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Original Article

Using a "Sonic Net" to Deter Pest Bird Species: Excluding European Starlings from Food Sources by Disrupting Their Acoustic Communication

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ABSTRACT Pest avian wildlife is responsible for substantial economic damage every year in the United States. Previous technologies used to deter starlings have generally failed because birds quickly habituate to startle regimes. In this study, conducted from May to July 2013, we focused on altering the foraging behavior of the European starling (*Sturnus vulgaris*), a pest bird that is responsible for crop losses and also poses notable risk for bird–aircraft strikes. The goal of our project was to develop an effective system to limit starlings' use of a food patch. Using nonlinear ultrasonic parametric arrays, we broadcast a directional sound that overlapped in frequency with starling vocalizations and was contained in a specific area, creating a "net." We hypothesized that the "sonic net" would disturb acoustic communication for starlings, causing them to leave and feed elsewhere. Using wild-caught starlings in a large aviary, we deployed the sonic net over one food patch while leaving another food patch unaltered, and assessed their presence and feeding for three consecutive days. The sonic treatment decreased starlings' presence at the treated food patch, on average by 46%. Additionally, we assessed whether the sonic net disrupted the birds' response to an alarm call. When under the sonic net, starlings did not respond to the alarm call, suggesting that the sonic net disrupted acoustic communication. The sonic net is a promising new method of decreasing foraging activity by pest bird species. © 2015 The Wildlife Society.

KEY WORDS acoustic masking, alarm call, bird strike, deterrent, noise pollution, parametric array, predation risk, starling, *Sturnus vulgaris*.

Agriculture, manmade structures, and the aviation industry suffer losses because of destruction and hazard caused by birds (Pimentel et al. 2000). For example, conservative estimates suggest that damages and delays following bird strikes cost the aviation industry and its insurers US$ 1.2 billion/year (Allan 2006). Such economic impacts do not account for loss of life, which can also result from birds striking aircraft (Linz et al. 2007). The annual economic costs due to the overall damage caused by pest birds has been estimated at US$ 1.9 billion in the United States (Pimentel et al. 2005).

Numerous technologies have been developed to deter pest birds from socio-economically important areas, most of which use species-specific alarm calls, predator calls, live predators, or loud noises such as those produced by propane exploders or pyrotechnics (Bomford and O'Brien 1990). Although initially effective, these technologies undergo dramatically diminished success rates within a few days or even hours of exposure because of quick habituation (Bomford 1990, Bomford and O'Brien 1990, Belant et al. 1998), which makes these devices neither effective nor economically sustainable for a long-term application (LeMieux 2009). Making long-term physical habitat changes to exclude birds is not a preferred solution because of the high environmental costs (Blackwell et al. 2009*a*). Direct control, such as trapping and euthanizing large numbers of pest birds to protect agricultural and industrial structures, has little to no impact on the overall pest population (Homan et al. 2005). Chemically applied deterrents such as methyl-anthranilate can deter certain pest bird species but can also be washed away with rain and irrigation (Werner et al. 2005) and thus require repeated treatments depending on the season and crops treated. Therefore, this form of bird deterrence can be expensive to

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maintain and can result in chemical residues on crops and in runoff water (Aronov and Clark 1996). Avicides such as DRC-1339 (3-chloro-4-methylaniline hydrochloride) can reduce pest bird populations through direct culling (Homan et al. 2005, 2013) but can also affect nontarget species (Avery et al. 1998, Linder et al. 2004).

An integrated understanding of birds' sensory ecology and associated behaviors can aid the development of effective and sustainable methods of pest bird exclusion (Blackwell et al. 2009*a*, *b*). Specifically, we studied the European starling (*Sturnus vulgaris*) as a model pest bird and report experiments in which we manipulate the acoustic environment of these birds so as to mask acoustic communication and displace flocks of starlings from food sources in captive aviaries. In agriculture, European starlings have been estimated to cause US$ 800 million of damage per year (Pimentel et al. 2005). Because these birds often roost and feed in large numbers near airports they also pose a substantial risk for aircraft (Linz et al. 2007). Therefore, there is societal interest in displacing flocks of European starlings.

European starlings use vocal communication for mating calls, territorial defense, and to indicate the quality and location of food or to warn of approaching predators (Feare 1984). In other species, if environmental noises overlap with the frequency (i.e., acoustic pitch) range of bird communication, the birds exposed to noise often suffer fitness deficits (Klump 1996, Brumm and Slabbekoorn 2005, Barber et al. 2010, Kight and Swaddle 2011, Kight et al. 2012); this is likely because vocalizations are acoustically masked by noise and birds cannot hear each other effectively (Wiley 2006). Importantly, we also know that environmental noise that overlaps with avian communication can displace some bird populations and restructure ecological communities (Francis et al. 2011).

Here we build on these observations and employ a noise that is designed to overlap with European starling vocal communication and investigate whether a spatially controlled introduction of this noise, which we term a "sonic net," effectively displaces starlings from a food source and also prevents starlings from responding to an alarm call playback. By applying our sonic net to one food source and not the other in a large outdoor aviary over 3 consecutive days, we examined whether this type of controlled sound can displace flocks and lessen the amount of food eaten. We hypothesized that starlings would be deterred from feeding at the food patch affected by the sonic net. We also investigated whether our sonic net reduced starlings' response to an alarm call playback. We hypothesized that the 2- to 10-kHz sound would mask perception of the alarm call, leading to a relative lack of increase in vigilance behaviors when the alarm call was played.

STUDY AREA

The study took place in outdoor aviaries at the College of William and Mary, Williamsburg, VA, USA.

METHODS

Subjects and General Housing

Seventy wild-caught adult European starlings, trapped during February 2013, were housed in 10 flocks of 7 birds in large outdoor cages (3 m × 2.5 m × 2 m) with *ad libitum* access to nutritionally complete food (Bartlett Milling Co., L.P., Statesville, NC), drinking water, and perches. The aviary complex was on a remote part of the William and Mary campus and birds were generally only disturbed by animal care and research staff. The housing cages were visually and acoustically isolated from the experimental aviary. We identified the sex of all birds and applied numbered and colored leg bands for easy identification. The College of William and Mary Institutional Animal Care and Use Committee approved the use of vertebrate animals in this study (IACUC-2012-11-23-8173-jpswad).

Creation of a Sonic Net

To create our "sonic net," we employed ultrasonic parametric arrays to produce a highly directional beam of sound in the 2- to 10-kHz range at an amplitude of approximately 80 dB sound pressure level (SPL) at the food sources (Dieckman et al. 2013). Conventional loudspeakers emit sound in a nondirectional way (Gan et al. 2012). However, ultrasonic parametric arrays transmit a highly directional sound beam much like a spotlight (Yoneyama et al. 1983, Pompei 1999, Gan et al. 2012). The beam starts out as a mixture of 2 ultrasonic frequencies. A nonlinear conversion interaction between the sound waves results in an audible sound that is the difference between the 2 ultrasound frequencies and that remains highly directional.

Aviary Experiment

Each experimental trial was performed on one flock of 6 birds at a time (out of the 7 in a cage, leaving 1 extra bird in case of injury) from May to July 2013. Prior to an experimental trial, the birds were food-deprived for 2 hr to encourage foraging behavior (Devereux et al. 2006, Quinn et al. 2006). Experiments took place when there was no rain and <16 km/hr winds because the interaction of rain and wind with the aviary roof created loud artificial noise that would hinder experiments.

Each flock was introduced to the experimental aviary (Fig. 1; a U-shaped aviary comprising two end cages approx. 3 m × 6 m × 2.5 m connected by a long corridor aviary approx. 3 m × 7.5 m × 2.5 m) 24 hrs prior to the beginning of a noise treatment sequence to acclimate to the aviary (Fig. 2). Each treatment day started at 0900 hours and ended at 1700 hours. The experimental aviary was a long U-shaped cage where the birds could access a food patch at both ends, and where the food patches were connected by a long area that contained only water. Hence, birds had to feed either at patch A or patch B (Fig. 1). In the 8-hr trials, birds had sufficient time to feed at both ends of the aviary and were always observed to feed at both ends on their acclimation day (i.e., before sonic net exposure). At the beginning of every day, including experimental trial days, we placed 500 g of

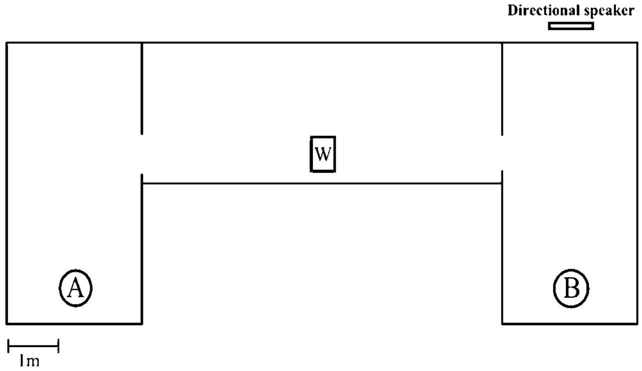

Figure 1. Plan view of the aviary experimental area, where we analyzed influence of the sonic net on captive starling flocks, from data collected from May to July 2013. Circles (A) and (B) indicate food patches. Rectangle (W) indicates water dish.

food in a standardized tray at both patch A and B. The tray was large enough to catch food spilled by the birds.

On the day following the acclimation day, we performed a baseline trial (Day 1) where a flock of birds was not exposed to any additional noise (i.e., the sonic net) at either patch A or B. We recorded the birds' presence and foraging using a 4-camera closed-circuit television system (Lorex, Inc., Markham, ON, Canada). From these recordings we counted the number of birds at both patch A and B every 5 min of the 8-hr trial and also recorded whether the birds were feeding. We also measured the mass (g) of food eaten from patches A and B. On the next day we commenced a series of 3 noise-treatment days in which one of the food patches (A or B) was affected by the presence of a sonic net. This sonic net was produced by broadcasting a noise in the 2- to 10-kHz range at approximately 80 dB SPL using an MP3 player connected to an Audiospotlight parametric array speaker (Holosonics, Watertown, MA). High-amplitude broad-frequency noise may mask important signals that birds might be transmitting (Swaddle et al. 2006). The high directionality of the noise produced by the parametric array allowed us to fill side A or B with noise without any noise leakage to the opposite side, which was confirmed by sound recordings at patches A and B.

For half of the flocks (randomly determined), we applied the sonic net at patch A on Day 2, patch B on Day 3, and patch B again on Day 4 (i.e., an ABB pattern; Fig. 2). For the other flocks, we applied the sonic net at patch B on Day 2, patch A on Day 3, and patch A again on Day 4 (i.e., a BAA pattern; Fig. 2). This sequencing allowed us to control for side-bias among the groups of starlings. We placed a visually similar mock speaker on the quiet side to control for the visual presence of a speaker. As for the baselines trial, we used the closed-circuit television system to record the presence and foraging behaviors of the birds in each of the noise treatment trials and we also measured how much food was eaten at patches A and B.

Analysis 1: Aviary experiment.—We recorded a bird as present if it was perched, on the ground, hanging on the side of the aviary, or foraging. A bird was recorded as foraging if it was feeding or sitting in the provided food dish. We calculated the amount of food consumed in the 8-hr trials by subtracting the weight of food remaining in the food dish at the end of the trial (after removal of feces) from the initial 500 g provided on each side. We tested whether the 2- to 10-kHz sonic net affected the presence of starlings, the feeding behavior of birds, and the amount of food eaten with repeated-measures analysis of variance (ANOVAs) with both the treated side of the aviary and day of the experiment as within-subjects independent variables. We also explored whether the effectiveness of the sonic net on birds' presence and feeding changed over the 3 days of the experiment by examining the interaction of the sonic net treatment with day of the experiment (treatment × day interaction).

Alarm Call Experiment

We also performed a captive experiment to test whether starling responses to a broadcast conspecific alarm call were lower in the presence of a sonic net. Experimental trials where we assessed birds' change in vigilance in response to an alarm call were conducted on 18 groups of 3 randomly chosen starlings (no birds were tested more than once) from August to October 2013. The groups of 3 birds were placed in a small cage (0.9 m × 0.75 m × 0.4 m) 24 hr prior to the trials to acclimate to the experimental cage setting with *ad libitum* food and water. Birds were food-deprived on experimental days for 1 hr prior to the trials to encourage feeding behavior. In the experimental cage, we provided the group with 2 small water dishes and a small food dish with their standard food. We placed mealworms in a sand tray below the mesh cage bottom. The mealworms were able to burrow in the sand, which motivated the birds to probe to locate them and thus

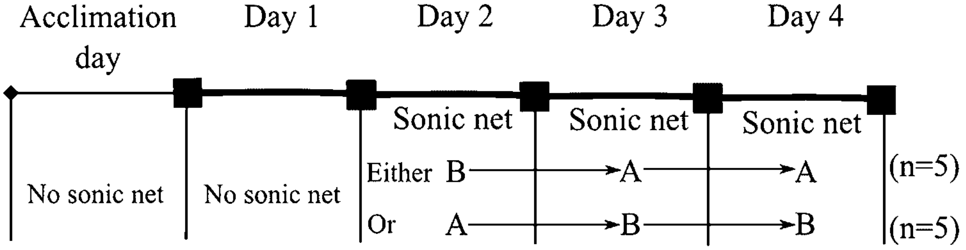

Figure 2. Schematic of the aviary experiment, wherein we analyzed influence of the sonic net on captive starling flocks, from data collected from May to July 2013. (A) and (B) indicate food patches (Fig. 1). For half of the flocks, the sonic net was applied in a BAA treatment sequences whereas the other half of the flocks were subject to an ABB treatment sequence. Both sequences were preceded by an aviary acclimation day and a reference day with no sonic net treatment.

feed frequently. The parametric array speaker was placed 4 m away, and the same 2- to 10-kHz noise used in the aviary experiment was broadcast at 80 dB SPL.

To start each experiment, we gave a group of birds 5 min to acclimate and then applied a 2-treatment sequence. Nine of the 18 experimental flocks experienced a treatment sequence that started with a quiet control treatment followed by the sonic net treatment, whereas the remaining 9 flocks experienced a treatment sequence that began with the sonic net treatment and was followed by a quiet control treatment. This alternation in treatments allowed us to control for the effects that the order of the treatments could have had on the behavioral response of the birds. Each treatment lasted 10 min and at the end of the first 5 min of each treatment, we played a 2-s alarm call three times in quick succession (Fig. 3). The broadcast starling alarm-call spectrogram was within the 3- to 9-kHz range (Feare 1984) and thus would be masked by the overlapping 2- to 10-kHz range sonic net. The alarm call was broadcast using nondirectional speakers placed 1 m from the experimental cage and was also broadcast at 80 dB SPL relative to the center of the birds' cage.

The 2- to 10-kHz sonic net could also have altered the birds' behavior simply because it was a loud sound rather than specifically masking the perception of the alarm call; therefore, we also tested 14 flocks under a white noise broadcast in the 0.1- to 2-kHz range at 80-dB SPL using the same treatment sequence. The lower frequency range sound was not predicted to mask perception of the alarm call but could have caused nonspecific alterations of vigilance behavior because of the presence of a loud noise. The experimental design was the same as in the sonic net trial described above except that we had a smaller sample size, which allowed for 7 of the 14 experimental flocks to experience a treatment sequence that started with a quiet control treatment followed by the sound treatment while the remaining 7 flocks experienced a treatment sequence that began with the sound treatment followed by a quiet control treatment.

Analysis 2: Alarm call experiment.—We analyzed video from each trial for vigilance of the individual birds. We analyzed snapshots of the 60 s preceding the alarm call in each treatment and of the 60 s following the alarm call in each treatment for presence of vigilance behavior. We quantified a vigilant bird as having its head above body level or perched on the side of the cage (Quinn et al. 2006).

In the 2 alarm-call experiments, we explored whether the birds' vigilance response to the playback of an alarm call was influenced by the presence of a sonic net (either at 2–10 kHz or at 0.1–2 kHz) by using a repeated-measures ANOVA with both alarm call (precall compared with postcall) and sonic net (presence compared with absence) as within-group independent variables and percentage of time vigilant as the dependent variable. We further examined the relative effects of the alarm call on the vigilance of the birds by using paired t-tests of birds in the control (no sonic net) and sonic net situations, comparing their vigilance in the minute preceding and the minute following the playback of the alarm call.

In both the aviary and alarm call experiments the assumption of data sphericity (i.e., data are correlated) was violated in all repeated-measures ANOVAs; therefore, we interpreted Greenhouse–Geisser adjusted F-ratios. Percent data from the aviary experiment was arc-sine transformed to improve normality of residuals. We performed all statistical analyses with SPSS Statistics Version 20.0 (IBM Corp, Armonk, NY) employing 2-tailed tests of probability.

RESULTS

Aviary Experiment

Presence of the 2- to 10-kHz sonic net significantly deterred flocks of starlings from a food source (Greenhouse–Geisser $F_{1,9} = 10.6$, $P = 0.010$, partial η-squared effect size = 0.540). On average, starling presence was reduced by approximately 46% (Fig. 4). There was no general effect of day on the presence of birds at the food patches (Greenhouse–Geisser $F_{1.1,9.8} = 0.300$, $P = 0.616$, partial η-squared effect size = 0.032), nor was there a change in the effectiveness of the sonic net at deterring birds over the 3 days of the experiment (Greenhouse–Geisser $F_{1.2,11} = 2.67$, $P = 0.128$, partial η-squared effect size = 0.229; Table 1).

Presence of the sonic net reduced the number of starlings feeding at the affected food patches (Greenhouse–Geisser $F_{1,9} = 11.9$, $P = 0.007$, partial η-squared effect size = 0.570). On average, the presence of feeding birds was reduced by 54% (Fig. 4). Consistent with the feeding data, there was less food eaten at the food patch affected by the sonic net (Greenhouse–Geisser $F_{1,9} = 8.73$, $P = 0.016$, partial η-squared effect size = 0.492). On average, food eaten was reduced by 45% (Fig. 4). Day of the experiment did not influence the overall pattern of feeding by the birds (Greenhouse–Geisser $F_{1.1,9.8} = 1.32$, $P = 0.283$, partial η-squared effect size = 0.128),

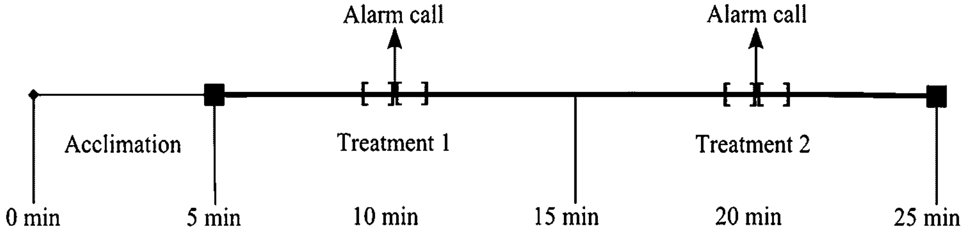

Figure 3. Schematic of the alarm-call experiment timeline over which we analyzed influence of the sonic net on captive starling flocks, from data collected from May to July 2013. Visual representation of a single trial where (Treatment 1) and (Treatment 2) are either "sonic net" or "quiet" treatment. Bracketed areas indicate pre- and postalarm call data-collection time intervals.

and the effect of the sonic net on deterring feeding did not change notably over the course of the experiment (Greenhouse–Geisser $F_{1.1,10} = 4.16$, $P = 0.065$, partial η-squared effect size = 0.316; Table 1). Birds were still deterred on Day 3 ($t_9 = 2.77$, $P = 0.022$). Although there was no general effect of day of experiment on the amount of food eaten (Greenhouse–Geisser $F_{1.1,9.9} = 2.17$, $P = 0.172$, partial η-squared effect size = 0.194), there was an indication that effectiveness of the sonic net at reducing the food eaten diminished over the 3 days of the experiment (Greenhouse–Geisser $F_{1.2,10.7} = 7.84$, $P = 0.015$, partial η-squared effect size = 0.466; Table 1); yet, there was still less food eaten on the sonic net side of the aviary on Day 3 compared with the control side ($t_9 = 2.48$, $P = 0.035$).

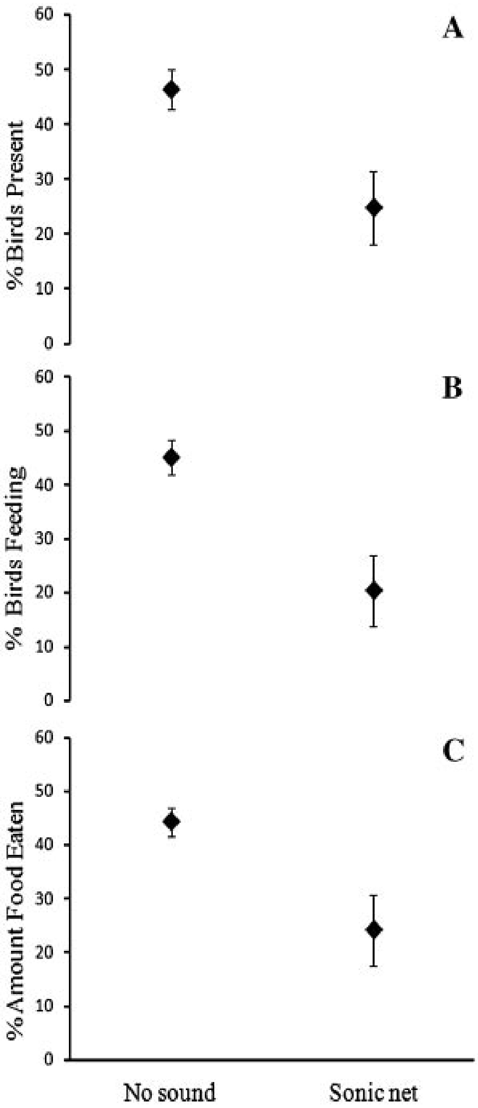

Figure 4. Effects of the sonic net in the aviary experiment, wherein we analyzed influence of the sonic net on captive starling flocks, from data collected from May to July 2013. All values are mean ± standard error. (A) Reduction in the percentage of birds present under the sonic net when compared with the same area under a no sound treatment. (B) Reduction in the percentage of birds feeding under the sonic net when compared with the same area under a no sound treatment. (C) Reduction in the percentage of food eaten under the sonic net when compared with the same area under a no sound treatment.

Alarm Call Experiment

Sonic net of 2–10 kHz.—The groups of starlings increased their vigilance following alarm call playback (Greenhouse–Geisser $F_{1,17} = 40.2$, $P \leq 0.001$; Fig. 5), and this response differed when birds were exposed to the 2–10-kHz sonic net (Greenhouse–Geisser $F_{1,17} = 32.6$, $P \leq 0.001$). Specifically, when the sonic net was not applied (i.e., the control condition), the groups of starlings responded very strongly to the alarm call ($t_{17} = 6.69$, $P \leq 0.001$). However, when the birds were exposed to the 2- to 10-kHz sonic net, they did not show any vigilance response to the alarm call ($t_{17} = 0.914$, $P = 0.370$). This difference is consistent with the interpretation that the 2- to 10-kHz sonic net masked the starlings' perception of the alarm call playback.

Sonic net of 0.1–2 kHz.—As before, the starlings showed increased vigilance in response to the alarm call (Greenhouse–Geisser $F_{1,13} = 45.9$, $P \leq 0.001$) and this response differed somewhat when the birds were exposed to the 0.1–2 kHz sonic net (Greenhouse–Geisser $F_{1,13} = 5.97$, $P = 0.030$). As with the previous communication trials, the groups of starlings showed a very large increase in their vigilance in response to the alarm call when there was no sonic net over their cage ($t_{13} = 6.01$, $P \leq 0.001$). When we applied the 0.1- to 2-kHz sonic net, the birds still responded strongly to the alarm call playback by increasing their vigilance ($t_{13} = 3.81$, $P = 0.002$). Hence, the birds were able to perceive the alarm call and respond appropriately when exposed to the 0.1- to 2-kHz sonic net. This observation is consistent with the interpretation that the lower frequency sonic net did not mask starling alarm calls.

Table 1. Summary of the influence of the sonic net on captive starling flocks, from data collected from May to July 2013. Data shown are the percent of bird presence, percent birds feeding, and percent of food eaten in the sound-treated patch. All means are shown ± standard error. Sample size is 10 flocks on each day of the experiment. If birds apportion their activities equally on the sound-treated and nontreated sides of the aviary we would expect 50% values on all days of the experiment. All values are <50%, indicating that the sonic net deterred the starlings from that side of the aviary.

Day of experiment	% Bird presence		% Birds feeding		% Food eaten	
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
1	19.69	8.23	16.41	7.49	20.46	7.64
2	25.79	8.06	19.84	7.65	24.20	7.00
3	29.00	9.31	25.00	9.04	27.85	8.93

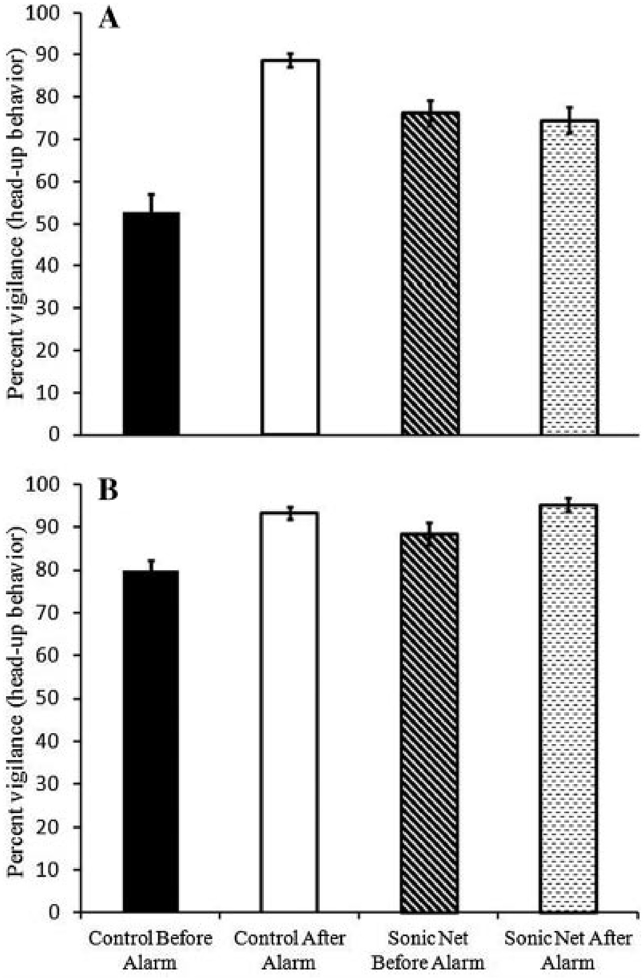

Figure 5. Mean (± SE) percent time spent vigilant through different stages of the alarm call experiment, wherein we analyzed influence of the sonic net on captive starling flocks, from data collected from May to July 2013. (A) There was no increase in vigilance to the broadcast of an alarm call when under a 2- to 10-kHz sonic net. (B) There was an increase in vigilance in response to the broadcast of an alarm call when under a 0.1- to 2-kHz sonic net.

DISCUSSION

Our results indicate that the sonic net is effective at deterring European starlings from food patches in an outdoor aviary over a 3-day period. On average the presence and feeding of small flocks of starlings was approximately halved by our sound treatment. We feel this is a notable achievement relevant to displacing this nuisance species because the starlings were continuously exposed to the sonic net for 8 hr a day for 3 consecutive days—a length of time that is likely sufficient for substantial learning and accommodation if the birds were able to adjust or habituate to the sonic net. We did not observe evidence that birds were less deterred on Day 3 compared with Day 1 of exposure to the sonic net. However, there was some indication that their food consumption recovered somewhat, but was still lower than in the reference treatment without the sonic net. This latter response in feeding but not occupancy may be an artifact of the birds having no predators in the aviary and birds learning that they could feed at a slightly faster rate without truly compromising their already altered predation risk. It is also possible that the birds may have continued to recover their feeding responses if the experiment was extended beyond 3 days. We intend to investigate this possibility in further aviary trials and in our current field trials. Currently, we can only make conclusions regarding a 3-day exposure to the sonic net.

The alarm call experiments support our general conclusions. The starlings did not respond to an alarm call when experiencing a sonic net that we hypothesized would mask the alarm call (i.e., the frequency range of 2–10 kHz). However, they did respond when the sonic net was designed to not mask the alarm call (i.e., the frequency range of 0.1–2 kHz). Therefore, we conclude that the sonic net that we applied in the aviary trials (2–10 kHz) likely masked auditory communication for starlings, which we hypothesize, led to an increase in perceived predation risk of the affected area and, hence, decreased occupancy and feeding efficiency by the birds.

We are not the first to indicate that a bird species can be largely excluded from an area dominated by noise. The relatively low-frequency environmental noise produced by natural gas drilling platforms restructures entire bird communities by driving off certain species and favoring others (Francis et al. 2011). However, to the best of our knowledge, we are the first to use a spatially controlled noise that is designed to mask acoustic communication to deter a pest avian species. Many of the current technologies used to deter pest birds lose their effectiveness very quickly (Bomford and O'Brien 1990). Our data indicate that European starlings are still deterred after 3 days, but we will need to extend these trials to understand more fully whether the birds can acclimate to the 2- to 10-kHz sound. In our current field trials, we are applying the same type of sonic net to wild, free-ranging birds for several weeks. Our sonic net treatment likely increases perceived predation risk, so we predict that the effectiveness of this sonic net will be greater in field conditions compared with our aviary. In the aviary, birds were not exposed to real predation threats, whereas birds' inability to detect predators reliably will carry greater costs in nature. However, we urge caution in trying to apply our current study directly to the field because results obtained with a single species in a spatially controlled environment cannot easily be extrapolated to wild birds of multiple species in much different localities (hence, our current field testing).

Even given these interpretational limitations, it is still important to try to understand how and why European starlings are displaced by the 2- to 10-kHz sound. It is possible that our sonic nets are effective at excluding starlings because starlings commonly form large flocks (Morrison and Caccamise 1990, Caccamise 1991) where foraging success and the probability of food discovery can be increased by vocal communication within the flock (Clark and Mangel 1984, Giraldeau 1984). Sharing information about foraging success benefits the birds in that it reduces the searching time and leads to an increase in individual foraging rates (Caraco 1981, Clark and Mangel 1984, Templeton and Giraldeau 1995). Birds that are unable to communicate tend to forage less efficiently because they are unable to share information about predators and thus have to spend more time vigilant instead of foraging, a hypothesis supported by the results from our alarm call experiments. Additionally, we hypothesize that perceived predation risk is increased when birds are less able to rely on audible messages that relay information about predatory threats, such as alarm calls or sounds emitted directly by predator species themselves (Klump and Shalter 1984, Gyger et al. 1986, Smith 1986).

At a time where anthropogenic noise pollution affects wildlife populations (Brumm and Slabbekoorn 2005, Barber et al. 2010), the results from this study can also help us better understand how and why bird communities are affected by chronic noise. We predict that with increasing frequency (pitch) of noise pollution we will see greater disturbance of behaviors mediated by vocal communication, such as foraging and antipredatory behaviors. Decreased foraging and increased perceived predation risk, in such situations, will likely result in lower individual and population fitness (Klump 1996, Kight and Swaddle 2011, Kight et al. 2012) and/or lead to population displacement.

Here we propose a novel system for excluding European starlings from habitats, which has potential for lessening human–wildlife conflict. We used highly directional speakers to produce a contained net of sound that appeared to mask auditory communication and rendered the treated area acoustically unsuitable without causing noise pollution in the surrounding area. In controlled aviary conditions, we reduced the presence of starlings by 46%, on average, but we predict the magnitude of this effect may be larger in the field when birds face real predation threats. These promising results on this single species would need to be expanded upon to include studies of multiple species communities in natural and free-living conditions before this concept could be employed at socioeconomically important sites such as airports and agricultural fields. Such studies are currently underway.

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