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Novel method for monitoring common terns at a large colony in northern Lake Huron, USA

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ABSTRACT

Novel monitoring and management techniques may be required when working with colonial waterbirds nesting on anthropogenic sites. We tested the utility of fixed sampling frames (quadrats) for estimating number of common tern (*Sterna hirundo*) nests and colony dynamics at a site in northern Lake Huron, U.S.A. We also examined whether within-season herbaceous vegetation management affected number of nests. We were unable to detect any avoidance of fixed quadrats (N = 15) versus staked quadrats (N = 15) over 10 count days in 2015 (Mann-Whitney, $P \geq 0.16$). Both distance from human disturbance (m) and Julian day were significant ($P < 0.01$) predictors of number of nests. Based on these findings and using quadrat data from peak count days each year from 2011 to 2016, we estimated a low of 1100 nests in 2013 and a high of 2000 nests in 2016. We also were unable to detect any differences in the number of nests in quadrats with vegetation treatments (N = 10) versus controls (N = 10) during 11 counts in 2016 (Mann-Whitney, $P \geq 0.18$). For common terns, and potentially other colonial waterbirds breeding on anthropogenic sites in the Great Lakes, we conclude that a fixed quadrat methodology may provide a useful way of estimating colony size and colony dynamics. Future studies should be conducted to compare our novel method with more traditional monitoring techniques.

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Introduction

The common tern (*Sterna hirundo*) is a species of conservation priority in six of the nine states bordering the Great Lakes. As such, the Great Lakes population of common terns is a management priority for the Midwest administrative region of the U.S. Fish and Wildlife Service (USFWS) (Cuthbert et al., 2003). According to Morris et al. (2010), the common tern population in the Great Lakes decreased 19% from 1976 to 2009, with a mean decline of approximately 1% per year. Throughout the late 20th century, common terns were displaced from low lying islands, shoals, and other natural nesting areas due to high water levels (Shugart and Scharf, 1983). Nesting birds often relocated to anthropogenic structures such as piers, jetties, and navigational structures (Courtney and Blokpoel, 1983). Such sites currently contain a significant number of the common tern colonies in the U.S. Great Lakes (Cuthbert et al., 2003; Morris et al., 2010, 2012). However, because many of these sites are attached to the mainland, they allow better access for mammalian predators that are often absent from islands (e.g., domestic dog, *Canis lupus familiaris*, other canids, domestic cat, *Felis catus*). Human disturbance can also be a concern at these sites.

One of the challenges for conservationists is the ability to accurately and/or precisely estimate the size of a population unit within the constraints of resource limitations (e.g., time and money) and disturbance concerns (Bookhout, 1994). For Great Lakes populations of common terns or other colonial waterbirds (e.g., double-crested cormorants, *Phalacrocorax auritus*; ring-billed gulls, *Larus delawarensis*; herring gull, *L. argentatus*; Caspian terns, *Hydroprogne caspia*) that are often monitored by direct nest counts (Cuthbert and Wires, 2011), human disturbance during monitoring may present opportunities for eggs and chick predation by gulls or may induce additional stress in birds already nesting in areas with human activity. Because anthropogenic sites used by colonial waterbirds may be dissimilar to sites that are more natural and may have different conservation issues associated with them, such as predator or vegetation management, more novel monitoring techniques may be required.

Since the late 1990s, a common tern colony has been located on a pier at the U.S. Coast Guard (USCG) facility in northern Lake Huron; monitoring and management of the birds, their breeding habitat, and potential predators are the responsibility of Seney National Wildlife Refuge (NWR). Because this colony is the largest known common tern colony in the upper Great Lakes (Cuthbert and Wires, 2011) and is located on a pier perched 4 m above Lake Huron, monitoring is important, but challenging. Conducting complete ground-based (direct) nest counts among the monoculture of herbaceous vegetation increases the odds

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that chicks and eggs are crushed. Moreover, the time required for such an effort increases stress on adults early in the breeding season (mid-May) and the likelihood of hatch-year birds jumping off the pier and drowning later in the season prior to fledging (early July). Consequently, monitoring the number of nests within the site has been accomplished by using a square sampling frame made of polyvinylchloride (PVC) tubing placed and left on the ground in a manner more commonly done with vegetation sampling (Bookhout, 1994). Because these quadrats are not removed between counts and can be systematically or randomly placed prior to the arrival of nesting birds each spring, this approach ultimately requires less time to sample, reduces the need to walk throughout the site, provides the basis for a statistical extrapolation to estimate the total number of nests in the colony and, when combined with data derived from digital motion cameras, provides the ability to evaluate management concerns that affect productivity (e.g., predation). When combined with vegetation management, the use of quadrats fixed in space and over time may allow for evaluation of vegetation patterns at the same time nest counts are conducted. However, the efficacy of using fixed quadrats for estimating colony size has not been reported in the literature. If effective, this approach may have broad utility for monitoring common terns and other colonial waterbirds nesting on anthropogenic sites elsewhere in the Great Lakes (Cuthbert et al., 2003, Morris et al., 2010, 2012).

Our overarching research question was: do data derived from fixed quadrats provide a useful estimate of the number of breeding common terns within a breeding season? We addressed this question by examining these related questions:

1. Do common terns avoid nesting within fixed quadrats made of PVC tubing?
2. Does a gradient in nesting density exist across the site and how might this affect colony size estimates?
3. What are point estimates for the size of the colony?
4. Does vegetation management used to minimize herbaceous cover within a breeding season affect the number of nests?

Methods

Study area

The study site was located within a 0.097 ha area at the east end of the active USCG pier in northern Lake Huron, St. Ignace, Michigan (N45°51′19″, W84°42′5″). An electrified, chain-link fence (~2.5 m in height with 6.25 cm mesh) was constructed to separate birds from USCG personnel and exclude mammalian predators: striped skunk (*Mephitis mephitis*), raccoon (*Procyon lotor*), domestic dog, domestic cat, red fox (*Vulpes vulpes*), and mink (*Mustela vison*). The pier extended east approximately 125 m into Lake Huron. The most western 74 m of the pier is where the USCG vessel *BISCAYNE BAY* and visiting vessels moored; this area also has an associated parking lot where most human activity occurred. The remaining 51 m at the eastern end of the pier was composed of a uniform rocky substrate on which herbaceous vegetation grew. This area of the pier was the location where navigational structures were stored during winter months, where common terns nested, and where vegetation management occurred.

Nest count and vegetation treatment protocol

Since 2011, multiple nest counts were conducted across multiple days each year using fixed quadrats in a frame constructed of 1.25 cm diameter polyvinylchloride (PVC) tubing glued together using PVC elbows (hereafter, fixed PVC quadrat). Because in some years there was a considerable amount of debris (e.g., building material, navigational devices) on the site, we systematically or randomly placed these quadrats on the ground. The weight and low profile of these fixed PVC quadrats precluded high winds from moving them. Based on the number of nests recorded in these fixed PVC quadrats during the maximum nest count day each year, we then extrapolated these density values (i.e., 1.47 nests m^{-2}, 1.41 nests m^{-2}, 1.10 nests m^{-2}, 1.53 nests m^{-2}, 2011–2014) over the entire area to estimate the size of the colony (unpub. data). However, by the end of the 2014 field season we realized there were two potential flaws in our approach: 1) we did not know whether birds avoided nesting in fixed PVC quadrats and 2) we did not know if a nesting gradient existed along the pier. Therefore, in 2015 we tested whether birds avoided nesting in fixed PVC quadrats and examined to what extent a nest gradient existed over the breeding season.

We established and maintained 30 1 m × 1 m sampling areas in three columns (east-west) throughout the site. Sampling areas were equally spaced 3.5 m apart. Of the overall 30 sampling areas, 15 consisted of fixed PVC quadrats while the other 15 were each marked by a 2 cm dowel (hereafter, staked quadrat) placed at quadrat center (a movable frame would later be used to sample staked quadrats, see below). Both fixed PVC and staked quadrats were arranged in an alternating pattern (Fig. 1). This systematic sampling was chosen over sampling at random to increase efficiency and reduce the likelihood of stepping on eggs and young. As such, and due to the uniformity of the site in terms of vegetation and other features, our methods follow the general guidelines of Anderson et al. (1979) for the use of transects in wildlife studies.

In 2016, we tested whether the management of herbaceous vegetation within a breeding season affected the density (number) of nests. In a review of management actions taken at tern colonies, Lamb (2015) indicated that vegetation is commonly managed at many sites to prevent secondary succession; but that the efficacy of these management

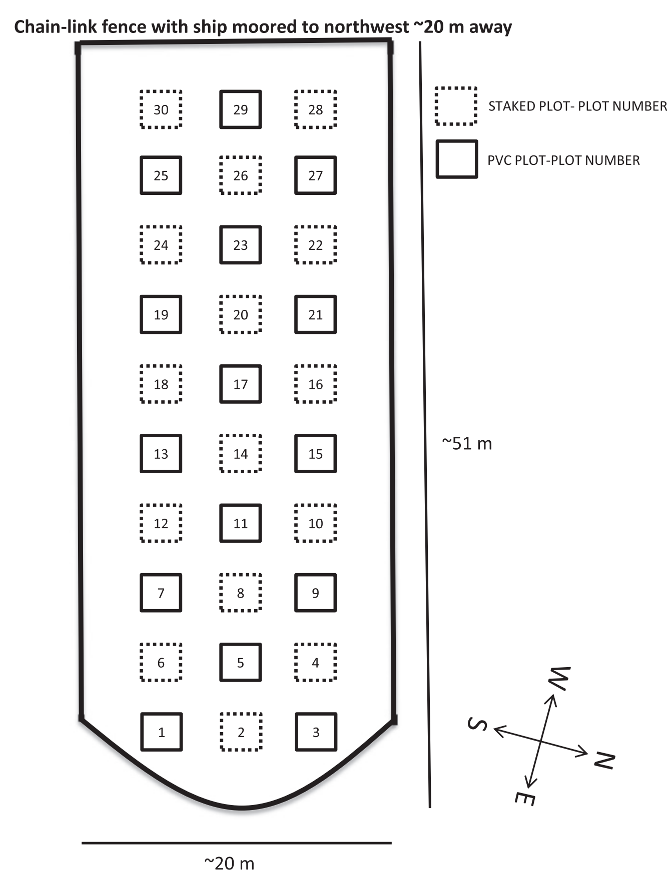

Fig. 1. Layout of U.S. Coast Guard pier St. Ignace, MI with locations of 30 1-m^2 common tern monitoring quadrats (2015). Map is not to scale as only ~3% of the site was sampled by quadrats.

actions is underreported. Currently, the mix of herbaceous cover at our site is similar to that described by Cook-Haley and Millenbah (2002) and is comprised of mostly non-native plant species: clover (*Meliotus* spp.), spotted knapweed (*Centaurea maculosa*), and wild parsnip (*Pastinaca sativa*). As in past years, all herbaceous vegetation at the site was mowed to ~10 cm in height in early May before birds began to nest. After mowing, 20 1-m^2 fixed PVC quadrats were laid out in two columns of 10 quadrats each in a manner similar to 2015 (east-west); and the percent cover of vegetation within each quadrat was determined visually. We then randomly assigned the entire sampling area containing the 10 fixed PVC quadrats to the south as treatment and the entire area containing the 10 fixed PVC quadrats to the north as control. Treatment involved spraying all vegetation with a 1.85% active ingredient solution of *Triclopyr* (Garlon 3A) before birds arrived, but after mowing. This herbicide kills all herbaceous vegetation and binds immediately to organic material. We then evaluated the effects of treatment over the breeding season by monitoring the number of nests and measuring vegetation height at three points (northeast corner, middle, southwest corner) in each quadrat during mid-June prior to our last nest count.

Throughout the entire study and since inception of our monitoring program, nest counts were conducted two or three times per week from late May to late June. The actual number of counts conducted each week was weather-dependent. During each count, the number of nests was recorded within each quadrat (fixed PVC or staked). We considered nests to be any depression with at least one egg, downy chick, or both. A 1-m^2 PVC quadrat was temporarily used to estimate the boundary of staked frames during each count in 2015. All counts in all years (2011–2016) were conducted up until the date at which chicks became mobile and left nests. At this time, counts ceased as mobile chicks could easily be frightened and jump off the pier from which they could not return.

Data analysis

Because our data consisted of nest counts that included integers 0–4 and a plot of raw data showed a moderately skewed distribution, we used a non-parametric Mann-Whitney *U* Test to address whether birds avoided nesting in fixed PVC quadrats and whether the number of nests differed between quadrats with or without herbicide treatment during each count day. The Mann-Whitney *U* test examines whether the distributions of two groups (e.g., fixed PVC vs staked quadrats; treated vs control) are equal. The main assumption is that during each count day data from the fixed PVC plots and staked quadrats and data from the treated vs control quadrats are independent. We also used logistic regression to test for differences using data pooled across all plots and all count days ($N = 300$ for density gradient and $N = 220$ for vegetation treatment).

To visually assess a potential nest gradient from the east to west side of the site, a schematic of the pier was created for each day a count took place with the number of nests within each fixed PVC and staked quadrat labeled and shaded in a manner corresponding with the respective number of nests. Darker shading indicated more nests being present within the quadrat. We used ordinal logistic regression to model the number of nests (nominal dependent variable) using two covariates (measurement independent variables): distance from fence (m) and Julian day. Finally, 95% confidence intervals were constructed for the total number of nests in the colony during each year we collected monitoring data (2011–2016) using values derived from peak count dates from each year as shown in the data for 2015 and 2016 (below) and retrospectively for data for 2011–2014 (see above). To evaluate the nesting gradient on the peak day, logistic regression was used to model the relationship between the presence of nests with distance from fence (m). For all analyses, we used $\alpha = 0.05$. Analyses were run using R 'stats' and 'MASS' packages (Venables and Ripley, 2002; R Core Team, 2013).

Results

Ten nest counts across 30 quadrats were completed in 2015 and 11 nest counts across 20 quadrats were completed in 2016. Nest counts began on 23 May of both years, with first chicks observed on 15 June (2015) and 13 June (2016). Nest counts ceased on 22 and 25 June in 2015 and 2016, respectively. During 2015, the number of nests recorded within all quadrats ranged from 0 to 3 quadrat^{-1}. The pooled number of nests counted within all 30 quadrats for any given count day varied between 5 and 54 nests, with the total number of nests generally increasing over the breeding season (Fig. 2). We were unable to detect any difference in the number of nests between fixed PVC quadrats and staked quadrats during any of our 10 counts, suggesting the populations from which sampling occurred did not differ (Mann-Whitney: $U = 90.00–110.5$, $P = 0.16–0.95$).

As observed in past years of monitoring, nesting began on the eastern periphery of the pier and, over time, progressed to the west and closer to the electric fence and USCG activity (Fig. 2). Logistic regression on the data from 2015 ($N = 30$) showed that the number of nests per quadrat depended on distance from the fence (regression coefficient b $= 0.91 \pm 0.12\ m^{-1}$, $P < 0.01$) and Julian day ($b = 1.13 \pm 0.13\ d^{-1}$, $P < 0.01$). Given a one meter increase in distance from the fence (e.g., from row containing quadrats 28–30 to row containing quadrats 25–27, Fig. 1), there was a 2.48 times greater chance that a higher nest count occurred. Similarly, given a one unit increase in Julian day, there was a 3.10 times greater likelihood of a higher nest count. However, when we examined nest presence as a binary variable (present or not present within a quadrat) on the peak count day (22 June, $N = 30$), distance from fence (m) was by itself not a significant predictor ($t = 1.56$, $P = 0.13$).

Using data from all years in which monitoring occurred (2011–2016), confidence intervals for the total number of nests on the pier were constructed for the peak nest count dates (Table 1). During 2011–2013 peak dates ranged over four days (2 June-6 June), while from 2014 to 2016 peak dates occurred on 22 June (tie, 20 June in 2016). Our resulting point estimates suggested 1700 nests in 2015 and 2000 nests in 2016 and a range of 1100–2000 nests from 2011 to 2016 (Table 1). In 2016, at the peak estimated number of nests at the site, mean nesting density was 2.04 nests m^{-2}.

After mowing, but prior to herbicide treatment in 2016, vegetation height in all quadrats was ~10 cm and mean (± 1 SD) percent cover was 76 (± 21) in the treated quadrats and 81 (± 21) in the control quadrats. Approximately four weeks later (13 June 2016), percent cover of live vegetation in all control quadrats was 100% and virtually zero in treated quadrats. The mean maximum vegetation height was 0.0 (± 0.0) cm in the treated quadrats and 29.1 (± 15.2) cm in the control quadrats. Across all count days, the number of nests recorded within treated and control quadrats ranged from 0 to 4 quadrat^{-1}. The grand mean across the 11 counts was 1.37 (± 0.74) nests in treated quadrats and 1.57 (± 0.72) nests in control quadrats. During none of the 11 counts were we able to detect a difference in the number of nests between treated and control quadrats (Mann-Whitney: $U = 40–50$, $P = 1.00–0.18$). When data were pooled across all count days, regression analysis further indicated treatment did not significantly affect the number of nests ($t = -1.35$, $P = 0.18$).

Discussion

Our findings suggest that birds do not avoid nesting in fixed PVC quadrats. Moreover, we suggest data derived from fixed PVC quadrats are useful in documenting colony dynamics and estimating the number of nests to a level useful for management purposes. Future monitoring should continue to occur across the site as we have outlined herein so as to capture any variability in nesting density that may occur. We also suggest that extrapolating nest density over the entire site may be warranted if data from peak count days are used. However, our

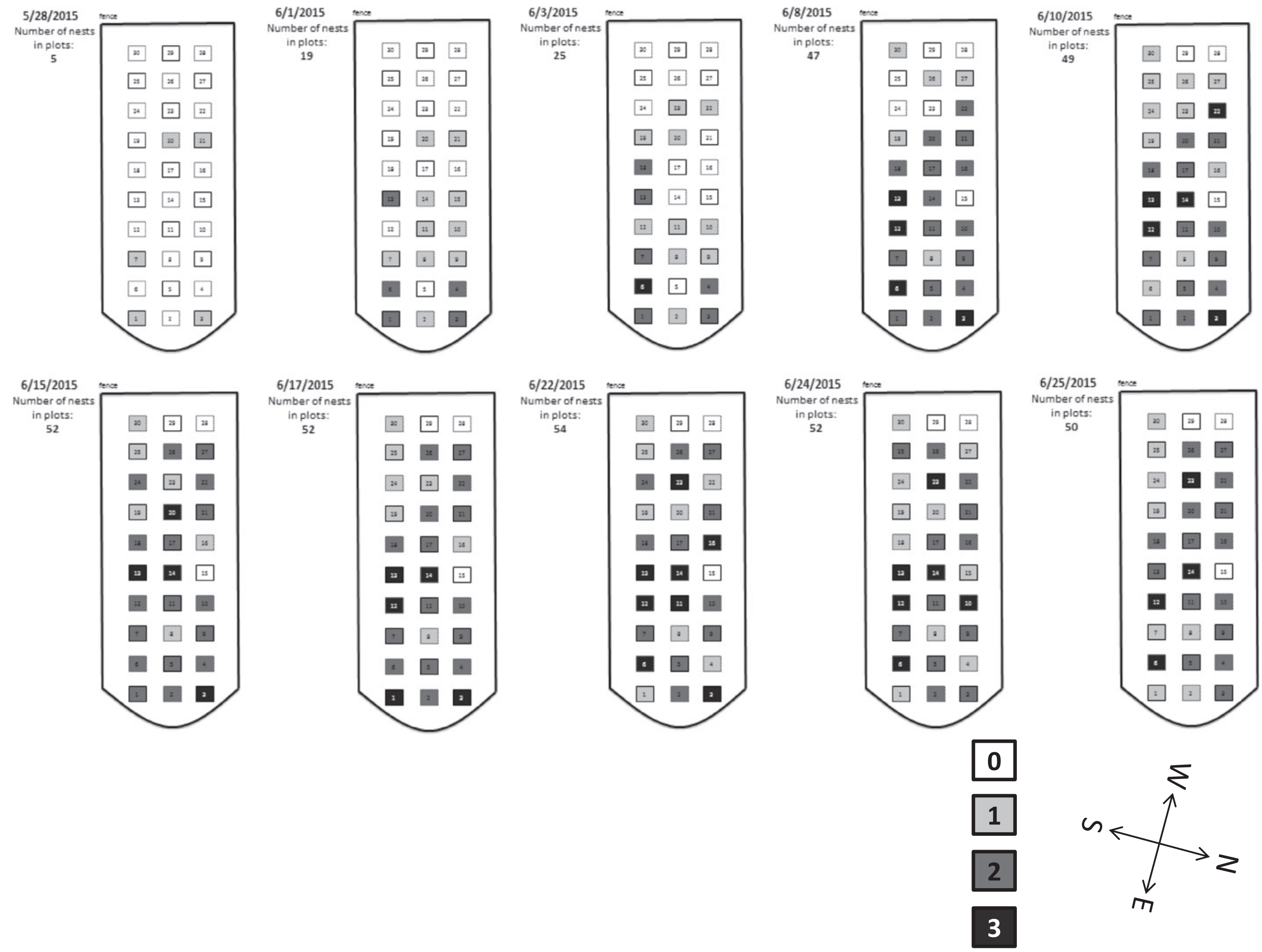

Fig. 2. Number of nests (raw data) in monitoring quadrats over 10 counts at the U.S. Coast Guard pier, St. Ignace, MI (2015). Map is not to scale as only ~3% of the site was sampled by quadrats.

study did not aim to compare our method directly with other methods more typically used to estimate colonial waterbird colony size in the Great Lakes (e.g., direct counts, aerial photo interpretation). Thus, our findings, as they relate to estimates of colony size, must be viewed with caution as only ~3% of the colony was sampled by our quadrats.

Observations made throughout the management history of this colony suggest that each year breeding birds arrived at the site early in the breeding season and initiated nesting at the most eastern periphery of the pier. As the number of birds arriving at the site increased, nesting ensued closer to the fence and human disturbance. Although we were not able to find literature demonstrating this pattern of avoidance for common terns, avoidance of human activity has been observed in Caspian terns (Raynor et al., 2012). Our results suggest that common terns may initially avoid human disturbance early in the breeding season, with most nests found as far away from the ship as possible. However, by the date peak counts were conducted, avoidance of humans may be reduced by the drive of newly arrived adults to nest within the confined space found closer to the fence and the ship. Even at the fine scale of a single pier, other potential explanations for this observed pattern include perceived avoidance of predators that access the colony from the same location as where the ship is moored and a predilection of common terns for nesting away from mainland areas.

The common tern is an asynchronous nesting species and the number of nests changes daily due to nest initiation, nest abandonment, predation, conspecific aggression, or other factors (Nisbet, 2000, 2002; Szostek et al., 2014). Our data suggest that at our study site there is considerable variability in number of nests at any point over any given breeding season and that consideration must be given for this in any estimate of colony size. Colony size fluctuations may be partially explained by the fact that many low lying islands within lakes Huron and Michigan are abandoned within a given year due to high water, weather events, or other causes (Cook-Haley and Millenbah, 2002). We suggest that many of these birds then relocate to the USCG pier, causing this site to be exceptionally dynamic in terms of the number of breeding birds present over the season and an increasingly long breeding season overall. Thus, to monitor this large and regionally important colony, it is important to conduct multiple counts in the season

Table 1
Estimated number of common tern nests and 95% confidence intervals (lower and upper bounds) on the peak nest count date for each year at the U.S. Coast Guard pier, St. Ignace, MI (2011–2016). Due to the large standard errors associated with these estimates, all values are presented to the nearest 100.

Year	Date of peak number of nests	Est. # nests	Lower bound	Upper bound
2011	6 June	1400	1300	1600
2012	5 June	1400	1200	1500
2013	2 June	1100	900	1300
2014	22 June	1500	1100	1800
2015	22 June	1700	1400	2100
2016	20 and 22 June (tie)	2000	1600	2300

(as we did) or time aerial surveys as close to the peak dates as we have shown (~22 June in high water years).

Johnson and Krohn (2001) indicated that timing of peak colonial waterbird counts varied among localities (islands), but were similar at a given island among years. Our data provide evidence that relatively little variability exists at a given nesting site in overall nesting phenology unless changes to nearby water levels occur. During years of greatest number of nests (2014–2016), upper Great Lakes water levels were high and birds may have abandoned nearby low lying islands and nested (or renested) at the USCG site (http://www.glerl.noaa.gov/pubs/brochures/lakelevels/lakelevels.pdf, accessed September 2015). This observation suggests that a correlation may exist among surrounding water levels, past colony productivity, and bird nesting chronology.

Conclusion

Although our study has not been replicated at other colonies in the Great Lakes or elsewhere, we suggest our methodology is useful for common terns, and potentially other colonial waterbirds, for the following reasons: 1) anthropogenic habitats are of increasing importance for breeding birds in the region and 2) anthropogenic habitats often require multiple visits throughout a breeding season for management of predators. We therefore conclude that our method for monitoring colonial waterbirds using fixed PVC quadrats may have broad utility at other anthropogenic sites in the Great Lakes.

Past research has documented levels of error among different methods used to estimate the number of colonial waterbird nests or breeding pairs; however, we were unable to find published studies pertaining specifically to common terns. Hutchinson (1979) compared aerial counts (those done from a plane whereby the observer counts nests in real time), ground counts (direct nest counts), and aerial photo counts (photo interpretation). Findings showed that aerial counts had a higher error rate (12%) compared to ground counts (5%), with error rates increasing to 33% for counts conducted by photo interpretation when vegetation was dense (usually late June and July). No published study we found used fixed quadrats to monitor colonial waterbirds, but studies have shown their use in evaluating habitat (Cook-Haley and Millenbah, 2002; Lamb, 2015). Future studies should include a more structured experimental design that compares ground based (direct) total counts, data from fixed PVC quadrats, and aerial photo interpretation using data collected concurrently.

The relative importance of vegetation management for common terns nesting on anthropogenic sites is unknown as there have been few controlled studies and publications. At our study site, vegetation was mowed annually before the birds arrived. However, mowing by itself maintains a dominance of herbaceous vegetation that by the end of the breeding season generally exceeds what many authors suggest as preferred conditions, namely cover of ≤30% and vegetation height of ≤0.60 m (see Cook-Haley and Millenbah, 2002; Lamb, 2015). In many of our control quadrats containing nests, vegetation cover was 100% and nearly 1.0 m in height. Although we were not able to document an effect of treatment on the number of nests, others have found complete herbicide treatments reduced the number of nests (Cook-Haley and Millenbah, 2002). Moreover, these authors suggested that patchy vegetation may benefit chicks by providing cover from predators and the elements. Anecdotal evidence at our site suggests that a monoculture of tall, herbaceous vegetation may hold moisture after rain events and lead to increased chick mortality. Our data suggest that mowing treatments continue, but that other treatments may yet be unwarranted. Additional study is required to ascertain how vegetation management may affect chick survival.

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