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FROM THE FIELD

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Investigating nocturnal UAS treatments in an applied context to prevent gulls from nesting on rooftops

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Abstract

Ring-billed (*Larus delawarensis*) and herring (*L. argentatus*) gulls are numerous and widespread in North America. These gulls rank among the top 9 species for risk of bird-aircraft collisions (hereafter strikes). The ubiquitous presence of gulls in urban coastal environments, including rooftop nesting behavior, are factors impacting strike risk. Our purpose was to assess gull response to a small uncrewed aircraft system (UAS) in hazing flights at night during the nest-building phase. We hypothesized that nocturnal UAS operation, like nocturnal predator disturbance, might reduce gull numbers and, thus, strike risk to aircraft. In spring 2021, we conducted UAS treatments over target roofs at least once every hour from 2000 until 0200, weather permitting, for 15 min and over a 14-day period for each site. The UAS flew directly above (~4 m) and then descended (~4 m/s) within 1 m of loafing gulls. No gulls interacted with the UAS and most flushed within 6 minutes. Generally, the first treatment of a night dispersed all gulls (min–max = 1–130 individuals) from the target roof for an extended period. Our operations were often grounded because of weather and our gull response data were limited because of few individuals present. We discuss our observations with particular attention to feasibility and possible implications such as shifting birds to other sites which, potentially, could be counterproductive for management.

KEYWORDS

antipredator behavior, bird strike, colony nester, drone, hazing, *Larus* spp., urban wildlife, wildlife damage management

Gull species (family Laridae) benefit from anthropogenic landscapes and often concentrate in urbanized areas (Monaghan and Coulson 1977, Rock 2005, Spelt et al. 2021). Consequently, gulls can establish large mixed-species nesting colonies in urban environments near airports, which may increase the probability of gull-aircraft collisions (hereafter strikes) and thus jeopardize bird and human safety (DeVault et al. 2018, Pfeiffer et al. 2018*a*). Under natural conditions, both herring (*Larus argentatus*) and ring-billed gulls (*L. delawarensis*), hereafter referred to collectively as gulls, nest on the ground in open habitats (Pollet et al. 2020, Weseloh et al. 2020). However, both species have adapted to rooftop nesting given that roofs are visited by few mammalian predators (e.g., red fox [*Vulpes vulpes*] and raccoon [*Procyon lotor*]) and are not prone to flooding (Fisk 1978, Southern et al. 1982, Belant et al. 1998). Once a nesting colony is established, breeding pairs tend to return to the same site, along with previous seasons' chicks that reached maturity and are returning to their natal colony for breeding purposes (Brown and Brown 2000, 2001). Natural predation and nest destruction may disrupt a colony (e.g., gulls engaging in alarm calls and short duration panic flights) but do not necessarily cause complete colony abandonment because of high site fidelity and dilution of predation risk, even with surplus killing, at large nesting colonies (Emlen et al. 1966, Kadlec 1971, Southern et al. 1982, 1985).

To reduce risk posed to aviation safety by gull nesting colonies near airports, managers have used exclusion, nest destruction, hazing via pyrotechnics or firearms, and egg oiling to reduce the local population (Blokpoel and Tessier 1991, Ickes et al. 1998, Olijnyk and Brown 1999, Engeman et al. 2012). Notably, direct diurnal disturbance prior to egg laying and during the nest material gathering phase was not found to be effective at reducing nesting gulls at a colony in New York (Olijnyk and Brown 1999). However, preincubation hazing efficacy could potentially be enhanced via nocturnal, direct disturbance of gulls at the colony site, given the increase in perceived risk of predation associated with nocturnal conditions (Kruuk 1964, Emlen et al. 1966, Southern and Southern 1979, Southern et al. 1982).

For protection against nocturnal predators, gulls rely on selecting predator-free nesting locations (Southern and Southern 1979). When gulls are exposed to nocturnal predators, they exhibit ill-adapted antipredator behaviors (Southern et al. 1982). For example, some fail to react to predator approaches or engage in panic flights which could harm young or chicks (Southern et al. 1982). Antipredator behavior in birds likely differs at night because of limited sensory capabilities compared to daylight hours (Yorzinski and Platt 2012). Reduced sensory capabilities could explain why gulls are unlikely to engage in mobbing behaviors at night (Emlen et al. 1966, Southern et al. 1982, Frixione and Salvadeo 2021). Thus, enhancing perceived risk at night offers a promising approach to reduce the number of breeding gulls using a site.

Recent technological advances might make nocturnal, nonlethal gull management, particularly on rooftops, safer and more efficient. For example, small uncrewed aircraft systems (sUAS; a UAS weighing less than 24.95 kg) have been evaluated for hazing other bird species (Egan et al. 2020, Pfeiffer et al. 2021) but have yet to be evaluated in the context of preventing nest establishment by gulls. Gulls respond to approaching aircraft using antipredator behaviors (Bernhardt et al. 2010), thus it is conceivable that a UAS would be perceived as threatening. Further, a UAS can easily be manually maneuvered by an operator to access rooftop gull nesting colonies at night and flown in a hazing pattern at loafing gulls. In the future, these operations could potentially be autonomous and would reduce the need for personnel to work at night (Schiano et al. 2021). Such hazing patterns of a direct targeted swoop from altitude to loafing gulls would be similar to a great horned owl (*Bubo virginianus*) attack, which is a common nocturnal avian predator (Southern et al. 1982).

Our purpose was to assess responses by gulls using rooftop nesting locations to UAS hazing treatments at night during the nest material gathering phase. We hypothesized that gulls would react to UAS disturbance by fleeing (Frid and Dill 2002) and attempt to nest elsewhere with less direct disturbance (Southern et al. 1982). Our work involved an applied management context, in that we were limited to 2 sites; as such, our observations were anecdotal. We predicted that persistent nocturnal UAS hazing treatments of gulls during the nest material gathering phase of the breeding season would reduce the number of gulls from using the rooftops for nesting. From the perspective of method efficacy, we set a 50% decrease in gull numbers as a minimum effect size of interest to justify the use of this novel management tool compared to traditional methods (e.g., nest destruction) and given the necessary personnel and resources required (Lakens 2022). Our objective was to reduce the number of gulls nesting on 2 building rooftops by flying a UAS at night in a hazing pattern for 2 weeks prior to the first egg-laying date.

STUDY AREA

We conducted nocturnal UAS hazing treatments at 2 building roofs historically used by ring-billed and herring gulls for nesting: 1) a large picnic shelter (0.22 ha, 5 m tall) with a metal roof in Sandusky, Ohio USA along the shores of Lake Erie (41°28′43.84″N; 82°40′52.83″W); and 2) a large industrial warehouse building (2.4 ha, 6 m tall) with a tar-pebble roof surface in Chicago, Illinois USA (41°55′15.88″N; 87°51′42.61″W). The Chicago roof was 3 miles southeast of the O'Hare International Airport (ORD) and the nesting colony has been managed by the United States Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services' (WS) Illinois operational program as part of ORD's airport wildlife hazard management plan. The Chicago roof was in Class B airspace, and we obtained a Part-107 Airspace Authorization (2021-P107-CSA-05238) to operate a UAS below the 53-m above-ground-level restriction (AGL; UAS flight height restrictions [60 m] minus the height of the building [7 m]). Prior to the experiment, we examined risks of hazing gulls within the vicinity of ORD. The building roof in Chicago is perpendicular to the closest diagonal runway; therefore, aircraft flying over the building are roughly at 914-m AGL, which is much higher than the mean daily maximum altitude (e.g., 305–610-m AGL) of gulls (Shamoun-Baranes et al. 2006, Pfeiffer et al. 2018*b*) and typical nocturnal gull antipredator, flight-escape responses of 10-m AGL (Emlen et al. 1966). The Sandusky roof was in Class G airspace; thus, we did not need an Airspace Authorization to fly a UAS. At both target roofs, the UAS remained within visual line of sight in accordance with Federal Aviation Administration's sUAS operational rules (eCFR: 14 CFR Part 107—Small Unmanned Aircraft Systems).

METHODS

In Sandusky, during 14–27 March 2021, we flew a white DJI Phantom 4 Pro quadcopter (Da-Jiang Innovations Shenzhen, China). In Chicago on 3 April 2021, we flew a black 3DR Solo quadcopter (3D Robotics Berkeley, CA, USA) but experienced a software problem that negated our ability to use the quadcopter. Subsequently, during 6–7 April 2021, we flew a black/gray DJI Inspire 2 quadcopter (Da-Jiang Innovations Shenzhen, China). The diagonal width of the DJI Inspire 2 (0.61 m) was 24% larger than that of the 3DR Solo (0.48 m) and 54% larger than that of the DJI Phantom Pro 4 (0.35 m). However, given our limited sample size and the applied context, we did not attempt to control for airframe appearance. All WS procedures for UAS use were followed, including the use of a visual observer. Additionally, DJI platforms were flown in the offline mode.

All UAS were flown with rechargeable anti-collision lights (Firehouse Technology, Cleveland, OH, USA), with the white light attached to the dorsal, green light attached to the starboard, and red light attached to the port side. The 600 Lumen Cree anti-collision lights were set to the strobe setting. The DJI Phantom 4 Pro was flown with a proprietary GL300F transmitter and the DJI Inspire 2 was flown with a DJI Cendence transmitter. The 3DR Solo quadcopter was flown with a proprietary 3DR Solo transmitter. Battery durations and maximum wind speed limitations were similar for all platforms: ~20 minutes at a wind speed of 10 m/s.

We attempted to fly for at least 10 nights over a 14-day period: 14–27 March 2021 in Sandusky and 28 March–10 April 2021 in Chicago. The start dates were 2 weeks prior to historical first egg laying dates (2 April for Sandusky [Blackwell et al. 2000] and 16 April for Chicago [C. Pullins, Wildlife Services, personal communication]), as our hazing treatments were not allowed to be conducted when eggs were present, per the Migratory Bird Treaty Act (16 USC §703–712). At least once every hour for 6 hours a night (i.e., total flight time >1.5 hours/night for a maximum number of 12 treatments per night), starting at 2000 local time (Sandusky was in Eastern Daylight Time and Chicago was in Central Daylight Time), we flew the UAS in a hazing pattern at loafing gulls on the roofs for 15 minutes.

We launched the UAS from beneath the nesting locations to increase the perceived risk of the approach to loafing birds. Prior to a treatment, we manually selected a maximum operational altitude limit of 53 m AGL, and 45 m (Sandusky) and 90 m (Chicago) maximum horizontal distances to prevent fly aways associated with failure of the control element or onboard systems or both. Flight boundaries were created using the DJI Go 4 Application (SZ DJI Technology Co., Shenzhen, China, version 4.3.42) to select points on a satellite image of the target roofs.

Before each treatment, the pilot-in-command (PIC) performed a preflight safety check of the UAS on the ground and then ascended to either a vantage point (12 m AGL) in Sandusky, or to the roof in Chicago. The PIC counted the number of gulls on the roof before the treatment using binoculars (Zeiss Conquest 8 × 30, Jena, Thuringia, Germany). Although not required as of April 2021 for UAS operation rules (eCFR: 14 CFR Part 107—Small Unmanned Aircraft Systems §107.29 Operation at night), during this experiment a trained visual observer was used to facilitate safe UAS operation by identifying and communicating hazards to the PIC. The PIC and visual observer communicated via radio.

The visual observer also recorded ambient conditions using an external weather station (Kestrel 5500 Weather Meter; Kestrel Instruments, Boothwyn, PA, USA) on a tripod with a weathervane to record wind speed (m/s), wind direction (degrees), and temperature (Celsius). The weather station was located on the ground at the launch site in Sandusky and on the roof in Chicago. The visual observer was able to obtain weather data from the elevated position in Chicago using the Kestrel Link Application (Kestrel Instruments, version 1.5.6.2) connected via Bluetooth technology. We canceled our operations if it was raining, snowing, temperatures were below freezing, or if wind speed or wind gusts were over the recommended UAS platform thresholds of 10 m/s.

The battery life was estimated at 20 minutes for all UAS platforms; therefore, we flew the hazing treatment pattern for ~14 minutes and then started the manual return to the launch point. This operation provided ample battery to return and facilitated draining a battery completely for optimal battery performance. The PIC launched the UAS from the ground and then flew horizontally to be in a position (~5 m) above the roof. The flight pattern included approaching from directly above loafing gulls at a 90° angle at about 4 m/s, as this approach increases perceived risk (Vas et al. 2015). We flew as close as possible to loafing gulls while avoiding a collision. If gulls flushed, we immediately maneuvered the UAS out of the way of the flushing bird(s) to avoid potential collisions. No animals were injured during this study. We maintained this defensive flight pattern for the entire treatment, even if all gulls were dispersed. Because of the visual limitations of operating at night, we made general notes as to time into the treatment that gulls reacted to the UAS. After the UAS was landed, the PIC counted the number of loafing gulls on the roof. These counts were used to calculate the gull remaining index (i.e., proportion of the number of gulls after a treatment/the number of gulls before a treatment; Pfeiffer et al. 2021). The gull remaining index considers flock size and is a proxy for efficacy of our treatment with lower values indicating that fewer birds remained. We repeated the treatment procedure at least once every hour for 6 hours, regardless of whether gulls were present on the roof. Our operation schedule was based on a typical work schedule for a wildlife damage management professional tasked with preventing gull nesting at a target location (C. Pullins, Wildlife Services, personal communication). In Sandusky, if the area was cleared of gulls the entire night, we noted gull presence the following day at 2000. In Chicago, we obtained latency to return data from a camera trap (Reconyx HF2 Pro Covert, Holmen, WI, USA) set to record when motion was detected.

Because our effort was operational in nature and limited in sample size, we report descriptive statistics. We obtained nest data from the previous year for both sites; we present gull nest numbers for the treatment year (2021) and no-treatment year (2020) as a general comparison.

RESULTS

We were unable to operate the UAS in Sandusky for 6 of 14 (43%) nights because of high wind speeds (n = 1 night, wind speed = 8.06 m/s, wind gusts = 11.94 m/s), high wind speeds and precipitation (n = 3 nights; $\bar{x}$ wind speed = 10.10 m/s, SD = 3.63 m/s; $\bar{x}$ wind gusts = 15.83 m/s, SD = 5.91 m/s; and $\bar{x}$ precipitation = 13.13 mm, SD = 13.49 mm), and lack of WS visual observer (n = 2 nights). In Chicago, we were unable to operate the UAS for 6 of 12 nights (50%) because of high wind speeds (n = 2 nights; $\bar{x}$ wind speed = 6.81 m/s, SD = 2.95 m/s; $\bar{x}$ wind gusts = 15.56 m/s, SD = 1.96 m/s), high wind speeds and precipitation (n = 2 nights; $\bar{x}$ wind speed = 4.72 m/s, SD = 0; $\bar{x}$ wind gusts = 14.72 m/s, SD = 1.96 m/s; $\bar{x}$ precipitation = 0.70 mm, SD = 0.71 mm), and lack of WS visual observer (n = 2 nights). Of the 6 nights we were able to operate in Chicago, we could only complete a full night (i.e., 6 hours) of treatments for 3 nights because of freezing temperatures (n = 1 night, temperature = −2°C) and UAS malfunctions (n = 2 nights). Further, we were unable to apply the treatment for the entire time in 10 treatments (Sandusky = 8 treatments and Chicago = 2 treatments) because of UAS malfunction (n = 3 treatments), low battery warnings (n = 4 treatments), rain (n = one treatment), and interference by non-participants (n = 2 treatments). Only one of these short duration treatments in Sandusky was conducted with gulls present prior to the treatment.

We flew the DJI Phantom 4 Pro quadcopter in Sandusky all 8 nights. We flew the same platform in Chicago for 4 nights, but on the fourth night when rotating the camera down and flying toward the roof we experienced a mishap in which the UAS malfunctioned and fell to the paved surface below. The following night, we flew the 3DR Solo, however, we experienced a fly away and battery malfunction, but implemented an immediate landing safely; we therefore ended operations for that night. We then used the DJI Inspire on the night of 6 April 2021 with no mishaps.

We conducted a total of 76 UAS hazing treatments; 58 in Sandusky and 18 in Chicago, representing a total of 13 flight hours across 8 nights in Sandusky and 4 flight hours across 6 nights in Chicago. On nights when we were able to fly in Sandusky, wind was negligible ($\bar{x}$ wind speed = 0.77 m/s, SD = 0.81 m/s) and temperatures were mild ($\bar{x}$ temperature = 7.46°C, SD = 5.16°C). Likewise in Chicago, wind was light ($\bar{x}$ wind speed = 2.29 m/s, SD = 1.58 m/s) and temperatures were mild ($\bar{x}$ temperature = 10.36°C, SD = 8.97°C). At both target roofs, there was enough ambient light to detect the light-colored gulls, but not enough light to distinguish species; therefore, total number of gulls was recorded. Despite planning our experiment to occur within the nest material gathering period, gulls were only present on the roofs for 16% of treatments (Sandusky = 11 treatments across 8 nights and Chicago = 1 treatment across 1 night). Even when gulls were present, not many were observed in Sandusky ($\bar{x}$ number = 1 gull, SD = 3 gulls). We estimated there were 130 individuals on the only night gulls were present on the roof in Chicago. All gulls flushed within 5 minutes during the first treatment of the night, except for treatment 46 which was the first treatment on the 7th night in Sandusky: we recorded 17 gulls on the roof before the treatment and one after, however, because of rain, we could only apply the treatment for 8.5 minutes.

For 12 UAS hazing treatments across both study sites with gulls present prior to the treatment, the mean gull remaining index was 0.00 (SD = 0.02). We were unable to calculate the gull remaining index if no gulls were present before a treatment (n = 64 treatments). Interestingly, in one treatment (i.e., treatment 18 which was the 3rd treatment on the 6th night in Sandusky) more gulls were present after than before (i.e., 0 gulls before and 3 gulls after) the hazing. If all gulls were flushed by the end of the hazing treatment, they generally did not return to the roof (n = 10 treatments; $\bar{x}$ number of returns per treatment = 0.55, SD = 0.50). In Sandusky, we recorded latency for

5 treatments while personnel were present on site, including 2 treatments in which gulls came back during the hazing ($\bar{x}$ latency period = 38 minutes; SD = 48.50 minutes). We noted that gulls were present on an adjacent roof before, during, and after all treatments in Sandusky; this roof was ~35 m south of the target roof, thus out of range for the UAS.

In Chicago, 130 gulls were present on the roof during only one treatment, which was the first treatment on the 6th night. All birds took flight in response to the hazing UAS within 6 min (Figure 1A,B). However, our hazing required the entire 15-minute period before the circling in-flight flock moved away. The flock relocated to a large industrial roof ~150 m to the west. No gulls returned to the roof until the following morning at 0722 as indicated by the camera trap (Figure 1C). Total latency time at this section of the target roof (i.e., within the view of the camera trap) was 8.58 hours.

At both locations, our hazing treatments resulted in no collisions or negative interactions with gulls. Some gulls would circle above the UAS watching its movements, but they did not move aggressively towards it in a mobbing behavior. However, given that we obtained only 12 observations of gull response to UAS approach, our inference to efficacy of the method is limited. Following our hazing treatments, gulls nested on both rooftops. In Chicago, both species were observed nesting 20 days after our treatments. At both study sites, fewer gull nests (Chicago = 60% decrease and Sandusky = 74% decrease) were observed in the treatment year 2021 (Chicago = 287 nests and Sandusky = 73 nests) than in the no-treatment year 2020 (Chicago = 713 nests and Sandusky = 280 nests).

DISCUSSION

Our assessment of a UAS as a hazing tool at night against gulls at rooftop colony sites during the nest material gathering phase revealed both logistical (e.g., timing, weather, and equipment) challenges and ecological consequences that would not necessarily reduce gull-aircraft strike risk. Although we planned the time-sensitive experiment to occur 2 weeks prior to the date of the first egg laid at each location, gulls were not consistently present in large numbers and, thus, limited our inference to efficacy of a hazing UAS in this nesting context. However, the first UAS treatment of the night generally caused gulls to disperse from the target roof and we documented no close negative interactions between the UAS and gulls. If the gull management goal involves moving prenesting gulls away from a target roof, not from an entire aircraft flight route, for a single night, UAS hazing treatments offer a potential tool.

Our treatments did not prevent nesting and, although there was a >50% reduction in observed nests in the treatment year (2021) than in the untreated year (2020), we could not discern a treatment effect because it was outside the scope of our study design (e.g., did not monitor multiple rooftop nesting colonies with and

FIGURE 1 Camera trap images from a mixed species gull nesting colony on an industrial rooftop in Chicago, Illinois, USA. On 6 April 2021, about 130 ring-billed and herring gulls flushed in response to a UAS hazing treatment (A and B). No gulls returned to the roof until the following morning (C).

without UAS hazing in the same year). The spring of 2020 corresponded with the start of the coronavirus disease 2019 (COVID-19) anthropause, which reduced human mobility and altered avian behavior (Schrimpf et al. 2021). Previous areas with high human traffic had fewer disturbances and gull nests were more prevalent in 2020 compared to 2021 (building managers in Sandusky, unpublished data), which could explain these observations.

Although we were unable to prevent gulls from nesting on target roofs, the absence of the constant UAS disturbance during periods of inclement weather could limit this tool compared to other options. At both locations, gulls reacted to the UAS by relocating to areas outside of the reach of the UAS and eventually returned to the target roofs to nest. Predator-induced abandonment of gull nesting colonies typically occurs later in the nesting season (e.g., peak hatching, Southern et al. 1982), thus, our treatments could have been perceived as less risky because gulls could easily relocate for the night and were not heavily invested in the site due to lack of eggs/chicks. With additional migratory bird permits, UAS hazing during incubation could have increase perceived risk to the point of nest abandonment. However, our observations that gulls moved, even if temporarily, to other nearby rooftops poses additional concerns depending on the management goal. If these nearby rooftops offer suitable nesting conditions, prenesting hazing could move the problem and, possibly, increase strike risk and/or introduce greater difficulty for managers to control the colony.

Given that high winds and precipitation greatly impeded our ability to operate a UAS in Illinois and Ohio, we question the feasibility of using this tool in a rooftop gull hazing context in the Great Lakes system or similar latitudes during early spring. Further, the possibility that gulls might select alternative nesting locations within the same vicinity reduces possible efficacy of our approach. That said, an integrated management plan that anticipates alternative nesting locations within a critical radius to airport operations and focuses UAS operations more intensely during the prenesting period could realize a greater buffer between gull colonies and airport operations.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

ETHICS STATEMENT

Our methods were reviewed under the USDA APHIS WS National Wildlife Research Center (NWRC) QA-3192, amendment number 02, and approved by the NWRC Institutional Animal Care and Use Committee (IACUC). Given that the UAS operations were conducted by federal personnel, the nesting colony in Chicago was managed to protect human and animal life, and the nesting colony in Sandusky was a surrogate study site, we were in compliance with the Airborne Hunting Act (eCFR: 50 CFR Part 19—Airborne Hunting).

DATA AVAILABILITY STATEMENT

Data are available at the USDA Forest Service digital repository: https://www.fs.usda.gov/rds/archive/catalog/NWRC-RDS-2022-002.

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