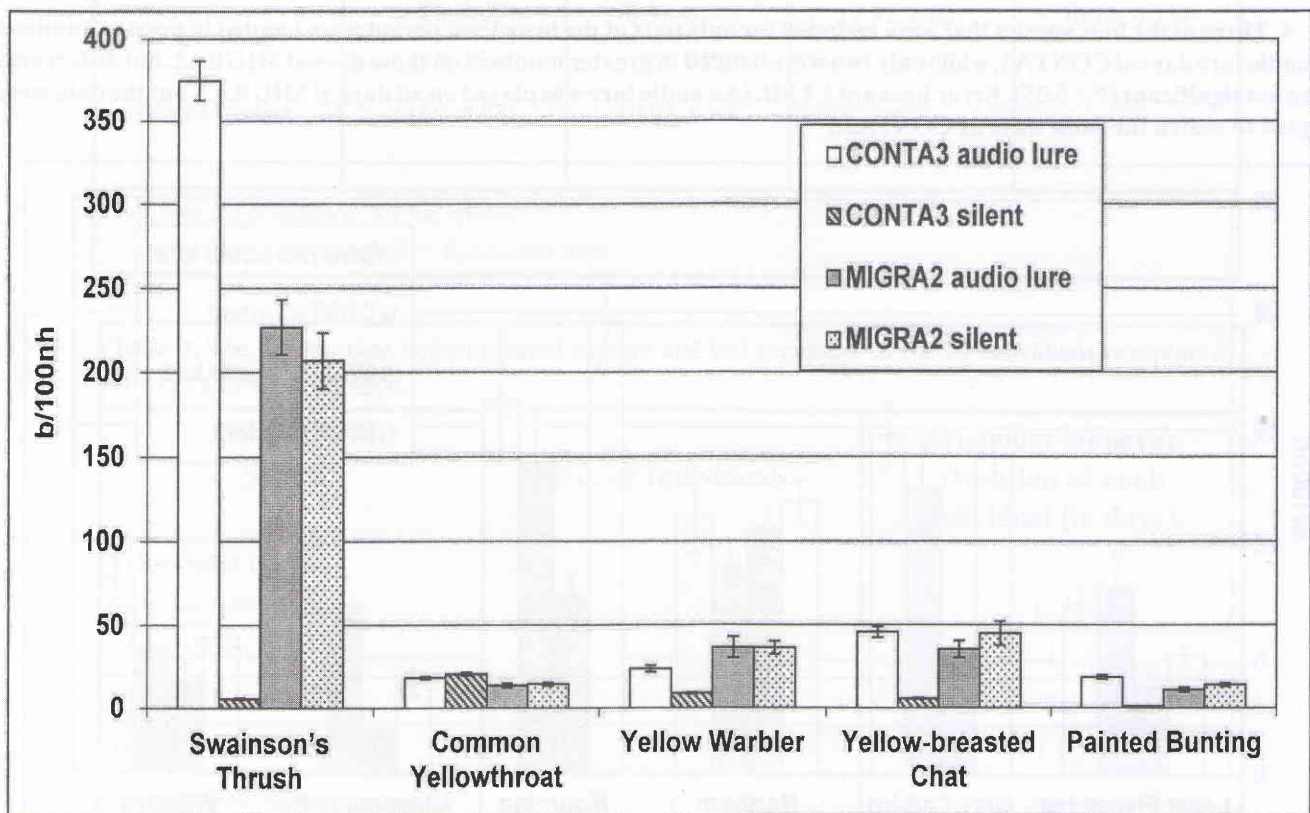

Fig 3. Three of the five species on the audio lure for the whole period were banded in significantly higher numbers at CONTA3 on audio lure days, while there was no difference in capture rate between days at MIGRA2. Significant results ($P < 0.05$) betwen audio lure and silent days, for three of the species, are starred (*). Error bars are ± 1 SD. An audio lure was played on all days at MIGRA2, but the data were aligned to match the same days as CONTA3.)
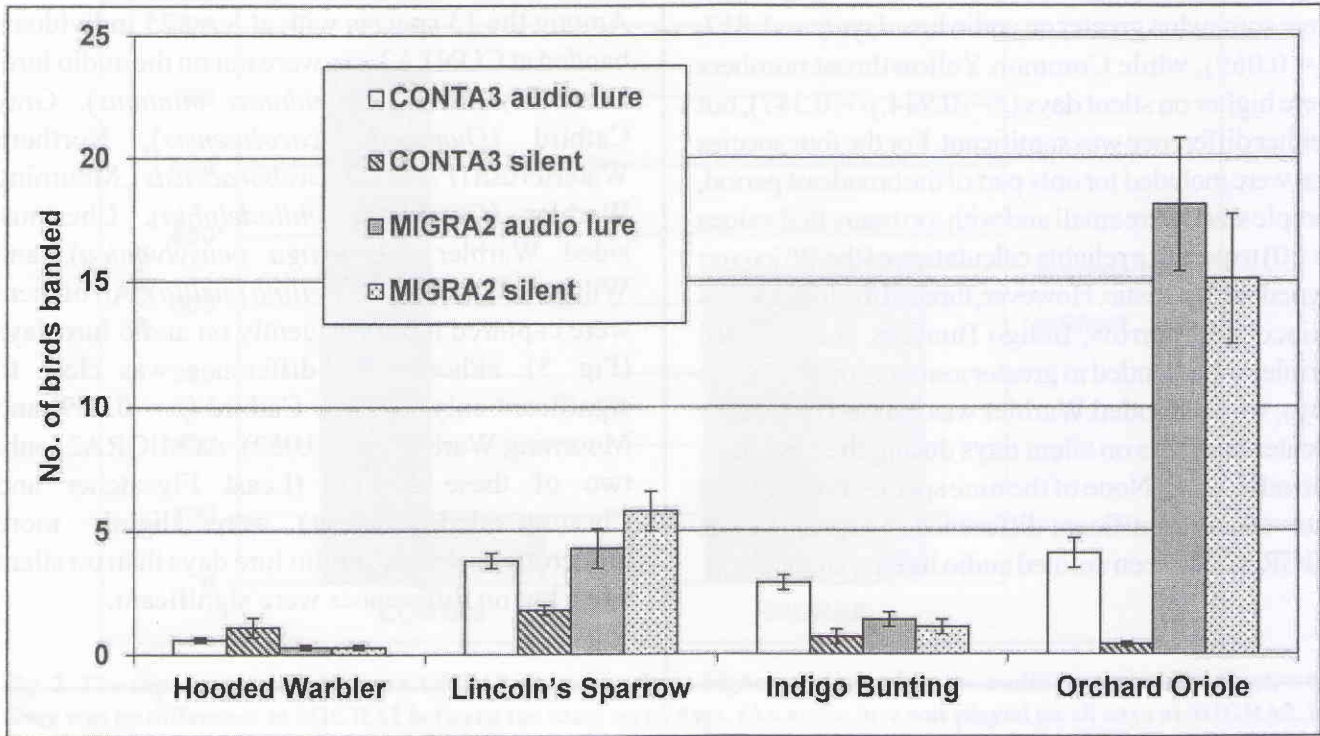
Fig. 4. Three of the four species that were included for only part of the broadcast period were banded in greater numbers on audio lure days at CONTA3, while only two were banded in greater numbers on those days at MIGRA2, but differences were not significant ($P > 0.05$). Error bars are ± 1 SD. (An audio lure was played on all days at MIGRA2, but the data were aligned to match the same days as CONTA3.)
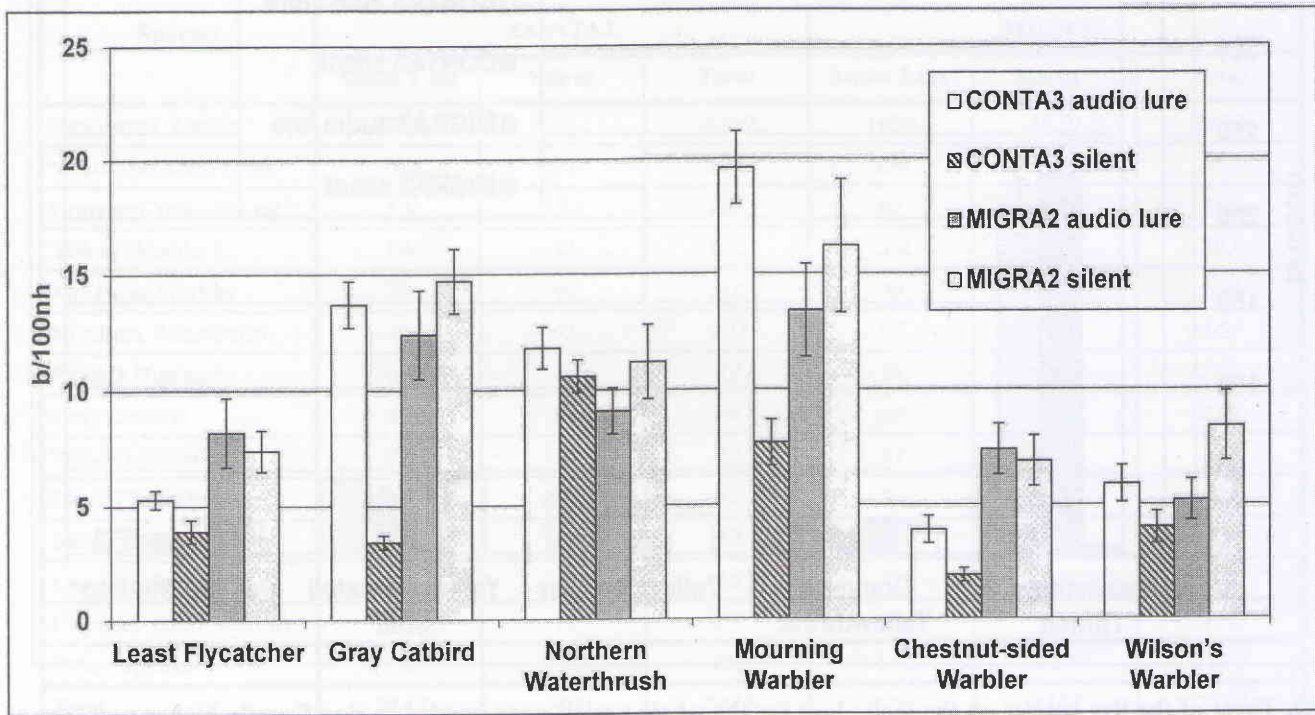
Fig. 5. Six of the 13 secies with at least 25 individuals banded were not broadcast on the audio lure, but all of them were banded more frequently at CONTA3 on audio lure days, though only two of them were marginally more numberous on those days at MIGRA2. Error bars are ± 1 SD. (An audio lure was played on all days at MIGRA2, but the data were aligned to match the same days as CONTA3.)

Table 2. Number of individuals captured, by age (second year or SY vs. after second year or ASY) and sex (female vs. male), of the five species included on the audio lure for the whole period at CONTA3, on audio lure and silent days. Yates' chi-square statistic and P value are given in parentheses. Significant results ($P < 0.05$) are in bold type.

Species	Audio Lure		Silent	
	SY vs ASY	F vs M	SY vs ASY	F vs M
Swainson's Thrush*	816,459 (99.40, **0.00**)	n/a	22, 18 (0.23, 0.64)	n/a
Common Yellowthroat	34, 34 (0,02, 0.90)	24, 44 (5.31, **0.02**)	85, 54 (6.48, **00.1**)	53, 86 (7.37, **0.01**)
Yellow Warbler	53, 34 (3.72, 0.05)	22, 52 (11.37, **0.00**)	89, 65 (3.44, 0.06)	44, 84 (11.88, **0.00**)
Yellow-breasted Chat	88.73 (1.22, 0.27)	77, 65 (0.31, 0.36)	11, 27 (5.92, **0.02**)	18, 15 (0.12, 0.73)
Painted Bunting [b]	16, 32 (4.69, **0.03**)	23. 25 (0.02, 0.89	n/a	n/a

[a] Sex was not determined for this species
[b] Sample size was too small ($N = 6$) on silent days.

Table 3. The median time between initial capture and last recapture of the 14 individuals recaptured at CONTA3 was two days.

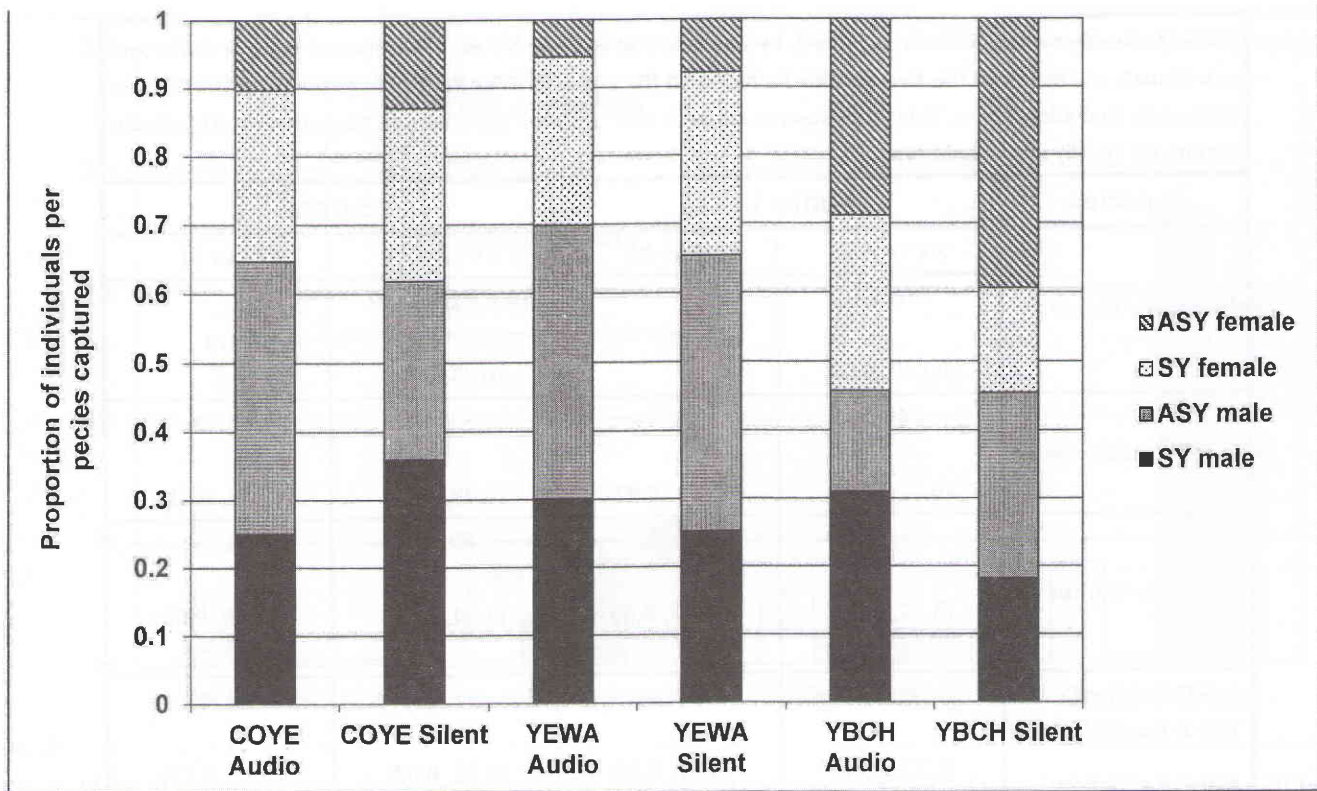| Species	No. of Individuals	Minimum Stopover Duration of each Individual (in days).
Yellow-billed Cuckoo (Coccyzus americanus)	2	1, 2
Wood Thrush	1	1
Northern Waterthrush		9
Yellow-breasted Chat	4	1,1,1,2
Common Yellowthroat	1	16
Yellow Warbler	2	6, 15
Magnolia Warbler (Setophaga magnolia)	2	4, 5
Wilson's Warbler	1	1

Fig. 6. Proportion of individuals captured, by age (second year or SY vs. after second year or ASY) and sex (female vs. male), of the four species included on the audio lure for the whole period at CONTA3, comparing audio lure and silent days. COYE = Common Yellowthroat, YEWA = Yellow Warbler, YBCH = Yellow-breasted Chat.

We found no differences in the capture rate by sex in relation to the audio lure. Males significantly outnumbered females for Common Yellowthroat and Yellow Warbler, but in both species the ratio was similar on audio lure and silent days (Table 2).

The rate of stopover was very low at both sites, even with the audio lure being played. At CONTA3, we recaptured only 14 individuals (0.5% of birds banded during the project) of eight species on subsequent days at the same site (Table 3). Minimum stopover duration ranged from 1-16 days, and the median length of time between first and last capture was two days. More than half (61%) of these individuals were banded on audio lure days, while only 43% of the recaptures were on audio lure days. The results were fairly similar at MIGRA2 despite the audio lure being played every day, with 55 individuals (0.8%) of 21 species recaptured between 1 and 22 days after banding, and median stopover duration was one day longer, at three days.

There were no mortalities and five injuries (0.17% of captured birds) at CONTA3. All were leg injuries, four of which occurred on audio lure days. During the same period at MIGRA2 there were seven mortalities (0.09%) and five injuries (0.07%), or a total of 0.16% of captured birds.

DISCUSSION

We found that the use of an audio lure had a significant effect on the overall capture rate of spring migrant passerines, which was seven-fold higher on audio lure days than on days with only passive mist netting. However, the results were highly variable among species. Swainson's Thrush showed the greatest response to the audio lure, with a capture rate nearly 70 times higher than on silent days, followed by Painted Bunting, with a capture rate 18 times higher with an audio lure. Warblers showed a mixed response, with Yellow-breasted Chat eight times and Yellow Warbler nearly three times more abundant when the audio lure was

played, while Common Yellowthroat and Hooded Warbler were marginally more numerous on silent days. However, Common Yellowthroat was similarly more numerous at MIGRA2 on silent days, suggesting that the pattern observed at CONTA3 may simply have reflected natural pulses of migration rather than avoidance of the audio lure.

It was apparent that species do not respond only to conspecific calls. Of the four species included on the audio lure for only part of the study, all were captured in higher numbers on audio lure days than on silent days, even during periods when they were not part of the broadcast. Among the six other most commonly banded species at CONTA3, the mean capture rate was, on average, twice as high on days with the audio lure, even though none of them were included on the broadcast.

Benefits of using audio lures. Our results are consistent with the literature suggesting that audio luring generally increases capture rate (e.g., Schaub et al. 1999). Where the estimate of population trends is an objective of banding programs, the statistical power required to reliably detect a change needs to be considered (Ralph et al. 2004). If the audio lure effort is standardized in a manner similar to passive capture (Dunn et al. 1997, Ralph et al. 2004), it could allow for an increase in sample sizes that would provide greater statistical power and permit trends to be calculated with greater accuracy (Steidl et al. 1997). The use of audio lures, therefore, has the potential to be valuable for species of conservation concern that typically occur in relatively low numbers, but for which accurate trend estimates are especially important for proper assessment of legal status and recovery progress (Schaub et al. 1999).

For many species, connectivity between breeding sites, migratory routes, and wintering regions remains poorly understood (Carlisle et al. 2009), but this can be enhanced through recoveries of banded birds. A higher capture rate may increase the number of encounters of foreign-banded birds. This has proven to be the case with Northern Saw-whet Owls, currently the only species in North America for which an audio lure is regularly used during migration. Between 1995 and 2015, 2.85% of Northern Saw-whet Owls banded were subsequently encountered (U. S. Department of Interior 2016). In contrast, the two most abundant species in our study, Swainson's Thrush and Yellow-breasted Chat, had encounter rates an order of magnitude lower, at 0.33% and 0.39%, respectively, during the same period (U. S. Department of Interior 2016). More widespread use of audio lures to augment capture rates could facilitate higher encounter rates for these and other species in the same way that it has for Northern Saw-whet Owls..

Concerns regarding use of audio lures. Our results reflect that the responsiveness of birds varies considerably among species, and even non-targeted species may respond positively to an audio lure (Møller 1992, Ralph 2013). Previous studies have suggested a potential for bias in sex ratios (e.g. Herremans 1989, Lecoq and Catry 2003), but among our four most abundant species, the proportion of males to females was similar for three species whether the audio lure was on or not (Table 2); unfortunately, Swainson's Thrush, the species that we captured in the highest numbers, can seldom be sexed during migration (Pyle 1997). Season of capture may also have an influence, as Lecoq and Catry (2003) studied a wintering, rather than migrating, population. However, Chin et al. (2014) found no sex or age bias in captures of Wood Thrush (*Hylocichla mustelina*) during a non-breeding season study using playback.

Brotons (2000) observed that audio luring may skew age distribution, although noting that it may vary by species, and could be influenced by weather and habitat as well. Our results reflected variability by species, with the response to the audio lure differing by age for four of the five species broadcasted throughout the study, but in various ways (Table 2). The proportion of ASY and SY Swainson's Thrushes banded on silent days was nearly equal, but on audio lure days the number of SY birds banded was nearly double the ASY total. SY Yellow-breasted Chats also seemed more attracted to the audio lure, given that they were similar in abundance to the older ASY birds on

audio lure days, but significantly outnumbered by them on silent days. Conversely, we banded the same number of SY and ASY Common Yellowthroats on audio lure days, but on silent days there were significantly more SY individuals, suggesting that they may have been deterred by the broadcast. In the case of Painted Bunting, twice as many ASY birds were banded on audio lure days as SY birds, but too few were banded on silent days to compare ratios. However, this may reflect differential timing in migration, as OAPSA data from subsequent years show our study period ended before the peak of SY Painted Bunting migration.

It is important to note that even during passive mist-netting, sex and age ratios may vary at spring stopover sites or in arrival times at breeding sites (Hussell 2004), with males usually arriving before females (e.g., Francis and Cooke 1986), and older birds before younger ones (e.g., Stewart et al. 2002), although this varies somewhat by species. The relative abundance of species can also vary with location in passive mist-netting (Remsen and Good 1996). These sampling influences warrant further study to determine whether the difference in capture rate is truly indicative of audio lure influence (e.g., are young birds more attracted to stopover where there appears to be others of their species?), or migration timing (we may have missed a pulse of one age class), or migration route (different age classes may use different migration routes). While there may be biases, data from audio luring studies could be compared with passive capture efforts with some caution, and with multiple years of monitoring, it may be possible to derive appropriate correction factors.

Concerns have been raised that audio lure broadcast may prompt migrants to shorten the distance they migrate on a given night and could result in them staying for a day in habitat that may be sub-optimal for food and/or shelter (Harper 1994, Schaub et al. 1999). This is unlikely to be the case for OAPSA, since most species were recorded on silent days as well as audio lure days. The practice at OAPSA has been to start the audio lure at 0200, to allow migrants time to leave at sunset. Some

European banders who employ an audio lure as part of their migration monitoring programs are permitted to play the lure for only 1.5 h before local sunrise, intended to reduce the perceived risk of birds interrupting their migration prematurely (C. Baudoin, pers. comm.). Other studies targeting certain species, such as Eurasian Reed-Warblers (*Acrocephalus scirpaceus*), have played audio lures either starting one hour after sunset (Schaub et al. 1999) or starting at sunset (Bulyuk et al. 2000, Henry et al. 2014) and continuing throughout the night. Guidance on timing does not appear to be empirically based, and further research on this topic is highly encouraged.

There is generally a high turnover of individuals during migration (e.g., Kaiser and Berthold 2004), though recapture rates at some sites are relatively high (e.g., 5%, Bonter et al. 2007; 3.6-5.7%, Suomala et al. 2012; 3-12%, Kuenzi and Moore 1991). Our recapture rate of 0.5% at CONTA3 and 0.8% at MIGRA2 suggests that the audio lure did not influence many individuals to stay in the area beyond the one night of induced landfall, but we do not know whether the birds stopped earlier than they would have without being lured and therefore their refueling requirements were not as high as if they had flown all night, or if the short stay was related to habitat quality. Of the three species that stayed the longest (Table 3), Northern Waterthrush and Yellow Warbler are known to be common winter residents in the lowland areas of Mexico (Howell and Webb 1995), and Common Yellowthroat is also known to overwinter at OAPSA. It is possible these were local birds rather than migrants passing through the site. Conclusions about stopover ecology using data from audio lure projects should be interpreted with caution, taking potential biases into consideration (Arizaga et al. 2015).

Although the rates of injuries and mortalities in banding are generally low (Spotswood et al. 2011), they nonetheless occur, and there may be concerns that the probability of injury or mortality increases when large numbers of birds are captured in a short period of time, as can be the case when using an audio lure. This risk can be substantially mitigated through

ensuring operations are managed by an experienced banding team that works within its capacity (Spotswood et al. 2011), and reduces net effort as necessary to keep capture numbers manageable; banders should consider the recommendations of Mackenzie and Gahbauer (2014) and Grosselet et al (in review) for safely managing large volumes of birds. The casualty rates at both stations in our study were well below the average injury rate of 0.59% and mortality rate of 0.23% reported by Spotswood et al. (2011). However, if effort frequently needs to be scaled back for the sake of safety, the implications of this on standardization of monitoring would need to be considered (Thomas et al. 2004). In our estimation, the use of an audio lure can be effective in increasing the capture rate of Neotropical migrants, both target species being broadcast and others, although the degree of response appears to vary considerably among species. Audio lures may be valuable where higher capture rates can increase the power of trend estimation, but the appropriateness of this technique should be determined on a case-by-case basis, taking into consideration all potential risks and evaluating biases, including effects on standardization. Further studies should explore additional target species, including rare species, to improve our understanding of audio lure effectiveness. Replicating this work in different locations would help assess variability in response of individual species. More research is also needed to assess length and timing of broadcast so that protocols can be standardized and sample sizes optimized.

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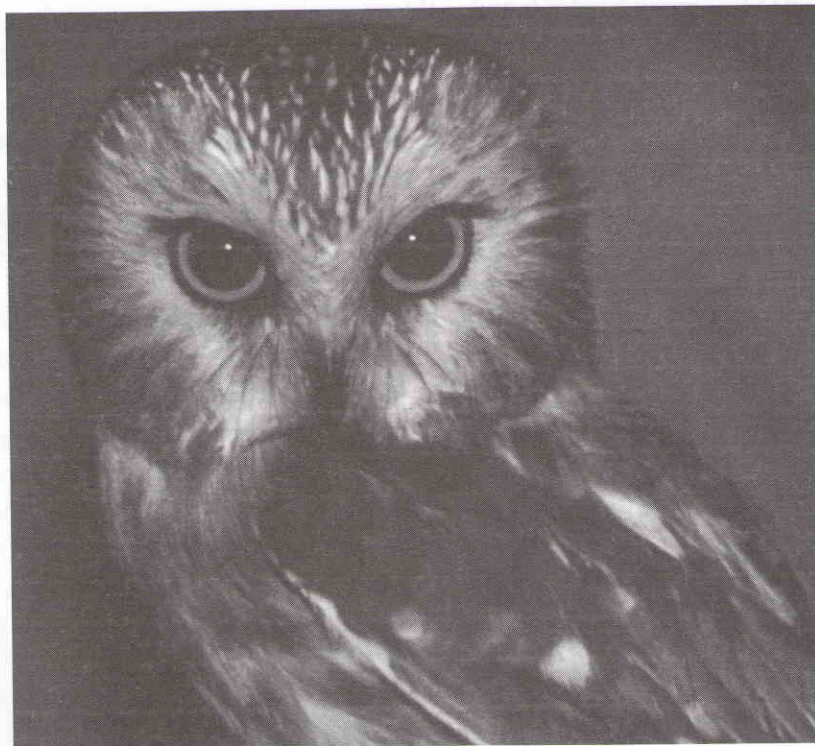
Northern Saw-whet owl
photo by R. Pantle