SHORT COMMUNICATIONS

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DIFFERENT AUDIO-LURES LEAD TO DIFFERENT SEX-BIASES IN CAPTURE OF NORTHERN SAW-WHET OWLS (*AEGOLIUS ACADICUS*)

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ABSTRACT.—Northern Saw-whet Owls (*Aegolius acadicus*) are banded across the United States, yet neither migration nor dispersal of Northern Saw-whet Owls are fully understood. In spring of 2007 and 2008, the banding station at Whitefish Point Bird Observatory in Michigan's Upper Peninsula began broadcasting male and female (respectively) audio lures at dedicated net arrays to complement the passive mist netting performed since 1994. We analyzed data from spring owl captures (1994–2016) that used either male "advertising call" audio lures, female "tssst" audio lures, or no audio lures. From the analysis of 6659 owls captured during that period, we found that (1) there was a substantial female-bias in the owls caught at the passive and male audio lure nets, (2) a more extreme female-bias in the owls caught at the male audio-lure nets than the passive nets, and (3) a nearly equal proportion of male and female owls caught at the female audio-lure nets. These results corroborate a model of differential migration, in which females compose a larger portion of migrating Northern Saw-whet Owls than males. We also found that audio lures that use female calls can increase relative capture rates of male Northern Saw-whet Owls during spring migration.

KEY WORDS: *Northern Saw-whet Owl*; Aegolius acadicus; *audio lure*; *banding station*; *migration*; *sex-bias*.

DIFERENTES RECLAMOS AUDITIVOS LLEVAN A DIFERENTES SESGOS SEXUALES EN LA CAPTURA DE *AEGOLIUS ACADICUS*

RESUMEN.—*Aegolius acadicus* es anillado en todos los Estados Unidos, sin embargo la migración y la dispersión de esta especie son poco conocidas. Durante la primavera de 2007 y 2008, la estación de anillamiento en el Observatorio de Aves Whitefish Point en la península superior de Michigan comenzó a emitir reclamos auditivos para atraer machos y hembras a sitios con redes de niebla desplegadas para completar los censos pasivos con redes llevados a cabo desde 1994. Analizamos los datos de captura en primavera de búhos (1994–2016) atraídos por audios de "reclamos de alarma" de machos, audios de "tssst" de hembras, o sin la utilización de audios. Del análisis de 6659 búhos capturados durante este periodo, encontramos que hubo (1) un sesgo sustancial hacia las hembras en los búhos capturados en las redes pasivas y en las redes con reclamos auditivos de machos, (2) un sesgo más extremo hacia las hembras en los búhos capturados en las redes con reclamos auditivos de machos que en las redes pasivas, y (3) una proporción casi igual de búhos machos y hembras capturados en las redes con reclamos auditivos de hembras. Estos resultados corroboran un modelo de migración diferencial, en el que las hembras componen una proporción mayor de individuos migratorios de *A. acadicus* que los machos. También encontramos que los reclamos auditivos que utilizan cantos de hembras pueden aumentar las tasas de captura relativas de machos de *A. acadicus* durante la migración de primavera.

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Northern Saw-whet Owls (*Aegolius acadicus*) have been banded since the 1960s, yet many aspects of their demography, dispersal, and migratory behavior require more study (Rasmussen et al. 2008). The first two decades of saw-whet owl banding efforts were stymied by relatively low capture rates (Whalen and Watts 1999), but in 1986, the playback of the Northern Saw-whet Owl male "advertising call" was developed and tested as an audio lure for attracting saw-whet owls into mist nets (Erdman and Brinker 1997). Their use notably increased the number of birds captured. Today the practice of broadcasting audio lures is widespread across saw-whet owl banding stations in the western Great Lakes region (Erdman and Brinker 1997) and across North America.

Historically, raptor banding stations have captured female Northern Saw-whet Owls at higher rates than males (Duffy and Matheny 1997, Beckett and Proudfoot 2012), whether capture was through passive mist netting, or through use of a male "advertising call" audio lure. Although the use of the male "advertising call" audio lure dramatically increased capture rates of saw-whet owls, it also exacerbated the female sex-bias in captures. Most banders use a morphologically based discriminant function analysis (DFA: Brinker et al. 1997, Brinker 2000) to determine the sex of saw-whet owls in the hand when genetic tools are unavailable, although one thorough study (Beckett and Proudfoot 2012) showed that owls classified as "unknowns" by the DFA may be more male-biased than the rest of the sampled owls. These biases continue to confound demographic models of migrating and breeding birds, and better documentation of male saw-whet owl movements will potentially aid in understanding these population dynamics.

From 1994–2007, the banding station at Whitefish Point Bird Observatory (WPBO) used passive capture mist nets, but since 2007 a subset of nets have been used with a male "advertising call" as an audio lure (henceforth "male-call audio lure"). In 2008, a second subset of nets was dedicated to the use of an audio lure that broadcasted the female "tssst" call (Rasmussen et al. 2008), a call given only by female saw-whet owls in pre-copulatory dueting with males (henceforth "female-tssst" audio lure). Although associated with mating, we have regularly observed females using this vocalization on spring migration (C. Neri and N. Mackentley unpubl. data). Here we present an analysis of sex ratios of birds caught at audio-lure nets and at passive nets. We predicted that the presence and type of audio lure has a significant effect on the proportion of male and female saw-whet owls caught in mist nets.

METHODS

Capture and Banding of Owls. From 1994 to 2016, Northern Saw-whet Owls were captured at WPBO (approximately 17 km north of Paradise, Michigan, USA) during spring migration using standard mist-netting procedures. From 1 April–31 May in 1994–2006 banding was conducted nightly, weather permitting. Beginning in 2007, the start date was moved to 15 March. Nightly banding operations began 30 min after sunset and ended 30 min prior to sunrise, with net checks made at 45-min intervals. Various net sizes were used for different species within the study area, but 12-m nets with 61-mm mesh and four pockets were used for the targeted capture of saw-whet owls. Net locations varied slightly due to annual variations in snow and standing water in the spring. Starting in 2007, a male "advertising call" was broadcast as an audio lure at five nets, and in 2008 the female "tssst call" was broadcast as an audio lure at two nets. Captured owls were banded with USGS aluminum bands in the lab. Mass, wing chord, and other morphological characters were measured. Mass and wing chord were used with the Brinker et al. (1997) discriminant function to determine the sex (male, female, or unknown) of each individual. Audio lures of Boreal Owl (*Aegolius funereus*) and Long-eared Owl (*Asio otus*) were used at other nets in our study area, but we did not include saw-whet owls captured at those nets in the analyses presented here. All nets (including audio-lure nets and passive nets) are within a 100-m radius of one another.

Tests of Annual Biases: We compiled the numbers of males, females, and individuals of unknown sex for each year and sorted them by net type (passive, male-call audio lure, female-tssst audio lure). The null expectation was that there would be parity of the sex ratio of known-sex birds captured at all net types. We tested this expectation by comparing ratios of known males and females, but excluding those classified as "unknown" sex by the discriminant function ("DF-unknowns"). We also further tested potential bias by distributing the DF-unknown birds between males and females, assuming the same ratio reported by Beckett and Proudfoot (2012): 92 unknown-sex birds genetically determined to be 36 males and 56 females. We compared observed and expected values of the proportion of males captured using the chi-square goodness-of-fit test (expected proportion of males = 0.5). Alpha-levels of significance were Bonferroni-corrected to account for each year serving as a test of sex-biased capture at the passive, male-call, and female-tssst nets.

Tests of Audio-lure Effects: To test the effect of audio lures on sex-biased capture rates, we performed two-tailed paired *t*-tests comparing the proportion of males caught in passive nets with the proportion of males caught in male-call audio-lure nets in the years 2007–2016. We similarly compared the proportion of males caught in passive nets to the proportion of males caught in the female-tssst audio-lure nets from 2008–2016. To test whether the presence of audio lures affected the overall sex ratio of birds captured while migrating in the area, we performed a two-tailed two-sample *t*-test (assuming unequal variances) comparing the proportion of males caught in passive nets in the years from 1994–2006 (no audio lures on site) to the proportion of males caught in the passive nets in the years from 2007–2016 (audio lures present at other nets).

Table 1. Capture numbers of Northern Saw-whet Owls classified to sex (male, female, unknown) based on the Brinker (2000) Discriminant Function, by net types at nets with no audio lures ("Passive"), with male advertising call audio lure ("M-call") and female 'tssst' call audio lure ("F-tssst"). Values listed in bold represent statistically significant sex-biases in the direction of the bolded sex.

	PASSIVE			M-CALL			F-TSSST			TOTAL
YEAR	NO. ♂	NO. ♀	NO. UNK	NO. ♂	NO. ♀	NO. UNK	NO.♂	NO♀	NO. UNK	NO.
1994	2	5	8	-	-	-	-	-	-	15
1995	4	**30**	22	-	-	-	-	-	-	56
1996	14	13	8	-	-	-	-	-	-	35
1997	3	3	7	-	-	-	-	-	-	13
1998	21	**54**	16	-	-	-	-	-	-	91
1999	14	**63**	10	-	-	-	-	-	-	87
2000	28	**58**	22	-	-	-	-	-	-	108
2001	17	**46**	28	-	-	-	-	-	-	91
2002	9	12	4	-	-	-	-	-	-	25
2003	9	15	7	-	-	-	-	-	-	31
2004	16	**50**	16	-	-	-	-	-	-	82
2005	16	**50**	16	-	-	-	-	-	-	82
2006	12	**51**	18	-	-	-	-	-	-	81
2007	15	**65**	14	39	**565**	52	-	-	-	750
2008	24	22	24	104	**495**	137	74	50	78	1008
2009	13	29	14	34	**331**	51	31	27	39	569
2010	5	12	9	56	**387**	74	12	19	22	596
2011	7	22	9	55	**492**	92	28	10	15	730
2012	6	20	9	33	**439**	51	30	22	47	657
2013	23	39	14	32	**444**	79	47	60	54	792
2014	2	5	3	7	**117**	8	16	17	22	197
2015	1	2	1	9	**169**	20	7	10	6	225
2016	3	12	4	8	**247**	17	6	**24**	17	338
All years	264	**678**	283	377	**3686**	581	251	239	300	6659

RESULTS

From 1994–2016, we captured 6964 Northern Saw-whet Owls in spring at WPBO. The 294 saw-whet owls captured at the nets with a Boreal Owl audio lure (2007–2016) were omitted from our analyses, as were the seven saw-whet owls captured at nets with a Long-eared Owl audio lure (2015–2016). We also omitted another 11 saw-whet owl records for which morphological data were missing. Of the remaining 6659 saw-whet owls analyzed, we used the DFA to classify 4603 as female and 892 as male saw-whet owls; 1164 (17.5%) individuals were classified as unknown sex by the DFA. During the passive-effort years 1994–2006, we trapped an average of 4371 ± 1073 net-hours/yr. Beginning in 2007 (earlier start date, additional nets at the audio-lure sites), the trapping efforts increased to an average of 7554 ± 2328 net-hours/yr.

In 9 of the 23 yr of banding, there was a significant female-bias in captures at the passive nets ($P < 0.002$), and in only two years (1996, 2008) were more males than females captured at passive nets. The aggregate sex ratio calculated across all years (226 males / 904 total birds, 0.25, Table 1) was significantly female-biased ($P < 0.002$). Nets associated with the male-call audio lure showed strong female-bias in each year (male owls never composed more than 17% of captures at these nets in any year), and across all years when considered in aggregate ($P < 0.005$). Captures at nets broadcasting female-tssst audio lure were not significantly different from parity in any year (nor in the aggregate), except in 2016 when there was a significant female-bias in captures ($P < 0.006$). When we artificially distributed all DF-unknowns from each year to males and females caught in those years, according the ratio documented by Beckett and Proudfoot (2012), there was no change in the significance of the biases in any year (or in the aggregate) across any treatment, although *P*-values changed slightly (Table 1).

The average proportion of males caught in passive nets (0.30 ± 0.10) was significantly higher than the average proportion of males caught in the male-call audio-lure nets (0.08 ± 0.04; $P < 0.001$) in 2007–2016. The average proportion of males caught in passive nets (0.31 ± 0.10) was significantly lower than the average proportion of males caught in the female-tssst audio-lure nets (0.49 ± 0.15; $P < 0.001$)) in 2008–2016. The average proportion of males caught in passive nets (0.25 ± 0.11) before use of

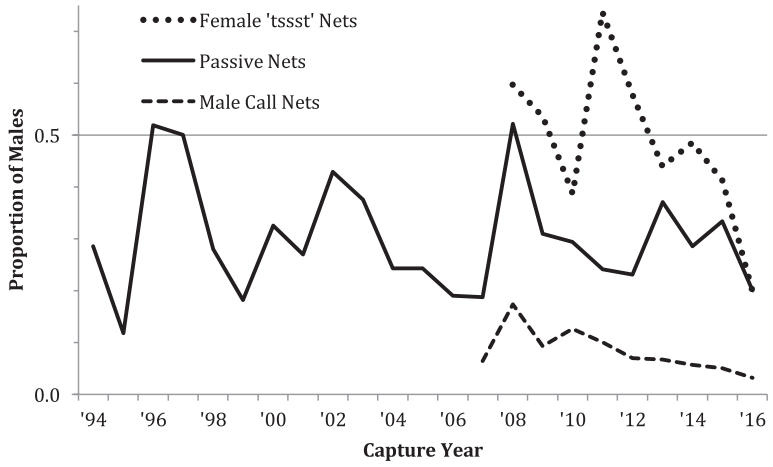

Figure 1. Proportion of male Northern Saw-whet Owls captured from 1994–2016 in passive nets, male-call audio-lure nets, and female-tssst audio-lure nets. The gray line at 0.5 represents the expected proportion of males if the sex ratio were at parity (1:1).

audio lures (1994–2006) did not differ significantly from the same measure (0.30 ± 0.10; $P > 0.3$) in the years during use of audio lures (2007–2016).

DISCUSSION

As is common at banding stations that capture Northern Saw-whet Owls, the overall captures at WPBO were significantly female-biased. Although the use of a male advertisement call as an audio lure dramatically increased overall capture rates (see Table 1), the male-call audio lure also made the female sex-bias in capture statistics more pronounced (Fig. 1). These observations are not unique to WPBO, as they have been documented at other sites that use passive nets and male advertising calls as audio lures (Beckett and Proudfoot 2012). Although it is logical that females would be preferentially attracted to the male advertising call (especially during spring), the general female-bias in sex ratios—passively caught or audio lured—remains an unexplained puzzle of Northern Saw-whet Owl life history (Rasmussen et al. 2008).

To our knowledge, WPBO is the first banding station to use a female "tssst" call as an additional audio lure. Although this audio lure did not lead to the capture of more males than females, it did dramatically bring the sex-bias of capture rates closer to parity (1:1). We hypothesize that this is due to males being preferentially attracted to the female's solicitous "tssst" call, but males likely still represent a smaller proportion of birds migrating past our study site. The relatively thin, weak quality of the tssst call does not broadcast as well as the male call, and this may partly explain the diminished overall capture rate at the female-tssst audio lure when compared to that of the male-call audio lure (C. Neri unpubl. data).

Given our results, researchers interested in attracting a more equal sex ratio of male and female saw-whet owls should consider using female "tssst" calls as audio lures at some nets, in addition to nets that use the male audio lure. The fact that the use of a female solicitation call only brought sex-ratios of captured owls near parity, rather than resulting in a male-biased sex ratio, further supports a model of differential migration in Northern Saw-whet Owls, in which females are more likely to migrate than males (Brinker et al. 1997, Beckett and Proudfoot 2012). However, we note that a stronger test of the differential migration model would include documenting movements of both female and male saw-whet owls in breeding ranges during nonbreeding periods. Our technique provides an improved method to preferentially capture males for this type of study. Another future potential test of the differential migration model would entail deploying a more expansive array of the quieter female-tssst calls at banding stations to provide an attracting stimulus that is more comparable to the stronger, more pervasive quality of the male-call.

Although the widely used morphology-based discriminant function (Brinker et al. 1997, Brinker 2000) is an improvement over body mass alone for determining the sex of birds in the hand, we found that significant numbers of captured saw-whet owls were classified as undetermined sex (17.5% of 6621 birds captured from 1997–2016) according to the DFA. Beckett and Proudfoot (2012) showed that relying solely on the discriminant function can lead to a preferential over-assignment of genetically male birds to the "unknown" class. In their analyses, the genetically determined sex ratio was still significantly female-biased (approximately 1:6), but not as biased as indicated by the morphologically based sex ratio (approximately 1:14). We recognize that the captured individuals of undetermined sex at WPBO might have been similarly male-biased, and it

may be that the female-tssst call at some nets lured even more males, which were also likely to be classified as unknowns. Consistent with that possibility, we note the percentage of captured DF-unknowns varied from 12.5% at the male-call nets to 23.8% at the passive nets to 38.0% at the female-tssst nets (Table 1). Genetic determination of the sex of DF-unknowns attracted to the three different types of nets would be necessary to find a more accurate estimation of the sex-bias of the birds attracted to the female-tssst audio lure; it may be more male-biased than we were able to diagnose.

Although the overall sex bias, or the sex bias in any individual year, might not have been as dramatically female-biased as our data indicate, that does not compromise our documentation of a dramatic shift in that bias to near parity (or possibly male-biased) in response to the female-tssst audio-lure presentation. We encourage other raptor banding stations to use the female "tssst" call to increase male capture rates, which will hopefully lead to a more comprehensive understanding of Northern Saw-whet Owl migration, demography, and life history.

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