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Behavior, Nest Site Selection and Success of Black Terns (Chlidonias niger)

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BEHAVIOR, NEST SITE SELECTION AND SUCCESS OF BLACK TERNS

By

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BEHAVIOR, NEST SITE SELECTION AND SUCCESS OF BLACK TERNS

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ABSTRACT

BEHAVIOR, NEST SITE SELECTION AND SUCCESS OF BLACK TERNS

By

Dawn S. Marsh

The Black Tern (*Chlidonias niger*) population has markedly declined over several decades in northern North America, the causes of which are still largely unknown. I monitored nest success and wetland use by Black Terns in three colony sites in northern Michigan throughout 2017 and 2018 and used traditional survey methods coupled with nest cameras to document Black Tern nest success and mortality events. Colony sites included in this study were experiencing invasion by non-native plant species including *Phragmites*, hybrid and narrow-leaved cattail (*Typha* spp.), and European frog-bit (*Hydrocharis morus-ranae*). Statistically significant differences ($P < 0.05$) were observed between the average percent cover of submerged aquatics and floating aquatics near nest sites and random points, which suggests that Black Terns may be avoiding areas with high levels of floating and submerged aquatic plants. While *Phragmites* and invasive cattails can degrade the overall structure of the marsh and limit suitable nesting habitat, European frog-bit and other invasive floating aquatic plant species may pose a greater threat to nest success by reducing the amount of open water at nest sites and preventing incubating terns from defending their nests from aquatic predators. I documented nest disturbance and predation events including an instance in which a common snapping turtle (*Chelydra serpentina*) depredated an entire brood of chicks. This study is the first to document snapping turtles as a predator of Black Terns. My results provide further insight into potential factors limiting Black Tern chick survival in the Great Lakes region and the use of nest cameras to monitor nest success.

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PREFACE

Each chapter is presented as a standalone manuscript in the formatting style of *Waterbirds*. (https://waterbirds.org/journal/information-for-contributors/).

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CHAPTER 1

BLACK TERN NEST SUCCESS, SITE SELECTION, AND RESPONSE TO INVASIVE PLANT SPECIES IN NORTHERN MICHIGAN

ABSTRACT.—The Black Tern (*Chlidonias niger*) population has markedly declined over several decades in northern North America, and the species is listed as a species of special concern in Michigan. The causes of the decline are not clear. I monitored nest success and wetland use by Black Terns in three established colony sites in northern Michigan during 2017 and 2018. I documented Black Tern nest success and mortality events of chicks using traditional survey methods coupled with nest cameras. Nest success rates ranged from 71% (49–85%) at Wigwam SWA to 82% (59–93%) at Dollarville SWMA during the study. Colony sites included in this study were experiencing invasion by non-native plant species including *Phragmites*, hybrid and narrow-leaved cattail (*Typha* spp.), and European frog-bit (*Hydrocharis morus-ranae*). The average percent cover of submerged aquatics was greater ($P < 0.05$) at random points than at nest sites, which suggests that Black Terns avoided areas with high levels of floating and submerged aquatic plants. The amount of submerged aquatic cover present at the time of nest site selection may help Black Terns select sites that will have less floating aquatic cover later in the nesting season. Black Tern nests were primarily composed of floating aquatics and muck mats at colony locations where suitable habitat was limited due to dense monocultures of invasive emergent plant species. Though *Phragmites* and invasive *Typha* spp. can degrade the overall structure of the hemi marsh and limit suitable nesting habitat, European frog-bit and other invasive floating aquatic plant species may pose a greater threat to nest success by reducing the amount of open water at nest sites and preventing incubating terns from defending their nests from aquatic predators. **Key words**. — Black Tern, *Chlidonias niger*, emergent wetlands, Great Lakes, invasive species, nest success, wetland species.

Black Terns (*Chlidonias niger*) are semi-colonial nesting waterbirds that require highly productive and ecologically diverse wetlands for breeding and may serve as indicators of the overall health of freshwater wetlands within their summer range (Matteson *et al*. 2012). Black Terns nest on floating mats of dead emergent wetland vegetation including hardstem bulrush (*Schoenoplectus acutus*) and cattails (*Typha* spp.). In the Midwest, Black Terns commonly nest in Great Lakes marshes, which are herbaceous wetland communities found along the Great Lakes shorelines and major connecting rivers (Kost *et al.* 2007).

The Black Tern population has noticeably declined rangewide. Results from the North American Breeding Bird Survey indicated a 2.25% annual population decline in the United States from 1966 to 2015 (Sauer *et al*. 2017). Along the Great Lakes, a 45% decline in Black Tern colonies was documented between surveys conducted in 1991 and surveys conducted during 1997–1999 (Scharf 2011). Black Terns were absent at seven historical nesting sites in a survey conducted by the Wisconsin Department of Natural Resources from 1980 to 2011 (Matteson *et al*. 2012). Two of the seven nesting sites are coastal, defined here as being located within 25 km of one of the Great Lakes. Black Terns once nested at numerous sites along the Green Bay shoreline but have disappeared from the area due to habitat degradation, pollution, human activities, an extended period of high water, and the subsequent spread of non-native *Phragmites*, which currently covers at least 75% of once-productive Black Tern habitat (Epstein *et al*. 2002; Matteson *et al.* 2012). In Michigan, 89 previously documented Black Tern colony sites have been abandoned since surveys were conducted during 1982–1988, and the number of townships with documented Black Tern observations during surveys has decreased, with a 71%

decline in the Upper Peninsula and a 48% decline in the northern Lower Peninsula over a 20-year period (Scharf 2011).

Great Lakes wetlands face a loss of diversity and community structure due to the introduction of invasive species, the bulk of which are plant species, including common reed (*Phragmites australis australis*), narrow-leaved cattail (*Typha angustifolia*), and hybrid cattail (*Typha* x *glauca*) (Mills *et al.* 1993; Galatowitsch *et al*. 1999; Kost *et al.* 2007; Trebitz and Taylor 2007; Lishawa *et al.* 2010). Successional processes, changes in water levels, and degradation of water quality can render wetlands unsuitable for nesting Black Terns (Novak *et al.* 1999). In the southern Great Lakes region, Black Tern occupancy rates decreased the most among 15 marsh-nesting bird species studied by Tozer (2016) during 1996 – 2013, possibly because of increases in *Phragmites* and purple loosestrife (*Lythrum salicaria*) cover throughout coastal wetlands.

Within the Prairie Pothole Region, Linz and Blixt (1997) observed a positive correlation between Black Tern wetland use and areas composed of open water and dead cattails. Black Tern nest success may be reduced by the presence of invasive plant species when monocultures of invasive stands limit open water in wetland complexes (Zedler and Kercher 2004). Research on the influence of invasive plant species on Black Tern colonies and nest success is needed to guide future management actions directed towards controlling invasive plant species in wetlands.

Previous research on Black Tern nest success has focused primarily on broadly describing preferred habitat and testing new on-the-ground nest monitoring techniques (Hickey and Malecki 1997; Mazzocchi *et al*. 1997; Naugle *et al*. 2000; Maxson *et al*. 2007). Additional studies have focused on developing indices for predicting nesting areas (Shealer and Alexander 2013; Wyman and Cuthbert 2016). Relatively few studies have been conducted in the northern

Great Lakes region (Shealer and Haverland 2000; Maxson *et al*. 2007), and only one study has been published documenting Black Tern nest success at a historic colony site in Michigan (Cuthbert 1954).

Nest success in semi-colonial nesting waterbirds is difficult to monitor due to observer time limitations, inaccessible nest locations, and potential detrimental effects on nesting birds from increased disturbance in the colony. Biologists rarely find Black Tern chicks five days post-hatch or older (Shealer and Haverland 2000), because they are mobile and difficult to track once disturbed by an observer. My goal was to 1) document nest success and related behaviors (parent-chick interactions, mortality events, and foraging behaviors) of Black Terns at multiple coastal and inland nesting sites in Michigan using traditional survey methods coupled with trail cameras, 2) determine whether Black Tern nest site selection and wetland use is associated with the distribution of invasive plant species, and 3) provide recommendations for management that enhances Black Tern nest success in coastal and inland wetlands throughout the Great Lakes region.

METHODS

Study Areas

Dollarville Flooding State Wildlife Management Area (Luce County, Michigan). The 445 ha Dollarville Flooding site is located 2.7 km west of Newberry in Michigan's Upper Peninsula and is accessible via a public boat launch (46° 35' 10.40" N, 85° 58' 20.23" W). The area is surrounded by undeveloped state forestland and contains about 200 ha of suitable nesting habitat for Black Terns (Fig. 1.1). Citizen scientist reports submitted to eBird (Sullivan *et al.* 2009) have described an annual breeding colony of about 40 Black Terns in the Dollarville Flooding area. *Phragmites* is well established there. The substrate is primarily composed of organic matter with sand interspersed throughout. Water depths are ≤ 1 m throughout the flooding (Kovacs 2014), but nest monitoring must occur by boat due to the unstable substrate. The area is popular with recreational boaters and anglers and is managed by the Michigan Department of Natural Resources (MDNR) as the Dollarville Flooding State Wildlife Management Area (SWMA).

Munuscong State Waterfowl/Wildlife Management Area (Chippewa County, Michigan). Munuscong Bay is located 10 km northeast of Pickford in Michigan's Upper Peninsula. Sault Tribe Inland Fish and Wildlife Department staff have observed at least two colonies of Black Terns nesting along the St. Mary's River in the 526 ha Munuscong wetland complex since 2015. Although Black Terns have nested in the Munuscong Bay area since at least 1992 (Sullivan *et al*. 2009), the nesting area may be threatened by encroaching non-native cattail, *Phragmites*, and European frog-bit. This area is currently the site of a multi-disciplinary study examining early detection of and management techniques for invasive plant species (S. Lishawa and S. Mackinnon, pers. commun.). Combined, the colonies have had about 25–50 nests annually from

2015 to 2017. (J. Lautenbach pers. commun.). The specific nesting area I studied is accessible through the Munuscong State Waterfowl/Wildlife Management Area (SWMA), 46° 20' 85.86" N, 84° 25' 55.11" W, and is managed by the MDNR (Fig. 1.2).

When Lake Huron water levels fell in the 1950's and 1960's, the MDNR created a 6.4 km dike system with three impounded units. Current management plans include the installation of water control structures to better manipulate water levels to promote hemi-marsh habitat (Jentoft 2015). The area is only accessible by boat or by walking along one of the diked impoundments. The bay is a popular recreational site for anglers. Freighters, or cargo ships, use the nearby St. Mary's River channel to travel between Lake Huron and Lake Superior. Water levels in the colony sites vary and can fluctuate 15 cm hourly, likely due to a combination of freighter traffic and the nearby Soo Locks (D. Marsh, pers. obs.).

During the summer of 2017, I monitored a small Black Tern colony site within a 42 ha area situated between the mouth of the Munuscong River and a diked wetland management area (Fig. 1.2). The area I surveyed in 2017 was limited due to time constraints and safety concerns. In 2018, the main colony site was located 0.25 km away from the site surveyed in 2017. The 2018 Black Tern nest sites were within the impounded wetland management area southwest of the Munuscong River mouth.

Wigwam Bay State Wildlife Area (Arenac County, Michigan). Wigwam Bay is located on Lake Huron and is 9.3 km southwest of Au Gres. The bay has a small colony of 30–50 Black Terns nesting annually (C. Putnam, pers. commun.). The nesting area (192 ha) is accessible by boat or by walking along a series of dikes separating the complex from Lake Huron (Fig. 1.3). The Michigan DNR manages the Wigwam Bay State Wildlife Area (SWA) through a system of dikes, impoundments, and water control structures. *Phragmites,* narrow-leaved cattail, hybrid cattail, and purple loosestrife are well established in the area. The National Audubon Society – Great Lakes has initiated a habitat restoration project in Wigwam Bay to improve nesting habitat for Black Terns through invasive species management (N. Miller, pers. commun.).

Nest Survey and Monitoring Methods

I evaluated nest site selection by Black Terns in relation to invasive species by conducting systematic nest surveys at each study area throughout the breeding season, about 25 May through July (Mazzocchi *et al.* 1997; Shealer and Haverland 2000; Maxson *et al.* 2007). I conducted the surveys on foot or by kayak depending on the study area. Potential nesting sites were located by observing Black Terns from a distance with binoculars and waiting for individual birds to land repeatedly in a single location. When I observed this behavior, I visited the location to determine whether suitable substrate existed for nest building or if a nest had been established. GPS coordinates were recorded for each nest found. At each nest, I also recorded the date found, clutch size, and nest substrate. At each nest, at least one egg was floated to determine stage of incubation, based on Hays and LeCroy's (1971) egg flotation method. I used the incubation stage to estimate when the first egg was laid and the predicted hatch date. I visited each site weekly from 20 May through 22 July. Weekly visits were believed to have little impact on the colony, because observer disturbance has a minimal effect on nesting Black Terns (Shealer and Haverland 2000). I considered nests successful if I observed at least one chick within 3 m of the nest site. I revisited nests weekly post-hatch until it was clear the nest had failed (broken eggshell or submerged eggs) or if no adults were observed mobbing or in the nesting area.

Nest Cameras

I used nest cameras (Bushnell Trophy Cam HD Essential E2 ®) to monitor nests, document hatching and fledgling success, and compare monitoring techniques. Ten nest cameras were installed at the Munuscong State Wildlife Management Area study area for the duration of the nesting season in 2018. Only six were installed in 2017. Cameras allowed nests to be monitored continuously rather than weekly. The nest cameras for the study were chosen based on their size and potential battery life. Before installation at nests, cameras were tested in the wetland to determine appropriate settings to minimize the number of photos without birds or predators present. The nest cameras were attached to 1.5 m tall green steel fence u-posts and were installed about 15 cm above the surface of the water (Fig. 1.4).

The cameras were installed before the predicted hatch date and remained focused on the nests until the nests became inactive or the hatch year birds were no longer present. During weekly site visits, memory cards and batteries in each camera were replaced and vegetation directly in front of the camera was removed to reduce the number of negative images, or images with no nest behavior data. The content of each memory card was reviewed between visits to determine the fate of each nest and document any nest disturbances. The use of cameras allowed me to compare colony-monitoring techniques (observations alone versus observations with cameras) and determine if cameras were able to record post-hatch behavior or predation attempts.

Vegetation and Wetland Characteristics

I identified and mapped suitable nesting habitat during preliminary site visits in late-May, just before the nesting season began. I conducted wetland vegetation assessments post-breeding season (mid-July) to limit disturbance to any remaining birds in the colony. Wetland vegetation for each colony was characterized through aerial imagery and on-the-ground verification. When invasive plant species were found at a colony, I mapped their locations during the vegetation assessment post-breeding season. I measured the distance between identified nests and invasive plant species using a laser rangefinder (Leupold RX-650 ®, accuracy ± 0.9144 m). I aimed the beam at the nearest stand of invasive plant species and recorded the distance to the nearest 0.1 m. If the closest invasive plant stand was not visible from the nest site, I used ArcGIS (ESRI 2015) to measure the distance between the plant stand and the nest. When the transition from native to nonnative vegetation was gradual, I recorded coordinates at the closest occurrence of nonnative vegetation.

All emergent vegetation within 2 m of the nest and 25 m of the nest was categorized as cattail (*Typha* spp.) and large-fruited bur-reed (*Sparganium eurycarpum*), bulrush, sedge, grass, or floating aquatics (similar to Maxson *et al*. 2007) using the following cover abundance scale: <1% - 1, 1-20% - 2, 21-40% - 3, 41-60% - 4, 61-100% - 5 adapted from Braun-Blanquet (1932). I also estimated the percent cover of submerged aquatic macrophytes through visual observations. In cases where an invasive species (e.g. European frog-bit) was present throughout the colony site, I categorized the percent cover for the species separately.

To maintain consistency with previous studies, I measured the following at each nest: mean water depth (water depth was measured along four sides of each nest), distance to open water (defined as an open area of water ≥ 0.25 m^2 in size), and the percent of open water (defined as an open area of water ≥ 0.25 m^2 in size) within 2 m of the nest (Mazzocchi *et al*. 1997; Maxson *et al*. 2007). The same information was collected at 20–35 random points (generated in ArcMap) within suitable nesting habitat at each colony. I defined suitable nesting habitat as areas interspersed with stands of emergent vegetation and open water with water depths ranging from 0.5 to 1.5 m.

Statistical Analyses

I used nest survival models in Program MARK (White and Burnham 1999) to investigate the influence of covariates (site, year, and nest substrate [cattail and bulrush, other]) on nest success. Nests with unknown fates were right-censored after the last date they were known to be active. I calculated nest success based on an incubation period of 21 days (Goodwin 1960; Bergman *et al.* 1970; Mazzocchi *et al.* 1997). I used multi-model inference and Akaike's Information Criterion adjusted for small sample sizes (AICc), AICc differences and AICc weights to evaluate support among competing models (Burnham and Anderson 2002). To investigate the influence of covariates (e.g., site, year, nest substrate), I began with two general models (null and time) with which I constrained success to be constant among covariates. I constructed seven additional models a priori to evaluate the influence of site, year, and substrate on nest survival. Models with ΔAIC values less than 2.0 were deemed competitive with the best model.

Nest camera data were analyzed qualitatively. Vegetation data were analyzed using SPSS (IBM Corp 2017). Nest site substrate composition was compared to the random substrate points using descriptive statistics (e.g., means and 95% confidence intervals) and independent samples t-tests. I compared nest site wetland characteristics to random sites located within suitable nesting habitat for the average percent cover of floating aquatics, submerged aquatics, native Typhaceae spp., non-native *Typha* spp., *Schoenoplectus* spp., *Carex* spp., Poaceae spp., *Phragmites* (Dollarville SWMA and Wigwam SWA), European frog-bit (Munuscong SWMA), and open water within 2 m and 25 m of the nest or a random point. The average water depth at nest sites and random points was examined using independent samples t-tests.

RESULTS

Nest Initiation and Success

Throughout the summers of 2017 and 2018, 52 Black Tern nests were identified within the Dollarville Flooding State Wildlife Management Area (SWMA) and 46 nests were identified within the Munuscong SWMA (Table 1.1, Fig. 1.1, Fig. 1.2). In 2018, 40 nests were monitored at Wigwam SWA (Table 1.1, Fig. 1.3). Nest initiation dates ranged from 26 May to 22 June, with the overall average being 2 June (Table 1.2). Nest initiation data were not available for Wigwam SWA in 2017 or 2018. Clutch sizes ranged from 1 to 3 at all sites with 89% of the nests having a 3-egg clutch at Dollarville SWMA, 87% at Munuscong SWMA, and 68% at Wigwam Bay SWA. Mean clutch size ranged from 2.61 to 2.93, with the largest average clutch size at the 2017 Dollarville Flooding colony, 2.93 ± 0.26 (SD; n = 27) and the smallest at the 2018 Wigwam SWA colony, 2.61 ± 0.63 (SD; n = 41).

The null model was the best-supported of my candidate models but support for the year model and the substrate model was similar (ΔAICs = 1.93 and 1.98, respectively; Table 1.4). However, the confidence intervals for the β values for both year and substrate included 0. Further, nest success rates were very similar among all three models and point estimates between years and between substrates were very similar with broadly overlapping confidence intervals. All other models received considerably less support (ΔAICs > 3). Thus, I detected no influence of year, nest substrate, or site on nest success of Black Terns, and all nest success estimates were generated with the null model.

Nest success rates ranged from 71% (49–85%) at Wigwam SWA to 82% (59–93%) at Dollarville SWMA. I documented predation at three of the 98 nests I monitored during 2017–2018. At one of the depredated nests, an egg appeared to have been punctured by an avian predator, likely an American crow (*Corvus brachyrhynchos*), blue jay (*Cyanocitta cristata*), or gull (*Larus* spp.) (Fig. 1.5*a*). The second predation incident I noted resulted in a chick being decapitated, with a tuft of down and the legs of the chick found in the nest (Fig. 1.5*b*). This may have been due to a mink (*Mustela vison*) because the species is known to decapitate prey and leave remains (Nuechterlein *et al*. 2003).

One of the nest cameras deployed in Munuscong SWMA documented a snapping turtle depredating an entire brood of chicks within five minutes at a nest site in 2017. The other three failed nests all appeared to have been flooded or depredated, as multiple eggs were found floating in the water within one meter of the nest site. At least one of the failed nests in 2018 was caused by nocturnal muskrat activity. The nest was located near a muskrat lodge and the nest camera documented a muskrat swimming and climbing over the nest repeatedly, eventually flooding the nest (Fig. 1.5*c*). The other nests showed no evidence to indicate the cause of the failure.

Many of the nests with unknown fates may have hatched considering exhibited parental behavior at the nest site (e.g., territorial or protective behaviors near the nest location). Nests classified as unknown were often visited a few days after the predicted hatch date and no chicks or eggs were observed within 3 m of the nest site. The chicks may have been depredated between hatch and the subsequent nest check, but the nest fate remains unknown.

Vegetation and Wetland Characteristics at Nest Sites

Of the 98 nests monitored at Dollarville SWMA and Munuscong SWMA, 88 (90%) were constructed solely out of cattail or in combination with bulrush, aquatic macrophytes, or muck. Two nests were placed on abandoned Canada goose nest mounds, three nests were made from horsetail, and three nests were located on invasive *Phragmites* root systems. Six nests (13%) were constructed out of bulrush or incorporated bulrush in the nest cup. Nest substrate data was not available for the nests at Wigwam SWA. Wetland plant species commonly found within 2 m of nest sites included common cattail, narrow-leaved cattail (*Typha latifolia*), hybrid cattail, hardstem bulrush, large-fruited bur-reed, common reed, yellow waterlily (*Nuphar advena*), white waterlily (*Nyphaea odorata*), northern bladderwort (*Utricularia vulgaris*), pondweed (*Potamogeton* spp.), willow (*Salix* sp.), and horsetail. European frog-bit was found throughout the Munuscong SWMA study areas (Fig. 1.3).

At the 2 m scale, differences in the average percent cover of Typhaceae spp. (non-native and invasive), *Schoenoplectus* spp., *Phragmites*, Poaceae spp., and open water between nest sites and random points in 2017 were not significant ($P > 0.05$); however, average percent cover differed significantly between floating aquatics and submerged aquatics (Table 1.5, Fig. 1.6). There was no significant difference between the 2017 nest sites and random points at Munuscong SWMA and vegetation data were not collected at Wigwam SWA in 2017 (Fig. 1.8).

In 2018, no significant difference was detected between the nest sites and random sites for Typhaceae spp., *Schoenoplectus* spp., *Carex* spp., Poaceae spp., submerged aquatics, and *Phragmites* at Munuscong SWMA or Wigwam SWA (Fig. 1.7, Fig. 1.8). The average percent covers of floating and submerged aquatics were significantly different between nest site locations and random points within the Dollarville Flooding SWMA study area (Table 1.5, Fig. 1.6). The average water depths at nest sites and random sites in 2018 were significantly different in Dollarville Flooding SWMA (t_{44} = 2.844, P = 0.007); however, no significant difference in water depth was documented at Munuscong SWMA or Wigwam SWA (Table 1.6).

The wetland characteristics sampled within a 25 m radius of the nest sites or random sites in 2018 were similar across most of the sampled wetland characteristics at all three study areas (Fig. 1.9, Fig 1.10, Fig. 1.11). I found a significant difference between the average percent cover of *Schoenoplectus* spp. (t_{39} = 2.085, P = 0.044) at Dollarville Flooding SWMA (8 ± 5% at nest sites, 18 ± 8% at random points). Significant differences in the average percent cover of submerged aquatics (t_{61} = 0.207, P = 0.031) and open water (t_{65} = 2.084, P = 0.041) were detected at the Munuscong SWMA study area. Nest sites appeared to have lower average percent covers of open water (27 ± 8% at nest sites, 41 ± 10% at random points) and submerged aquatics (15 ± 5% at nest sites, 24 ± 7% at random points). I compared the average distance from *Phragmites* from the 2017 nest sites and random points at Dollarville and did not detect a significant difference (P > 0.05). No test could be performed to determine whether nest site wetland characteristics are a predictor of nest success due to small sample sizes.

The average percent cover of submerged aquatics and open water at the 2 m scale was lower at nest sites than at random points for the Black Tern colony sites monitored at Dollarville SWMA and Munuscong SWMA in 2017, and all three study areas in 2018 (Fig. 1.6, Fig. 1.7, Fig. 1.8). Similarly, the average percent cover for floating aquatics at the 2 m scale appeared to be lower at the 2017-18 nest sites than at random points for areas sampled at Dollarville SWMA and Munuscong SWMA (Fig. 1.6 and Fig. 1.7). At the 25 m scale, the percent cover of open water was the only wetland characteristic that was consistent among the study areas from 2017 to

2018, and the amount of open water appeared to be greater at random points than at nest sites (Fig. 1.9, Fig. 1.10, Fig. 1.11).

DISCUSSION

Nest Initiation and Success

The average nest initiation dates for Black Tern colonies I monitored during 2017 and 2018, ranged from 1 June through 5 June (Table 1.2), similar to previously documented initiation dates. Nest initiation dates for Black Terns in the Great Lakes region have ranged from 11 May to 4 August with the majority of nests initiated during the first week of June (Bent 1921; Provost 1947; Cuthbert 1954; Mazzocchi *et al*. 1997; Shealer and Haverland 2000; Maxson *et al*. 2007). The phenology of Black Tern nest initiation has remained relatively unchanged over the past 100 years (Bent 1921; Provost 1947; Cuthbert 1954; Mazzocchi *et al*. 1997; Shealer and Haverland 2000; Maxson *et al*. 2007).

Mean clutch size, as reported in previous studies, ranges from 2.25 to 2.9 (Cuthbert 1954; Mazzocchi *et al*. 1997; Shealer and Haverland 2000). Black Terns commonly lay 3-egg clutches, but have been reported to lay up to five eggs (Bent 1921). Throughout my study, clutch size ranged from one to three eggs with over 65% of monitored nests having a 3-egg clutch. The larger average clutch size at Dollarville 2.93, ± 0.26 (SD; n = 27) may be related to the quality of the available nesting habitat. The Dollarville Flooding SWMA has far fewer invasive plant species than the Wigwam SWA and is more of a hemi-marsh in structure.

The nest success rates at Dollarville Flooding and Munuscong State Wildlife Management Area fall within the previously reported range. The nest success estimates for Dollarville (75% - 2017, 82% - 2018) and Munuscong (74% - 2017, 81% - 2018) were larger than the estimates for Wigwam colony (71% - 2018) but confidence limits overlapped considerably (Table 1.3). Previous estimates of nest success have ranged from 36% to 62%

(Mazzocchi *et al*. 1997; Shealer and Haverland 2000; Maxson *et al.* 2007). Although the point estimate of nest success for Dollarville is higher than previously reported averages, the wide confidence intervals overlap the reported range.

Nest failure in Black Terns has been attributed to heavy rains and wind, and predation by Black-crowned Night Herons (*Nycticorax nycticorax*), Great Blue Herons (*Ardea herodias*), Great Horned Owls (*Bubo virginianus*) and aquatic mammals, such as muskrats (*Ondatra zibethicus*) and North American river otters (*Lontra canadensis*) (Chapman and Forbes 1984; Shealer and Haverland 2000; Gilbert and Servello 2005; von Zuben and Nocera 2015). On 11 June 2017, a large storm front producing over 80 kph winds affected the Munuscong colony but none of the known nests were lost due to flooding. The nest cameras documented the terns incubating the eggs throughout the storm with no apparent damage. The monitored colony site in Munuscong Bay is protected from wave action caused by wind or by freighters traveling in the St. Mary's River. However, two nests appeared to have been destroyed with no apparent damage to the eggs. One of the nests was located in the interior of the colony site and was not likely to have been flooded due to wave action.

Non-native carp (Cyprindae) species may reduce Black Tern nest success. In Manitoba, carp have been documented destroying Western Grebe (*Aechmophorus occidentalis*) nests, which are constructed in a manner similar to Black Tern nests, by thrashing during the spawning period. Degradation of suitable nesting habitat is also a concern as carp can influence the density of aquatic macrophytes (La Porte *et al.* 2014). Common carp (*Cyprinus carpio*) were observed spawning throughout the nesting area at Munuscong in early June and may have caused nest failure at two sites located deep in cattails where wave action was unlikely to be a factor. The nests were destroyed and the eggs found floating nearby with no apparent puncture marks. While surveying and monitoring the colony, I commonly observed multiple carp during each visit rubbing up alongside my leg or thrashing against my kayak as I monitored the colony (Figure 1.5*d*). Nest cameras in the Munuscong SWMA documented many occurrences of carp thrashing near nests, soaking eggs and disturbing the incubating adult.

Snapping turtles have not been reported as predators of Black Tern chicks (as reviewed in Heath *et al.* 2009) but they are presumed to be a likely aquatic predator. Using nest cameras, I documented a snapping turtle depredating an entire brood of chicks in a matter of minutes. Without the camera, the nest would have been classified as failed with unknown cause, because no adults were present and there was no evidence of chicks in the area. The photos indicate chicks had nowhere to flee once the snapping turtle observed them, as the turtle swam through the nest substrate and circled back for the chicks. Another nest camera documented a snapping turtle swim up to a nest with eggs, lift its head out of the water, and then fully submerge. The chicks were not observed at the nest site five days post-hatch and may have been depredated by the turtle. Snapping turtles are relatively abundant in most northern Michigan wetlands, suggesting turtles could be important predators of Black Tern chicks.

Vegetation and Wetland Characteristics at Nest Sites

Nest success appears to vary regionally, temporally, and among colonies. Relatively few large Black Tern colony sites remain in the Midwest and it is difficult to identify relationships between nest success and habitat characteristics (Mazzocchi *et al*. 1997). Hypotheses surrounding nest site selection have included protection from wind and wave action, availability of floating substrates, ease of landing and taking off, and proximity to feeding areas (Maxson *et al.* 2007).

Mazzocchi *et al.* (1997) measured the mean water depth at nests and found them to range from 49.5–59.7 cm, with no significant difference between successful or unsuccessful nests. The average water depth at Black Tern nests can vary from 50–120 cm (as reviewed in Heath *et al*. 2009). The nests at all three study areas fell within the wide range of previously reported water depths (Table 1.6). Water levels among sites may vary daily, temporally, and regionally; but they have the ability to influence the structure of the wetland (Wilcox 2004). Shallow wetlands or areas with low water levels are likely to be invaded by *Phragmites* (Galatowitsch *et al*. 1999). Periods of high water levels are likely to eliminate competitively dominant emergent vegetation including *Typha* spp. and *Schoenoplectus* spp. (Wilcox 2004). Black Terns have also seemed to be attracted to areas with deeper water and bulrush, sedges, or grasses nearby (Maxson *et al*. 2007).

In previous studies, nests were often located within 7 m of open water but Black Terns tended to avoid dense stands of emergent vegetation, commonly described as being “too dense to paddle a canoe through” (Cuthbert 1954; Maxson *et al*. 2007). At Munuscong, many of the nests were located away from the water edge of the bay. The Black Terns may be avoiding areas with where there is a greater chance of nest failure due to wave action, or in rare instances, seiches.

The type of emergent vegetation present in a wetland could influence the amount of wave energy affecting colony sites. Bulrush stands often have greater stem density and underwater surface area than cattails (native and invasive) and thereby attenuate wave energy more efficiently due to the greater amount of frictional force applied to the wave (Hall *et al.* 1998). Black Terns may select locations with high densities of bulrush stems to reduce the likelihood of their flimsy nests falling apart from wave action. While cattails and bulrushes are often cited as key vegetative features in suitable Black Tern breeding habitat (Cuthbert 1954; Mazzocchi *et al.*

1997; Kost *et al.* 2007; Maxson *et al.* 2007), my data do not consistently show a preference for bulrush at nest sites.

The impact of invasive plant species typically is described as decreasing biodiversity and degrading quality habitat (Mills *et al.* 1993; Galatowitsch *et al*. 1999; Kost *et al.* 2007; Trebitz and Taylor 2007; Lishawa *et al.* 2010; Robichaud and Rooney 2017). In wetlands, invasive *Phragmites* and purple loosestrife have been described as degrading the wetland by reducing high quality bird habitat, reducing plant biodiversity, and changing wetland decomposition rates (as reviewed in Blossey *et al.* 2001; Robichaud and Rooney 2017). While I found no clear influence of invasive species on nest success or nest site selection, the influence of invasive plant species on nesting bird species has been documented in urban songbirds and grassland bird species (Schmidt and Whelan 1999).

Invasive plant species can affect predation rates in nesting birds. An invasive species of honeysuckle influenced predation rates on American Robin (*Turdus migratorius*) and Wood Thrush (*Hylocichla mustelina*) nests, as nests initiated in invasive *Lonicera* or *Rhamnus* shrubs experienced higher predation due to plant morphology (Schmidt and Whelan 1999). A similar effect may be occurring at the Wigwam SWA study area where nest success was estimated to be 10% lower than the 2018 Dollarville Flooding SWMA and Munuscong SWMA colony sites (Table 1.3). Of the study areas, the Wigwam wetland complex has experienced the greatest amount of habitat degradation from invasive plant species (D. Marsh, pers. obs.).

Phragmites australis has the potential to change the structure of the suitable nesting habitat available at Dollarville. Currently, the patches of *Phragmites* are in the early stages of invasion and may contribute to the heterogeneity of the wetland (Robichaud and Rooney 2017). Studies examining bird species richness and composition in response to *Phragmites* invasions have documented an increase in abundance and richness during the early stages of invasion (Meyer *et al.* 2010; Gagnon Lupien *et al.* 2014). However, Robichaud and Rooney (2017) recently found that bird species composition is altered by *Phragmites* after the species has become fully integrated in the wetland. *Phragmites* seems to reach an equilibrium point in the invasion once the species accounts for 50–80% of the marsh surface (Lathrop *et al*. 2003). *P. australis* has the potential to increase rates of sediment accretion in a wetland by 3–4 mm per year beginning at least seven years post-colonization. Dead litter collects on the surface of the marsh and traps organic and mineral matter that later forms sediment (Rooth *et al.* 2003). The increased accumulation of sediment may lead to the filling in of standing water habitat that Black Terns use for foraging and nesting (Lathrop *et al.* 2003).

The rapid expansion of *Typha* x *glauca* into Great Lakes wetlands is troublesome because invasive cattail species can negatively affect wetland composition whether they are alive or dead. The litter produced by *Typha* x *glauca* is dense, reduces the amount of light available to native plants and crowds out native emergent vegetation (Larkin *et al.* 2012). As a hemi-marsh species, Black Terns are dependent on wetlands with open water throughout emergent vegetation such as bulrush (*Schoenoplectus* spp.) and cattail (*Typha* spp.). Narrow-leaved and hybrid cattails are present at all three of the study areas and appear to be in different stages of invasion.

The Black Tern colony at Wigwam SWA was nesting primarily on floating aquatics or muck mats (83% of all known nests). This was likely due to the overall structure of the wetland, which differed substantially from what I observed at Dollarville SWMA and Munuscong SWMA. Anecdotal observations from surveyors noted that nests were first initiated in an area of the marsh composed of sedge hummocks. Late-arriving birds primarily nested on floating aquatics and muck mats (E. Rowan and A. Landgraf, pers. commun.).

Wigwam SWA has extensive stands of cattail; however, the stands have become a dense monoculture of invasive cattails and no longer exhibit a hemi-marsh structure. This may explain why the Black Tern colony largely nests in the periphery of the marsh, rather than the interior where Black Terns have a tendency to nest (Shambaugh 1995). Emergent invasive plant species likely do not negatively influence nest site selection during the early stages of invasion because the structure of the marsh is similar to one composed of native plant species. However, once a monoculture of invasive emergent plants has been established, habitat quality may be degraded to a point where Black Terns nest in areas with reduced emergent plant cover and increased exposure to avian and aquatic predators.

The spread of invasive plant species in Munuscong Bay was evident because most cattail stems at nest sites or random points were narrow-leaved cattail or hybrid cattail. The average percent cover of invasive cattail was 40% and native cattail was less than 10%. European frog-bit was also pervasive throughout the area. Frog-bit is a free-floating plant with the ability to form dense clusters on the surface of the water (Catling *et al.* 2003). Based on the percent cover data for European frog-bit, Black Terns may be selecting areas with less floating aquatics cover to ensure open water is present near the nest site. In 2017 and 2018, the average percent cover of floating aquatics and European frog-bit was lower at nest sites than at random sites (Table 1.5). The difference in frog-bit cover at nest sites and random points may be small, but the combination of frog-bit and invasive cattail in the emergent wetlands along the St. Mary's River may pose a substantial threat to nesting Black Terns. Extensive and repetitive management actions are necessary to promote native vegetation and control the spread of invasive plant species.

Though I found no significant difference in submerged aquatics between random and actual nest sites, there were subtle differences that are worth more study (Fig. 1.7). The percent cover of Typhaceae species at 25 m from random points and nest sites was about the same. However, the lower percent cover of cattails at nest sites may indicate Black Terns are actively selecting areas as close to the hemi-marsh structure as possible; therefore, actively avoiding areas with a higher percent cover of floating aquatic vegetation.

The significant differences in the average percent cover of submerged aquatics and floating aquatics within 2 m of nest sites and random points at Dollarville SWMA and Munuscong SWMA may indicate Black Terns use visual cues and actively seek areas with reduced coverage by submerged aquatic plant species. Black Terns may use these visual cues to predict floating aquatic cover later in the nesting season (Table 1.5). By selecting areas with reduced floating aquatic cover, Black Terns may be able to maintain a line of sight into the water and watch for aquatic predators, including snapping turtles, which suggests nest site selection could be driven by predator avoidance. Frog-bit germinates in late spring and is not visible until after sites have been selected and eggs laid (Catling *et al.* 2003). A single European frog-bit turion, or shoot, can cover about $1m^2$ in one nesting season, reducing the percent cover of open water and potentially negatively affecting Black Tern nest success (Cook and Lüönd 1982; Catling *et al.* 2003).

Management Recommendations

Based on my results, maintaining a hemi-marsh structure in the face of expanding invasive plant monocultures is important for maintaining areas of open water within suitable nesting habitat. While Black Terns may readily nest in stands of invasive emergent plants, the life history traits of invasive plant species indicate they are likely to maintain suitable wetland structure only a few years before the plant has colonized the area and the emergent vegetation is too dense for use by Black Terns. Additionally, increased cover of invasive floating aquatic plant species may be more detrimental to Black Terns by reducing the amount of open water at nest sites and preventing incubating terns from protecting the nest from aquatic predators.

The emergent wetlands in the Munuscong area may be threatened more than the wetlands at Dollarville, because the St. Mary's River is likely to be invaded by aquatic invasive species and invasive plant species that have arrived via the ballast of the shipping freighters (Mills *et al*. 1993). Inland colony sites located away from shipping corridors are still at risk of invasion from recreational anglers and boaters that may spread invasive plants by unintentionally transporting them between bodies of water. Early detection and rapid response methods, including mechanical removal, use of approved herbicides, water management, and prescribed fire, are needed at the Dollarville Flooding SWMA to prevent the spread of *Phragmites* throughout the study area.

The Wigwam SWA colony will likely see a decrease in Black Tern nest success in the future because of invasive plant species, unless openings are created within the dense, interior cattail stands. The site faces pressure from invasive plant species throughout the marsh and the surrounding area and will require extensive and repetitive management to restore quality Black Tern nesting habitat. If no management actions are taken, Black Terns will be restricted to nesting along the periphery of the marsh on floating aquatics and muck mats that offer less protection from predators.

Of the invasive plant species threatening hemi-marsh emergent wetland complexes in the Great Lakes region, invasive floating aquatics are likely to reduce Black Tern nest success the most. European frog-bit has the ability to alter existing hemi-marsh complexes by eliminating areas of open water interspersed with emergent vegetation (Cook and Lüönd 1982; Catling *et al.* 2003). Repeated mechanical removal of frog-bit from colonies may be required to prevent the species from completely invading wetland complexes.

Future Studies

My results provide a baseline of information and a snapshot in time at three historic and consistently active Black Tern colony sites in northern Michigan. In addition to refining nest monitoring methods to reduce the number of nests with unknown fates, long-term monitoring efforts of Black Terns and other wetland bird species are needed to improve our understanding of threats to historic colony sites. Additional studies examining the response of wetland bird species to invasive plant species in the Great Lakes region are necessary to determine appropriate management techniques. Long-term studies should be established in areas where the spread of invasive plant species is in the initial stages of colonization to better measure potential effects of invasive species throughout the colonization process. Experimental studies examining the effects of controlled invasive species management efforts, in areas with existing Black Tern colonies, on Black Tern use and nest success are recommended to determine the best course of action in the future. The implementation of a regional Black Tern conservation initiative group responsible for coordinating relevant research and monitoring efforts, while promoting collaboration, will be instrumental for developing management recommendations for Great Lakes wetland management and ensuring the species remains a fixture in North American emergent wetlands.

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TABLES AND FIGURES

Table 1.1 Number of Black Tern nests monitored and nest fate at each Michigan colony site in 2017 and 2018. The Black Tern colony at Wigwam State Wildlife Area was not monitored in 2017.

Year	Successful	Failed	Unknown	Total
Dollarville Flooding State Wildlife Management Area				
2017	11	3	12	27
2018	15	3	7	25
Munuscong State Wildlife Management Area				
2017	6	3	2	11
2018	19	4	12	35
Wigwam State Wildlife Area				
2017	--	--	--	--
2018	18	7	15	40

Table 1.2 Black Tern nest initiation dates, based on Hays and LeCroy's (1971) egg flotation method at each colony site throughout 2017 and 2018. Nest initiation data was not collected at Wigwam State Wildlife Area in 2017 or 2018.

Year	Earliest	Latest	Average
Dollarville Flooding State Wildlife Management Area (SWMA)			
2017	28 May	12 June	2 June
2018	28 May	22 June	5 June
Munuscong SWMA			
2017	30 May	10 June	5 June
2018	26 May	11 June	1 June

Table 1.3 Black Tern nest success in 2017 and 2018 at study sites in northern Michigan, USA. The colony site at Wigwam SWA was not monitored in 2017.

	2017		2018	
Study Area	Nests	Success (95% CI)	Nests	Success (95% CI)
Dollarville SWMA	25	75% (50–89%)	25	82% (59–93%)
Munuscong SWMA	9	74% (41–91%)	35	81% (61–92%)
Wigwam SWA	--	--	35	71% (49–85%)

Table 1.4 Candidate models used to evaluate the influence of study area, nest substrate, and year on nest success of Black Terns in three study areas in Michigan, 2017-18.

Model	*K*	AIC_c	ΔAIC_c	w_i	Model Likelihood
Null	1	127.24	0.00	0.41	1.00
Year	2	129.17	1.93	0.15	0.38
Substrate	2	129.22	1.98	0.15	0.37
Site+Substrate	4	130.29	3.05	0.09	0.22
Site	3	130.70	3.45	0.07	0.18
Year+Substrate	3	131.11	3.87	0.06	0.14
Site+Substrate+Year	5	132.03	4.79	0.04	0.09
Site+Year	4	132.29	5.05	0.03	0.08
Time	41	189.89	62.65	0.00	0.00

Table 1.5 Results of t-test comparisons of wetland characteristics sampled within 2 m of nest sites and at random points in 2017 and 2018 at study sites in northern Michigan.

	2017		2018	
Wetland Characteristic	*t*	*P*-value	*t*	*P*-value
Dollarville Flooding State Wildlife Management Area				
Floating Aquatics	4.355	0.001	3.502	0.001
Native Typhaceae spp.	--	--	1.718	0.092
Non-native *Typha* spp.	--	--	0.970	0.337
Open Water	1.490	0.142	1.616	0.113
Submerged Aquatics	1.741	0.088	2.501	0.016
Munuscong State Wildlife Management Area				
European Frog-bit	--	--	2.006	0.052
Floating Aquatics	--	--	2.187	0.034
Non-native *Typha* spp.	--	--	0.471	0.639
Open Water	--	--	1.229	0.223

Table 1.6 Average water depth (m) and distance to open water (m) with standard errors at Black Tern nest sites and random points at monitored colony sites in northern Michigan.

	Average Water Depth (m)		Distance to Open Water (m)	
	Nest Site	Random Point	Nest Site	Random Point
Dollarville Flooding State Wildlife Management Area (SWMA)				
2017	0.75 ± 0.03	0.84 ± 0.03	2.8 ± 1.0	1.1 ± 0.4
2018	0.57 ± 0.02	0.69 ± 0.03	2.4 ± 0.4	3.9 ± 0.7
Munuscong SWMA				
2017	0.99 ± 0.02	0.88 ± 0.04	4.4 ± 1.8	8.2 ± 1.5
2018	0.81 ± 0.02	0.85 ± 0.02	0.9 ± 0.3	3.0 ± 0.7
Wigwam Bay State Wildlife Area				
2018	1.00 ± 0.05	0.93 ± 0.04	1.2 ± 0.2	1.5 ± 0.4

Figure 1.1 Suitable Black Tern nesting habitat surveyed 2017 and 2018 in the Dollarville Flooding State Wildlife Management Area, Michigan, USA.

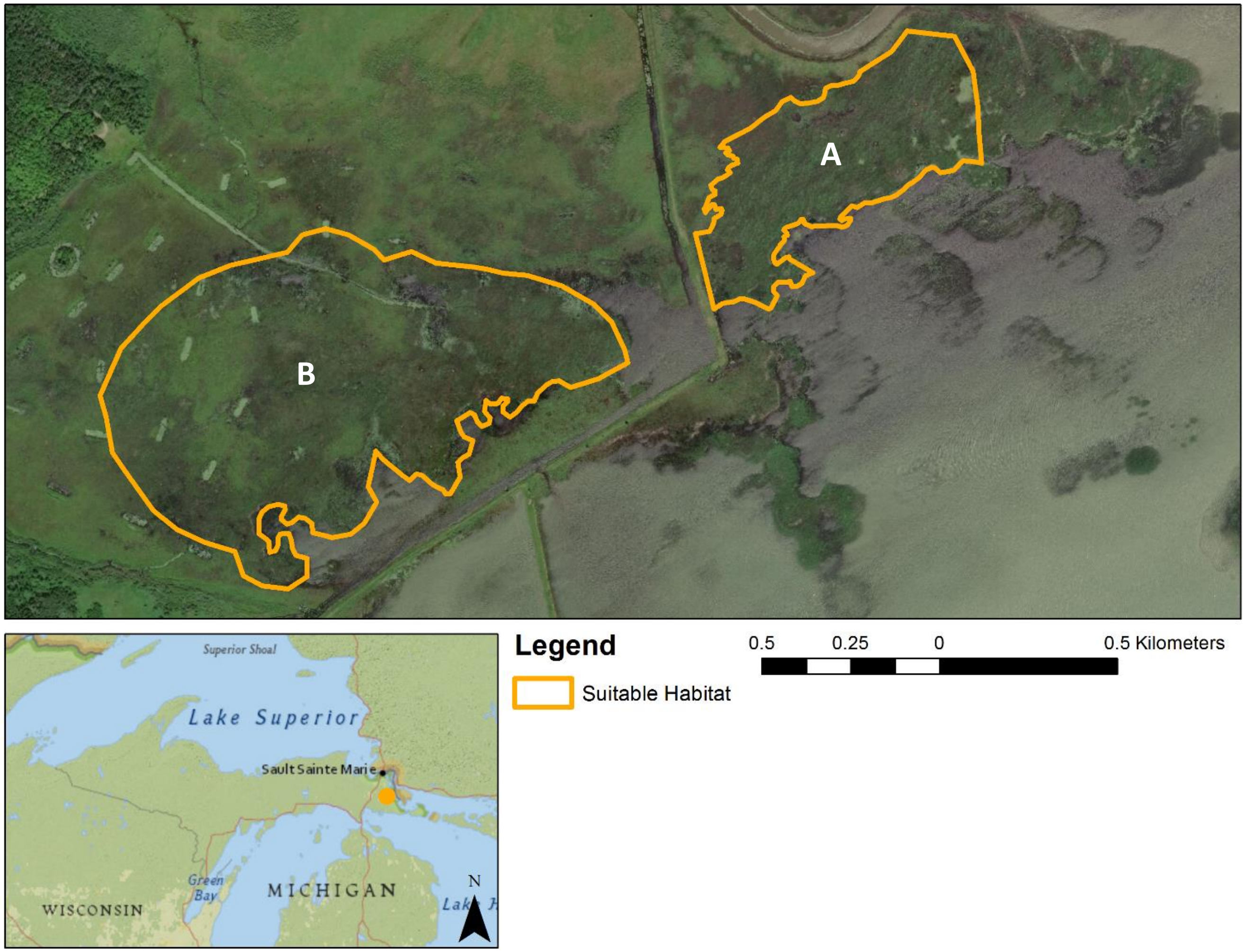

Figure 1.2 Suitable Black Tern nesting habitat surveyed in Munuscong Bay, Michigan, USA. Study area "A" was monitored in 2017, study area "B" was monitored in 2018.

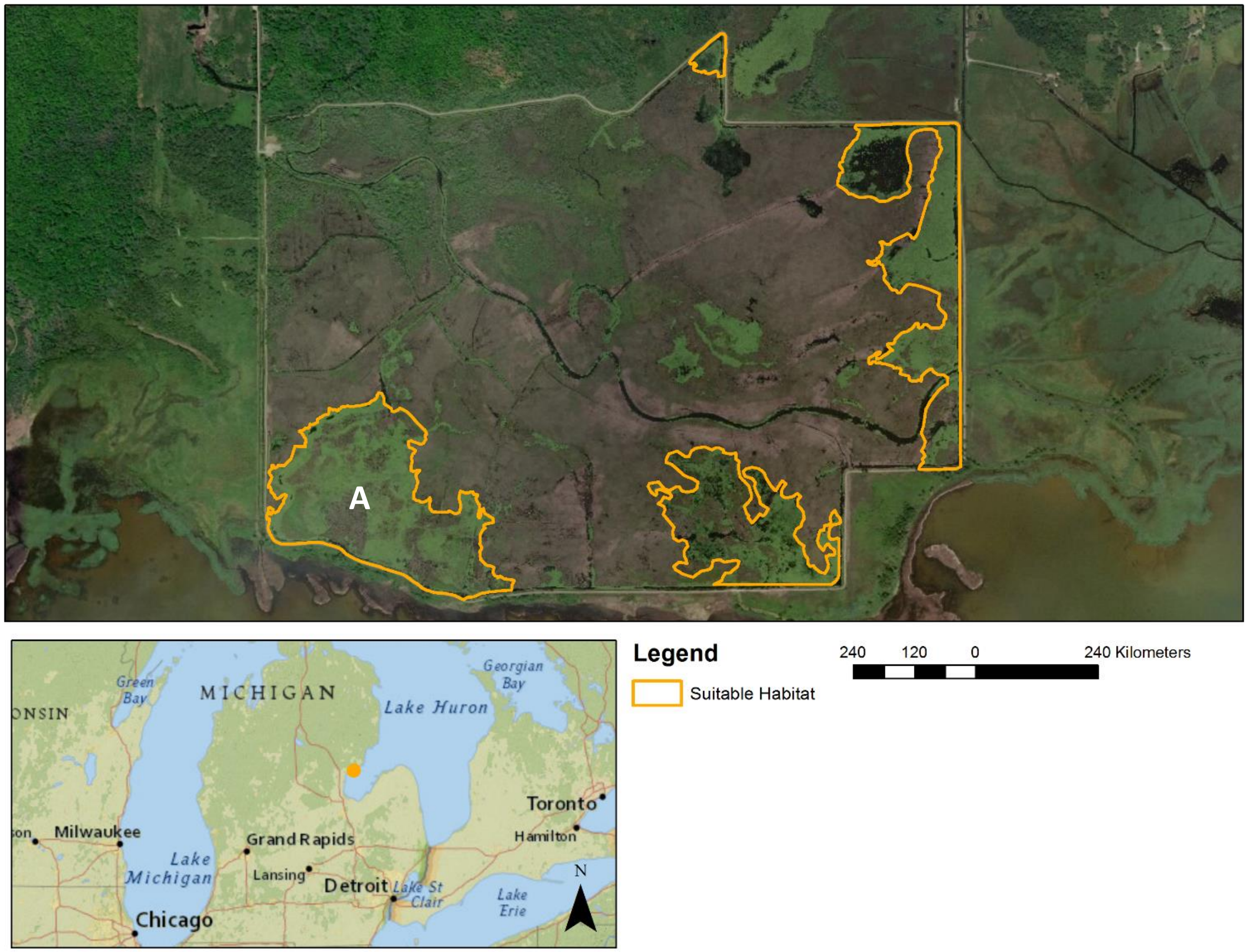

Figure 1.3 Suitable Black Tern nesting habitat surveyed 2018 in Wigwam Bay State Wildlife Area, Michigan, USA. Vegetation sampling was limited in study area "A."

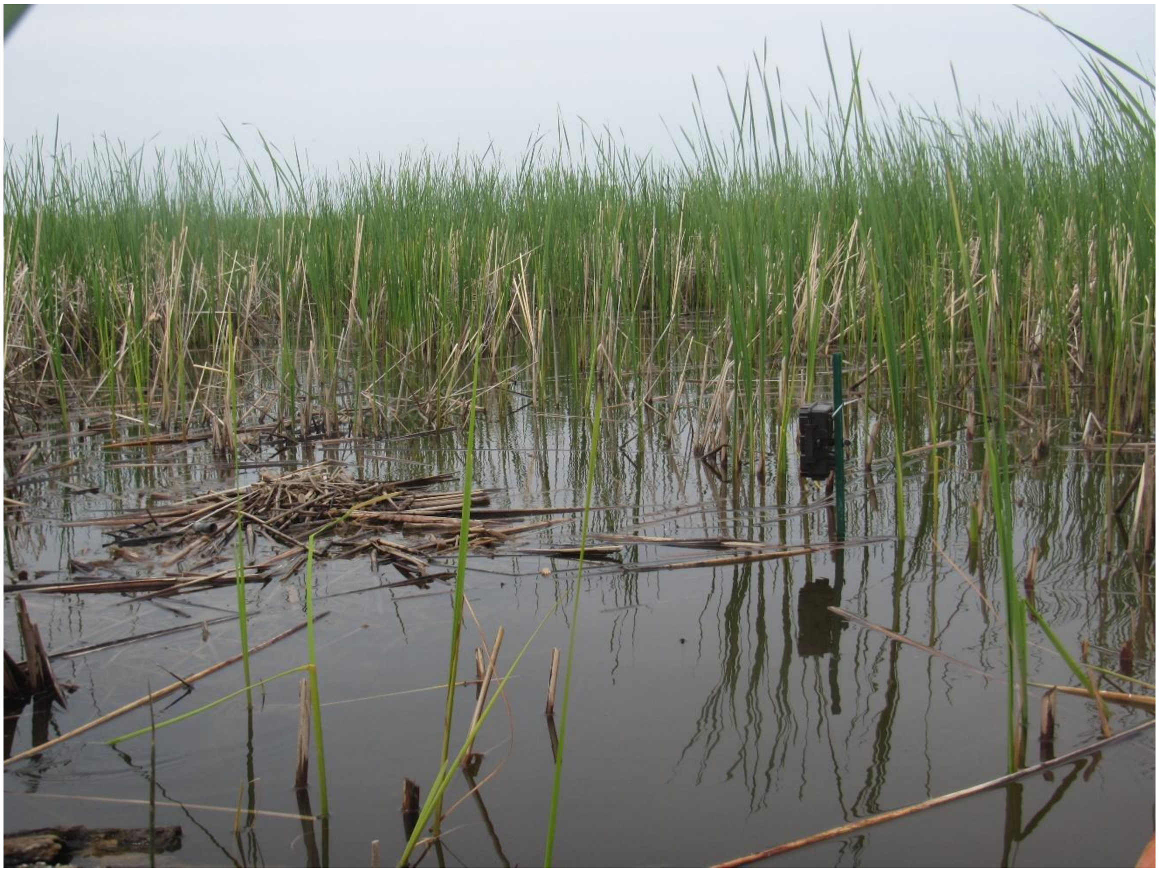

Figure 1.4 Example of a nest camera installed at a nest site in Munuscong State Wildlife Management Area in northern Michigan in 2018.

Figure 1.5 a) Black Tern (*Chlidonias niger*) egg with a puncture hole from an aerial predator, likely an American crow (*Corvus brachyrhynchos*), gull (*Larus* spp.), or a blue jay (*Cyanocitta cristata*), b) Remains of a Black Tern chick possibly killed by an American mink (*Mustela vison*), c) Muskrat (*Ondatra zibethicus*) disturbing a nest site, and d) Common carp (*Cyprinus carpio*) in the Munuscong State Wildlife Management Area, Michigan.

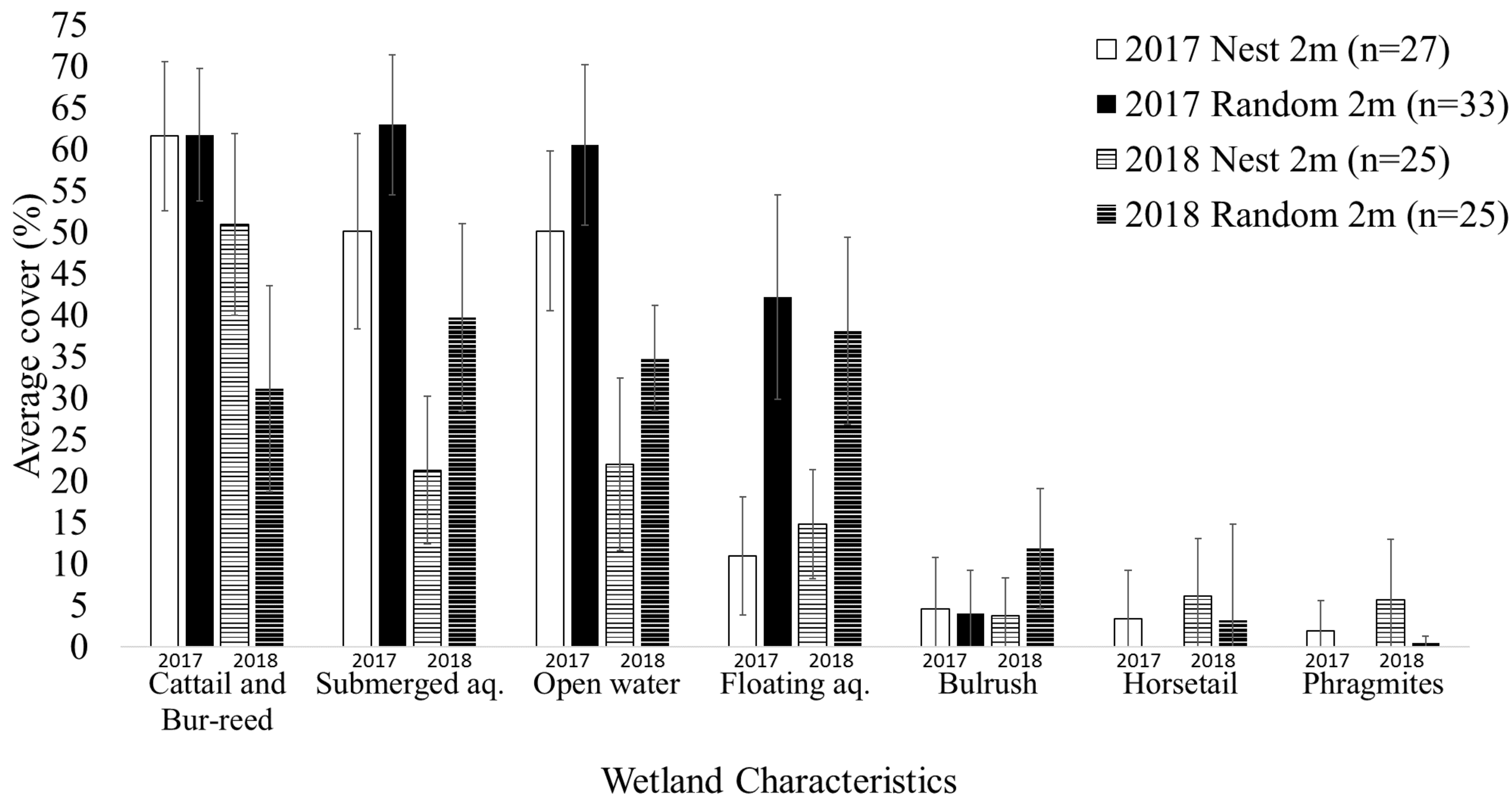

Figure 1.6 Average percent cover of selected wetland characteristics within 2 m of Black Tern nest sites and random points at the Dollarville Flooding State Wildlife Management Area in northern Michigan in 2017 and 2018. Confidence intervals (95% CI) are shown.

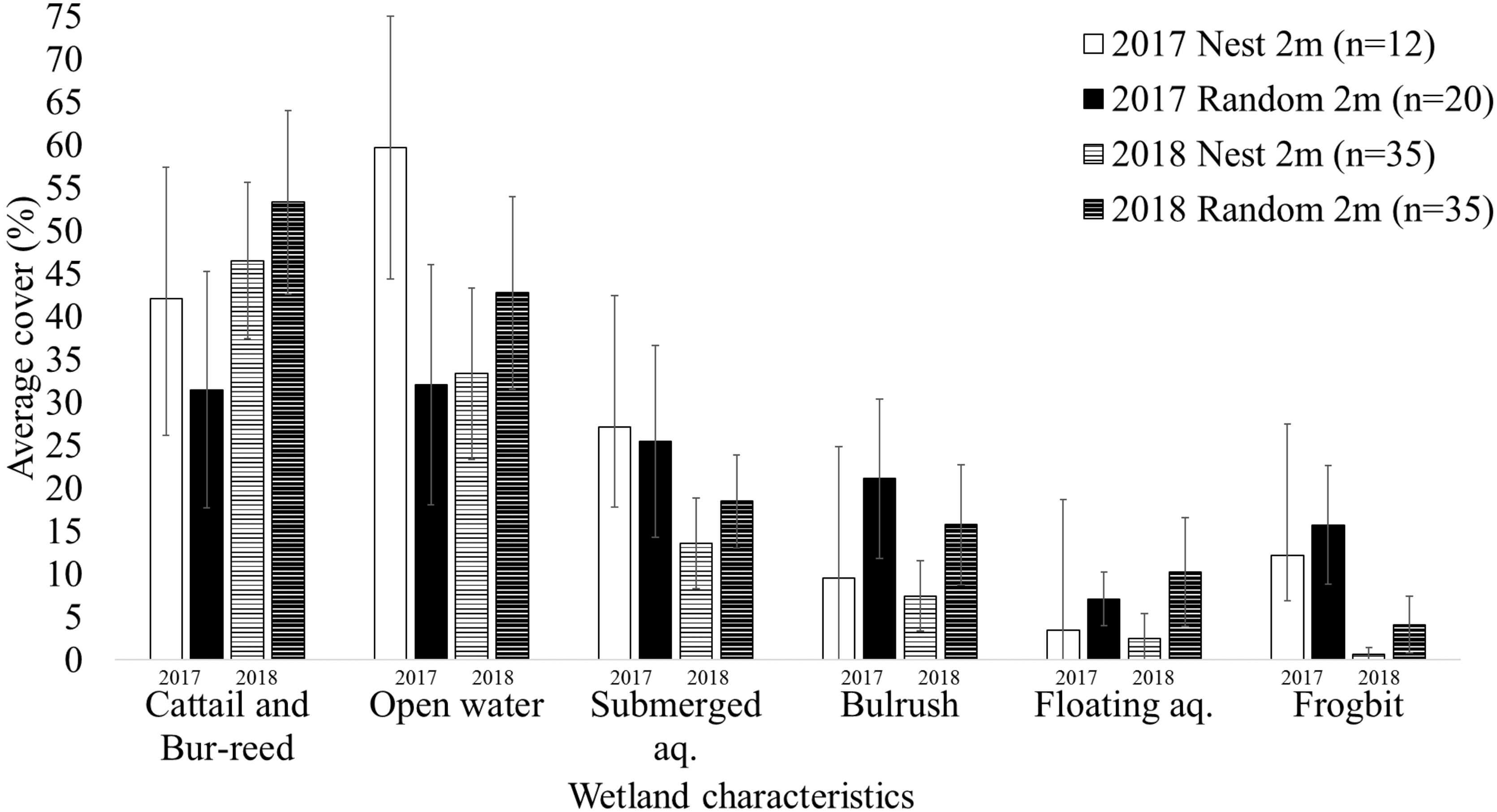

Figure 1.7 Average percent cover of selected wetland characteristics within 2 m of Black Tern nest sites and random points at Munuscong State Wildlife Management Area in northern Michigan. Confidence intervals (95% CI) are shown. Data from 2017 were collected at study area A and 2018 data was collected from study area B.

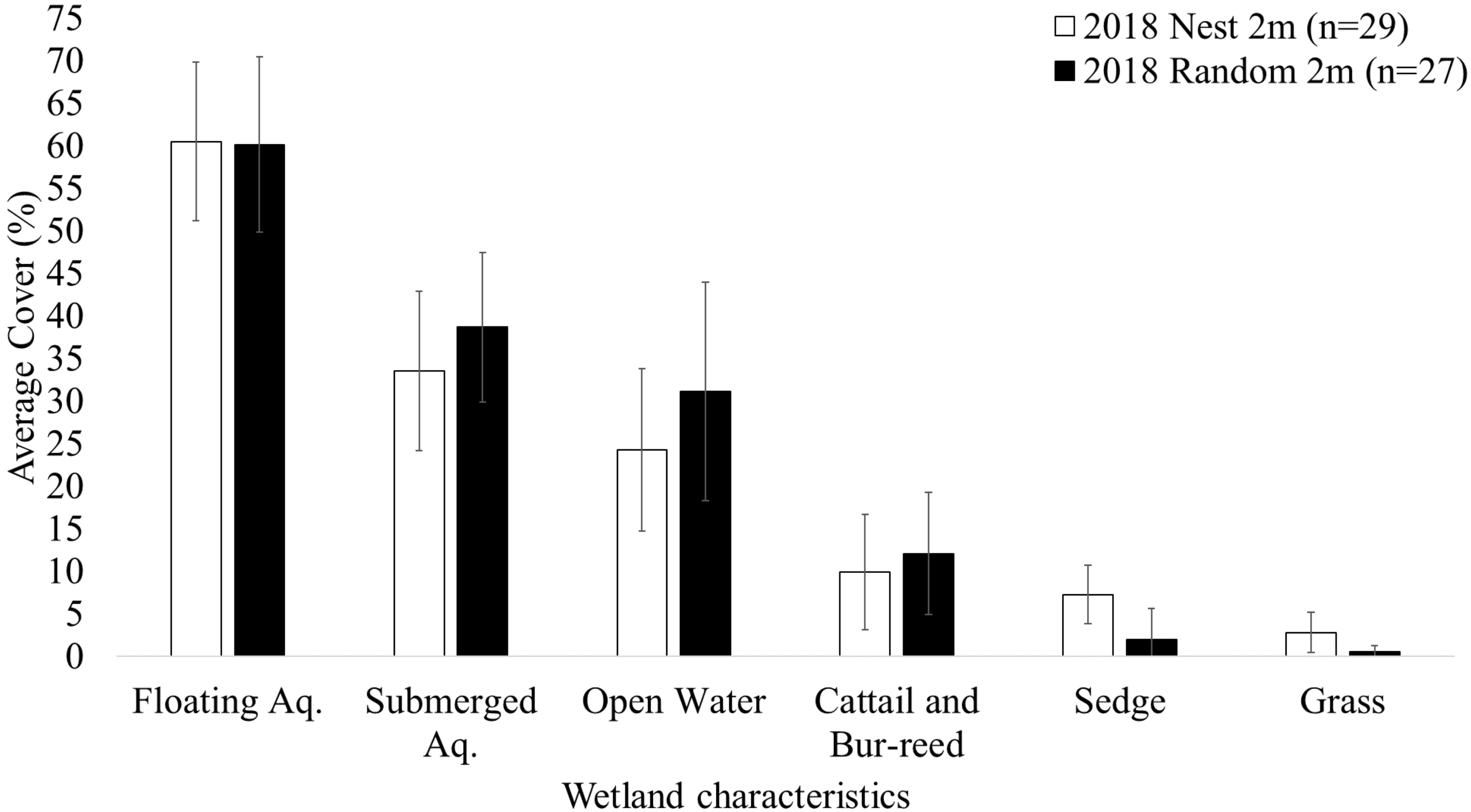

Figure 1.8 Average percent cover of selected wetland characteristics within 2 m of Black Tern nest sites and random points at Wigwam State Wildlife Area in northern Michigan. Confidence intervals (95% CI) are shown.

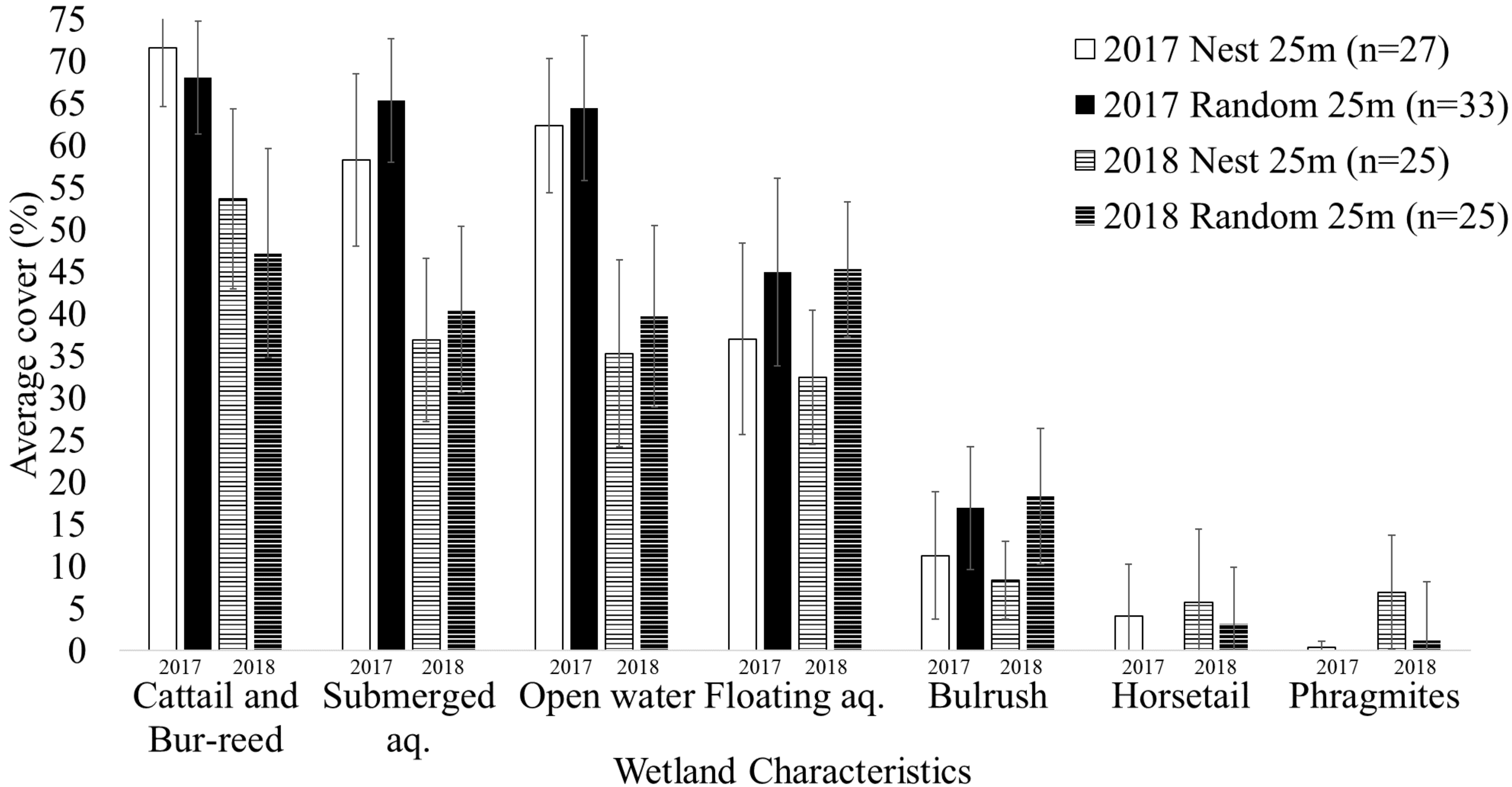

Figure 1.9 Average percent cover of selected wetland characteristics within 25 m of Black Tern nest sites and random points at the Dollarville Flooding State Wildlife Management Area in northern Michigan in 2017 and 2018. Confidence intervals (95% CI) are shown.

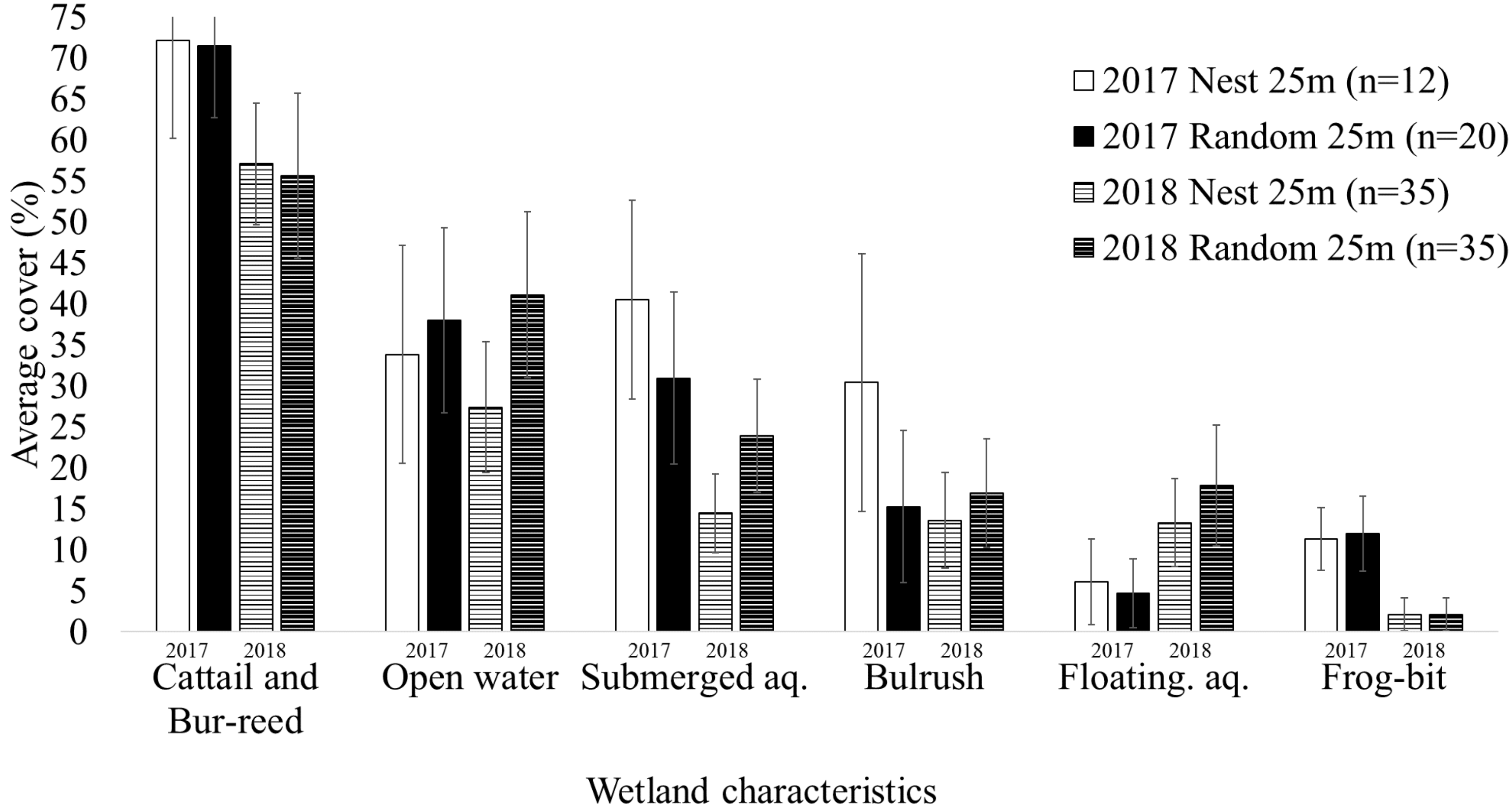

Figure 1.10 Average percent cover of selected wetland characteristics within 25 m of Black Tern nest sites and random points at Munuscong State Wildlife Management Area in northern Michigan. Confidence intervals (95% CI) are shown. Data collected in 2017 were collected at study area A and data collected in 2018 data were collected from study area B.

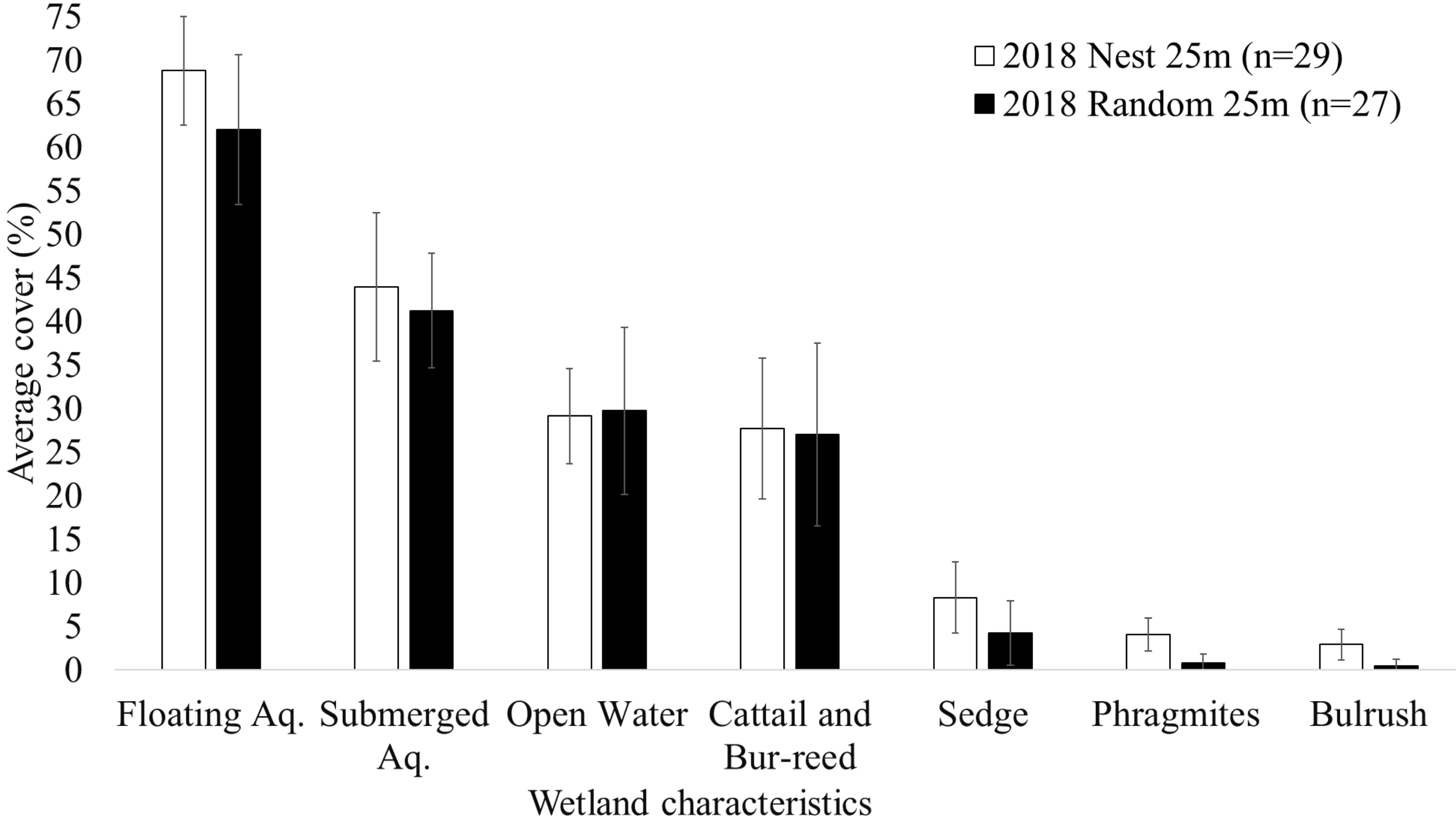

Figure 1.11 Average percent cover of selected wetland characteristics within 25 m of Black Tern nest sites and random points at Wigwam State Wildlife Area in northern Michigan. Confidence intervals (95% CI) are shown.

CHAPTER 2
BLACK TERN NEST SUCCESS AND BEHAVIOR IN NORTHERN MICHIGAN

ABSTRACT.—Black Terns (*Chlidonias niger*) are semi-colonial nesting waterbirds that breed in productive and ecologically diverse wetlands throughout northern North America. Historically, nest success and chick survival have been difficult to determine due to observer time limitations, inaccessible nest locations, and potential detrimental effects on nesting birds from increased disturbance in the colony. I documented nest success and nest attentiveness in a Black Tern colony in northern Michigan in 2017 and 2018 using a combination of nest cameras and weekly site visits. I observed no apparent difference in incubation constancy across early, middle, and late incubation stages. Hourly Black Tern nest attentiveness increased in the afternoon and decreased in the hours surrounding dawn and dusk. When chicks reached 6 days, post-hatch, average nest attentiveness dropped to 30% or lower. Nocturnal nest attentiveness remained high until the chicks were 6 or more days old, then nest attentiveness declined precipitously. My results may provide further insight into the use of nest cameras and potential factors limiting nest success and chick survival in the Great Lakes.

Key words. — Black Tern, cameras, *Chlidonias niger*, emergent wetlands, Great Lakes, incubation, nest attentiveness.

Black Terns (*Chlidonias niger*) are semi-colonial nesting waterbirds that breed in productive and ecologically diverse wetlands throughout northern North America (Matteson *et al.* 2012). The species was once a common sight in emergent wetlands (Bent 1921); however, the Black Tern population has noticeably declined rangewide. Recent North American Breeding Bird Survey results indicated a 2.25% annual population decline in the United States from 1966 to 2015 (Sauer *et al.* 2017). A 45% decline in the number of Black Tern colonies along the Great Lakes was documented between 1991 and 1999 (Scharf 2011; Sauer *et al*. 2017). In Michigan alone, about 89 previously documented Black Tern colony sites have been abandoned since surveys were conducted during 1982–1988 (Scharf 2011).

The causes of the Black Tern population decline are still largely unknown (Servello 2000; Wyman and Cuthbert 2017) despite an increase in the number of research and monitoring efforts across North America (Servello 2000). Numerous studies examining Black Tern nest success in North America have been published (Hickey and Malecki 1997; Mazzocchi *et al.* 1997; Naugle *et al.* 2000; Maxson *et al.* 2007), yet no clear limiting factors have been identified. Research priorities have shifted in recent years to wintering ecology and the use of stopover habitat, per Servello's (2000) recommendations. However, chick survival rates are still unknown so it is impossible to determine whether poor reproduction is limiting populations.

Historically, nest success and chick survival have been difficult to determine due to observer time limitations, inaccessible nest locations, and potential detrimental effects on nesting birds from increased disturbance in the colony. Additionally, chicks are mobile 24 hours after hatching and are rarely found by biologists five days after hatch date (Shealer and Haverland 2000). Knowledge regarding Black Tern incubation tendencies and behavior at nest sites stems largely from naturalist-based studies conducted in the 1950's and 1960's by dedicated biologists remaining stationary in makeshift blinds for hours at a time (Cuthbert 1954; Goodwin 1960).

Technological advancements and increased access to efficient monitoring tools have provided new opportunities for studying Black Tern behavior and nest success. For example, temperature loggers were used to monitor nocturnal nest attentiveness of Black Terns (Heath 2004) and nest cameras have been used to passively determine nest success in the Great Lakes region (von Zuben and Nocera 2015; D. Moore and N. Miller pers. commun.). However, the installation of cameras or other devices at nest sites could increase the likelihood of nest failure due to depredation or abandonment by marking the nest location and attracting the attention of predators, such as crows or ravens. No published research exists on the use of nest cameras to describe Black Tern nest attentiveness, chick survival, or response to nest cameras. My goal was to document nest attentiveness and related behaviors (parent-chick interactions, mortality events, and foraging behaviors) of Black Terns at a colony site in Michigan's Upper Peninsula in 2017 and 2018 using traditional survey methods coupled with nest cameras.

My study addressed the following research questions: 1) does incubation constancy vary during the incubation period?, 2) do incubating Black Terns leave eggs or chicks exposed to the elements or predators at a particular time of day?, and 3) are nest cameras an effective tool for monitoring nests and documenting associated behaviors?

METHODS

Study Area

Munuscong Bay is located 10 km northeast of Pickford in Michigan's Upper Peninsula. Sault Tribe Inland Fish and Wildlife Department staff have observed at least two colonies of Black Terns nesting along the St. Mary's River in the 526 ha Munuscong wetland complex since 2015. Combined, the colonies have had about 25–50 nests annually from 2015 to 2017 (J. Lautenbach pers. commun.). The specific nesting area I studied is accessible through the Munuscong State Waterfowl/Wildlife Management Area (SWMA), 46° 20' 85.86" N, 84° 25' 55.11" W, and is managed by the Michigan Department of Natural Resources (Fig. 2.1).

During the summer of 2017, I monitored a small Black Tern colony site located within a 42 ha area situated between the mouth of the Munuscong River and a diked wetland management area (Fig. 2.1). The area surveyed in 2017 was limited due to time constraints and observer safety. In 2018, the main colony site was located 0.25 km away from the site surveyed in 2017. The 2018 Black Tern nest sites were within the impounded wetland management area southwest of the Munuscong River mouth. Temperatures between 20 May and 22 July ranged from -1°C to 34°F (Table 2.1).

Nest Survey and Monitoring Methods

I conducted systematic nest surveys throughout the study area throughout the breeding season, about 25 May through July (Mazzocchi *et al*. 1997; Shealer and Haverland 2000; Maxson *et al*. 2007). Potential nest sites were located by observing Black Terns from a distance with binoculars and waiting for individual birds to land repeatedly in a single location. When I observed this behavior, I visited the location to determine whether suitable substrate existed for nest building or if a nest had been established. I conducted the surveys by foot or by kayak depending on water levels. At each nest, I recorded the date found, clutch size, and GPS coordinates. I floated at least one egg from each nest to determine the incubation stage of the nest, based on Hays and LeCroy's (1971) egg flotation method. I used the incubation stage to estimate when the first egg was laid and the predicted hatch date.

I visited each nest weekly from 20 May through 22 July in 2017 and 2018. Weekly visits were believed to have little impact on the colony, as observer disturbance has a minimal effect on nesting Black Terns (Shealer and Haverland 2000). Nests were deemed successful if at least one chick was observed at or within 3 m of the nest site during weekly site visits. Nests were visited weekly post-hatch until it became evident that the nest had failed (broken eggshell or submerged eggs) or if no adults were observed mobbing or in the immediate nesting area.

Nest Cameras

I used infrared, motion-activated nest cameras (Bushnell Trophy Cam HD Essential E2®) to document nest attentiveness, hatching and fledgling success. Nest cameras allowed nests to be monitored continuously rather than weekly. The nest cameras were chosen based on their size and potential battery life. Before installation at nests, cameras were tested in the wetland to determine appropriate settings to minimize the number of photos without birds or predators present. The cameras were programmed to take bursts of three photos (less than 1 second between photos) every 5 seconds whenever the motion sensor was activated. The nest cameras were attached to 1.5 m tall green fence steel u-posts and were installed about 15 cm above the surface of the water (Fig. 2.2).

Six nest cameras were installed at the Munuscong State Wildlife Management Area study area for the duration of the 2017 nesting season (Fig. 2.3). An additional four cameras (10 total) were added before the 2018 field season to increase colony coverage (Fig. 2.4). The cameras were installed once nests were located, and remained focused on nest sites until the nests became inactive or the hatch year birds were no longer present (Fig. 2.5). During site visits, memory cards and AA alkaline batteries in each camera were replaced. I removed or trimmed emergent vegetation directly in front of the camera to reduce the number of negative images, or images with no terns or predators visible. The content of each memory card was reviewed between visits to determine the fate of each nest and document any nest disturbances.

Data Collection and Statistical Analyses

I reviewed each photo and recorded the time stamp if the image depicted any of the following behaviors: terns landing or leaving, copulation, hatching, or predation events. The time stamps for each relevant activity were added to an Excel spreadsheet and arranged in a manner that allowed the time between activities to be calculated. I then classified the time between activities as “on nest”, “off nest”, or “copulation”. The photos taken by cameras that malfunctioned (25% of cameras in 2018), by either not displaying settings or repeatedly resetting the time and date between site visits, were reviewed for predation events or unusual behavior. Carp or other wetland fauna may have caused the cameras to reset the time and date by jostling the attached post, but the true reason remains unknown.

The incubation stage of each nest, as determined by the results of the Hays and LeCroy (1971) flotation test, was used to determine whether the images were from early, middle, or late incubation. Each incubation period covered a period of about 7 days, based on the documented average incubation period of 21 days (Cuthbert 1954; Goodwin 1960; Bergman *et al.* 1970; Mazzocchi *et al.* 1997). The date recorded by the nest camera was used to categorize image data as occurring during early, middle, or late incubation. The number of days post-hatch was estimated based on the day the first chick hatched, observations made in the field, the predicted hatch date, or a combination of all three methods. In addition to incubation stage, I examined Black Tern nest attentiveness during daylight (06:00 hr – 22:00 hr) and nighttime hours (22:00 hr – 06:00 hr) and among incubation stages and post-hatch.

I calculated the average percentage of time adult Black Terns spent at individual nest sites for each period of interest. The total time on the nest was divided by the amount of time monitored, either hourly or daily, to calculate the percentage of time adult Black Terns spent at the nest site. Due to the lack of independence for time sequence data, I was unable to identify an appropriate statistical test that would allow differences across incubation stages and time of day to be tested for statistical significance. I used means and 95% confidence intervals to compare nest attentiveness during daylight and nighttime hours. Nest success was estimated using nest survival models in Program MARK (White and Burnham 1999).

RESULTS

Nest Cameras

I reviewed 834,493 images taken during the 2017 and 2018 field seasons, not including those from cameras that malfunctioned. Cameras were placed at 14 nests to document nest attentiveness throughout incubation and post-hatch (Fig. 2.5). At least one egg hatched in 13 (93%) of these nests and at least one chick survived until 6 days post-hatch from 11 (79%) of these nests. The fates of all camera-monitored nests (*n* = 14) were determined. I documented nest behavior at 100% of the nests equipped with cameras. However, four cameras malfunctioned in 2018 and I did not include the associated data in the analyses.

Incubation Constancy and Nest Attentiveness

I observed no apparent difference in incubation constancy across early, middle, and late incubation stages (Fig. 2.6). On average, eggs were incubated at least 72% of the night (from 22:00 hr to 06:00 hr) in 2017 and 89% in 2018. Black Terns spent at least 57% of daylight hours at nest sites in 2017 and at least 85% in 2018 across all incubation stages. At least one adult Black Tern was present at the nest 46 to 91% of the time during daylight hours in 2017 and 87–96% in 2018 (Fig. 2.7). Diurnal nest attentiveness appeared higher overall and less variable during 2018. Nest attentiveness seemed to be lower two hours after sunrise (06:00 hr to 08:00 hr) and two hours before sunset (20:00 hr to 22:00 hr).

Attentiveness of Black Terns post-hatch during daylight hours appeared to be greater in 2017 (Fig. 2.8). A decline in nest attentiveness with days post-hatch was observed in 2017 and 2018. The average nest attentiveness declined more in 2018, with less than 5% of daylight hours spent at the nest site 6 days post-hatch. Nocturnal attentiveness remained above 85% for the first 5 days post-hatch (Fig. 2.9). In contrast, average nocturnal nest attentiveness in 2018 remained above 95% for the first 5 days post-hatch.

Post-hatch nest attentiveness appeared to be lower between 18:00 hr and 20:00 hr than during other time blocks (Fig. 2.10). However, nest attentiveness did not seem to differ between hours throughout the day and the sample size was small. The percentage of time spent on the nest ranged from 39% (19:00 hr) to 60% (21:00 hr) in 2017 and from 62% (18:00 hr) to 81% (21:00 hr) in 2018.

Predation Events and Nest Disturbances

I documented a variety of disturbances created by common wetland fauna (Table 2.3). Muskrats (*Ondatra zibethicus*) caused the majority of the recorded nocturnal disturbances by using nests as feeding platforms or clambering over the nests while traveling to or from their lodges. Throughout the day, carp were responsible for numerous alarm responses by thrashing next to the nest and soaking the eggs or chicks. Over the course of two years, only one predation event was observed. I documented a snapping turtle (*Chelydra serpentine*) depredating an entire clutch of chicks within 5 minutes. At least one nest failure may have resulted from nocturnal muskrat activity that knocked the eggs out of the nest cup. I also documented an instance where a snapping turtle swam up to a nest with eggs, lifted its head out of the water, and then fully submerged. The chicks were not observed at the nest site 5 days post-hatch and may have been depredated by the turtle.

Nest Success

Throughout the summers of 2017 and 2018, 46 nests were identified within the Munuscong SWMA (Fig. 2.1). In 2017, I located 11 nests within a 42 ha area situated between the mouth of the Munuscong River and a diked wetland management area (Fig. 2.2). The area surveyed was limited due to time constraints and observer safety. In 2018, the primary Black Tern colony site was located 0.25 km away from the site surveyed in 2017 (Fig. 2.3). The max recorded air temperature was 4°C warmer in 2018 than in 2017, with an average recorded daily high temperature of 27°C, but the average daily low temperatures were the same (Table 2.1). Nest success during the 2017 breeding season, based on an incubation period of 21 days (Goodwin 1960; Bergman *et al.* 1970; Mazzocchi *et al.* 1997), was estimated at 74% (95% CI = 41%, 91%). Nest success was estimated to be 81% (95% CI = 61%, 92 %) in 2018.

DISCUSSION

Relatively few studies have examined nest incubation or nest attentiveness tendencies in Black Terns throughout the entire nesting season (Cuthbert 1954; Goodwin 1960; van der Winden 2005) and no studies have examined incubation tendencies by hour. The average percent of time spent at nest sites in this study were similar to previously documented nest attentiveness (Table 2.4). Though incubation behavior in Black Terns has not been widely examined, it has been documented for a similar marsh-nesting tern species, Forster's Terns (*Sterna forsteri*). Similar to Black Terns, the incubation constancy of Forster's Terns at nest sites was observed to be 97% throughout the breeding season (Hall and Miller 1991). Hourly Black Tern nest attentiveness increased in the afternoon and decreased in the hours surrounding dawn and dusk (Fig. 2.7). Based on the recorded air temperatures in 2017 and 2018, Black Tern nest attentiveness does not appear to be influenced by air temperature (Table 2.1). Ultimately, I was unable to identify the cause, or causes, for the higher nest attentiveness in 2018.

Nocturnal behavior at the nest site could explain the decrease in attentiveness around dawn and twilight. Female Black Terns prefer to spend nighttime hours at communal night roosts away from colony sites, leaving nocturnal incubation to be predominantly conducted by the male (van der Winden 2005). Before nightfall, the female Black Tern may be participating in the "twilight flight", as described by Trautman (1939), while the males forage and prepare for extended incubation bouts with few to no breaks from 22:00 to 06:00 hr (Fig. 2.6).

Adult Black Tern nest attentiveness declines as chicks mature. I documented nest attentiveness to be 80–83% when chicks are 0 to 2 days old (Table 2.4). Other studies have documented nest attentiveness post-hatch to be 85%, on average, during the first day followed by a steady decline as the brood ages (Cuthbert 1954; Goodwin 1960; van der Winden 2005). When the chicks are at least 6 days old, attentiveness drops to 30% or lower (Fig. 2.8). Around this time, chicks become nearly impossible to find at the nest site (Shealer and Haverland 2000). Chicks were documented at the nest sites from hatching to fledging, but as time wore on, the chicks spent increasingly more time away from the nest and only returned sporadically. In my study, nocturnal nest attentiveness remained high up until the chicks were at least 6 days old, then nest attentiveness declined precipitously (Fig. 2.9).

Nest failure in Black Terns has been attributed to weather events and predation by Black-crowned Night Herons (*Nycticorax nycticorax*), Great Blue Herons (*Ardea herodias*), Great Horned Owls (*Bubo virginianus*) and aquatic mammals, such as muskrats (*Ondatra zibethicus*) and North American river otters (*Lontra canadensis*) (Fig. 2.11; Chapman and Forbes 1984; Shealer and Haverland 2000; Gilbert and Servello 2005; von Zuben and Nocera 2015). Many of the common wetland species I observed throughout this study were previously documented in the literature (Table 2.3). Muskrats and Great Blue Herons were documented at the nest sites, but no evidence of depredation was observed in my study (Fig. 2.11).

Non-native carp (Cyprindae) species may reduce Black Tern nest success. In Manitoba, carp have been documented destroying Western Grebe (*Aechmophorus occidentalis*) nests, which are constructed in a manner similar to Black Tern nests, by thrashing during the spawning period (La Porte *et al.* 2014). Common carp (*Cyprinus carpio*) were observed spawning throughout the nesting area at Munuscong State Wildlife Area in early June and may have caused nest failure at two sites located in cattail stands where wave action was unlikely to be a factor. The nests were destroyed and the eggs found floating nearby with no apparent puncture marks. While surveying and monitoring the colony, I commonly observed multiple carp during each visit rubbing up alongside my leg or thrashing against my kayak as I monitored the colony. I documented numerous occurrences of carp thrashing near nests; soaking eggs and disturbing the incubating adult (Figure 2.11*d*).

Snapping turtles have not been reported as predators of Black Tern chicks (Heath *et al.* 2009) but they are considered a likely predator. Using nest cameras, I documented a snapping turtle depredating an entire clutch of chicks in a matter of minutes. The photos indicate chicks had nowhere to flee once the snapping turtle observed them, as the turtle swam through the nest substrate and circled back for the chicks. Snapping turtles are relatively abundant in most northern Michigan wetlands, which suggests turtles could be important predators of Black Tern chicks.

Historically, birds have not been documented as a common prey item for snapping turtles (Alexander 1943; Obbard and Brooks 1981). Snapping turtles prefer shallow wetlands with depths less than 2.5 m and areas with high waterlily cover (*Nuphar* and *Nymphaea* spp.) (Obbard and Brooks 1981). Bird remains account for less than 1% of snapping turtle stomach contents by volume. The majority of snapping turtle stomach contents are composed of aquatic plants and fish species (Alexander 1943). Snapping turtles are predominantly diurnal and are most active in the morning hours 06:00–08:00 hr. Afternoons are often spent basking; however, a second spike in activity has been recorded occurring during 1400–16:00 hr (Obbard and Brooks 1981). In the snapping turtle incident I documented, the turtle ambushed the chicks at 14:05 hr, aligning with the documented increase in afternoon snapping turtle activity. Though birds may not be common snapping turtle prey items, the opportunistic depredation of entire broods of Black Tern chicks has the potential to reduce the overall chick survival rate in a colony drastically, despite a high nest success rate (74% in 2017 and 84% in 2018).

Biologists are increasingly using nest cameras to document nest success, predators, or organism behavior for difficult to study species (Cox *et al.* 2012). Nest cameras have been used to document predation events at shorebird and waterbird nest sites throughout the Great Lakes region (Dimatteo *et al.* 2015; von Zuben and Nocera 2015; Corace *et al.* 2017). Nest cameras have proven useful in gaining new information about Black Tern nesting biology. Great Horned Owls were not known to consume Black Tern eggs until nest cameras deployed at a colony site in the Kawartha Lakes region of Ontario, Canada documented numerous predation events (von Zuben and Nocera 2015).

In addition to identifying and documenting new predators of Black Tern chicks, the use of nest cameras reduced the number of nests with unknown fates. The fates of all camera-monitored nests (n = 14) were determined, whereas, 21% of the same nests had unknown outcomes when based solely on in-person site visits. Black Tern chicks are mobile and leave the nest when disturbed to blend in with nearby vegetation. On occasion, chicks were never observed near the nest despite no evidence of depredation, leading to nests with unknown fates.

In 2017, the maximum number of chicks observed while conducting in-person site visits was 6 (60%) of 10 total chicks from nests monitored with cameras and only 11 (46%) of 24 were counted in 2018. Additionally, chicks could be monitored for a longer period of time with nest cameras. The oldest observed chick in 2017 was 13 days based on in-person site visit versus 17 days based on the nest camera; in 2018, the disparity was even greater with the oldest observed chick only 8 days (in-person site visit) versus 18 days (nest camera). The use of nest cameras provided additional insight into nest attentiveness by adults once chicks have hatched, documented the continued use of nest sites by chicks 17 and 18 days post hatch, and addressed the challenge of documenting chicks five days after they have hatched (Shealer and Haverland

2000). As chicks become more mobile, the likelihood of the nest camera documenting predation events decreases because the chicks are less likely to remain at the nest site when threats are detected.

Nest success did not appear to be negatively influenced by the presence of nest cameras. Thirteen of the 14 deployed cameras documented chicks at the nest site. One camera in 2017 was aimed at a nest in the early stages of construction. The camera documented numerous Black Tern copulation events, but no eggs were ever laid. One of the adults may have died, because one of the adults repeatedly landed at the nest site for days after the last copulation event and then eventually stopped visiting the site. The second failed nest was attributed to muskrat behavior and did not appear to be driven by the camera's location or presence. Though my sample size was limited (n = 14), the presence of cameras at Black Tern nest sites did not influence nest success in a similar study by von Zuben (2018).

Research and Management Recommendations

Black Tern nest success and chick survival rates continue to be a challenge to document. Though nest cameras may improve our understanding of adult behavior and nest predators, nest-monitoring methods should be refined further to reduce the number of nests with unknown fates. When Black Tern chicks begin leaving the nest site for extended periods, about 5–6 days post-hatch, it becomes increasingly difficult to document chick fate (Shealer and Haverland 2000). Additional cameras aimed at nearby muskrat lodges or other suitable wetland features, including mats of floating aquatics or emergent vegetation debris, may provide further insight into chick behavior and fate. Nest cameras may not negatively influence nest success but care should be taken to avoid creating predator perches or drawing unwanted attention to nest site locations.

Additionally, long-term monitoring efforts of Black Terns and other wetland bird species are needed to improve our understanding of threats to colony sites and further explore adult behavior at nest sites, including incubation constancy and nest attentiveness. Preserving Black Tern colony sites with relatively high nest success rates should remain a management priority. Despite the implementation of additional monitoring efforts in North America, our understanding of basic Black Tern natural history is limited. Further research is needed to define likely problems in the annual cycle of Black Terns that are causing breeding populations to disappear. The implementation of predator or disturbance control efforts, such as imposing a "no wake" rule during the breeding season in popular waterways with documented Black Tern colony sites, should be considered as possible conservation measures in the interim.

In the Great Lakes region, a 50% population increase is needed to eliminate the current Black Tern population deficit of about 8,800 individuals (Soulliere *et al.* 2018). As of 2018, no survival rate benchmarks have been established to address the identified population deficit. The definition of parameters for population replacement, including nest success, chick survival, and other measures, needs to occur to conduct population sensitivity analyses confidently (Crouse *et al.* 1987; Conroy *et al.* 2002). Answers will likely come from an integration of results from field research and population modeling for all aspects of the Black Tern annual cycle.

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TABLES AND FIGURES

Table 2.1 The average low and high temperature readings from the weather station located closest to the Munuscong State Wildlife Management Area, Pickford 3 NE, MI US Weather Station (USC00206583), throughout the Black Tern breeding season (NOAA 2018).

	Average Temperature	Range
	2017 (20 May – 22 July)	
Low	10°C	-1–17°C
High	23°C	17–29°C
	2018 (20 May – 22 July)	
Low	10°C	0–21°C
High	27°C	16–34°C

Table 2.2 Nest fate of Black Tern nests monitored at Munuscong State Wildlife Management Area, MI in 2017 and 2018.

Year	Successful	Failed	Unknown	Total
2017	6	3	2	11
2018	19	4	12	35

Table 2.3 Species documented by nest cameras and Black Tern response to the disturbance, alarm or tolerant. Alarm responses indicate the adult was agitated and flew off the nest in an aggressive manner. Tolerant responses indicate the adult Black Tern did not fly off the nest to ward off the intruder.

Common Name	Scientific Name	Response
Avian		
Canada Goose	*Branta canadensis*	Alarm
Wood Duck	*Aix sponsa*	Tolerant
Mallard	*Anas platyrhynchos*	Tolerant
Pied-billed Grebe	*Podilymbus podiceps*	Tolerant
Great Blue Heron	*Ardea herodias*	Alarm
Sora	*Porzana carolina*	Tolerant
Red-winged Blackbird	*Agelaius phoeniceus*	Tolerant
Fish		
Carp	*Cyprinus carpio*	Alarm
Herpetofauna		
Midland Painted Turtle	*Chrysemys picta*	Alarm
Snapping Turtle	*Chelydra serpentina*	Alarm
Mammalian		
Muskrat	*Ondatra zibethicus*	Alarm

Table 2.4 Black Tern nest attentiveness (the percentage of time spent at the nest site out of the total time documented by nest cameras) across incubation stages and chick age. Previously documented Black Tern nest attentiveness included for comparison.

Year and Colony Location	Incubation Stage			Age of Chicks (days)	
	Early (%)	Middle (%)	Late (%)	0–2 (%)	6+ (%)
2017 Munuscong Bay, MI	60	70	77	83	33
2018 Munuscong Bay, MI	89	93	92	80	2
1950–1951 Indian River, MI[1]	--	--	97	99	6
1955–1957 Oswego County, NY[2]	--	84	95	88	--
1998–2001 Netherlands[3]	--	--	--	81	--

[1]Cuthbert 1954, [2]Goodwin 1960, [3]van der Winden 2005

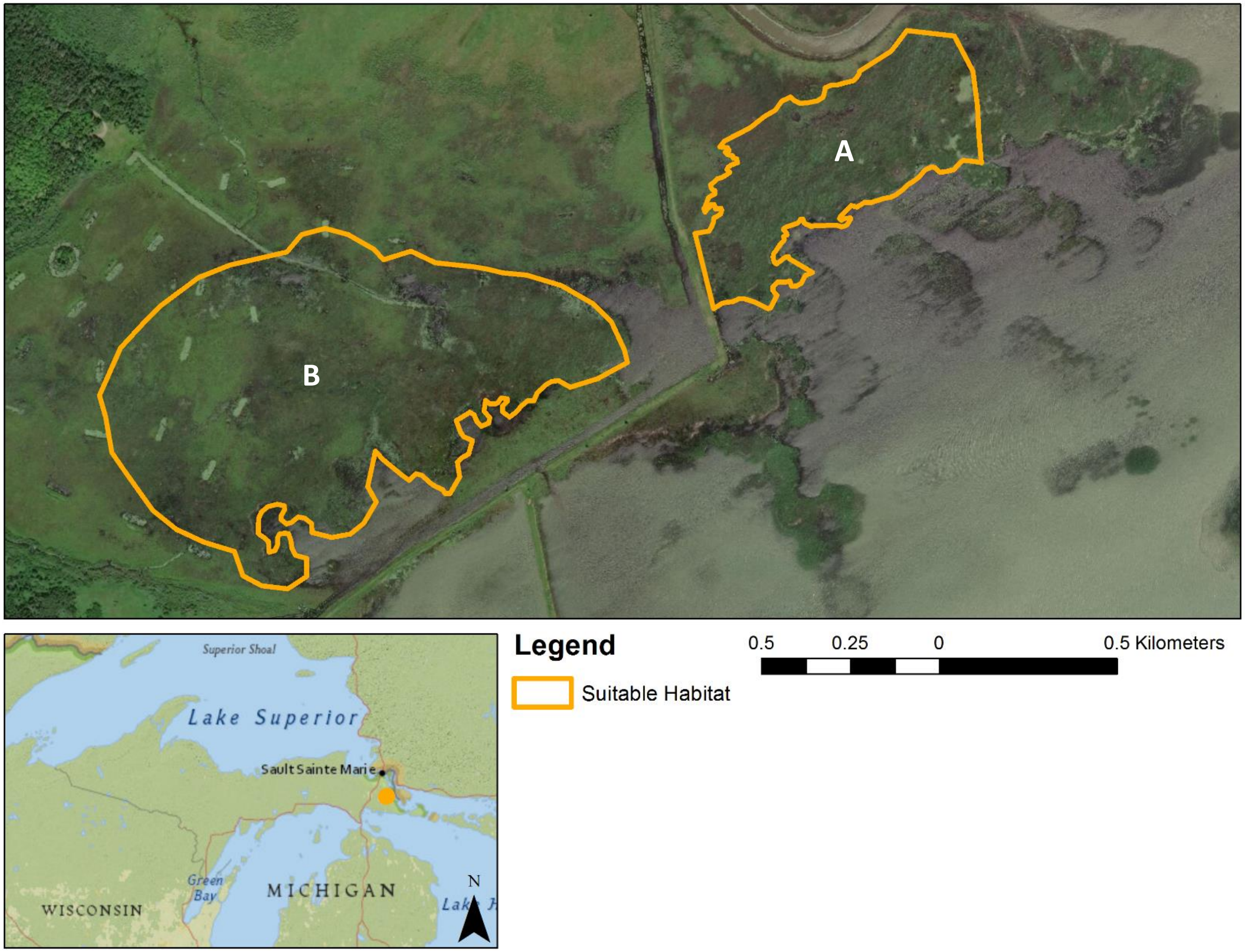

Figure 2.1 Suitable Black Tern nesting habitat surveyed in Munuscong Bay, Michigan, USA. Study area "A" was monitored in 2017, study area "B" was monitored in 2018.

Figure 2.2 Nest camera attached to a green, steel fence post 1.5 m away from a Black Tern nest in the Munuscong State Wildlife Management Area in northern Michigan in 2018.

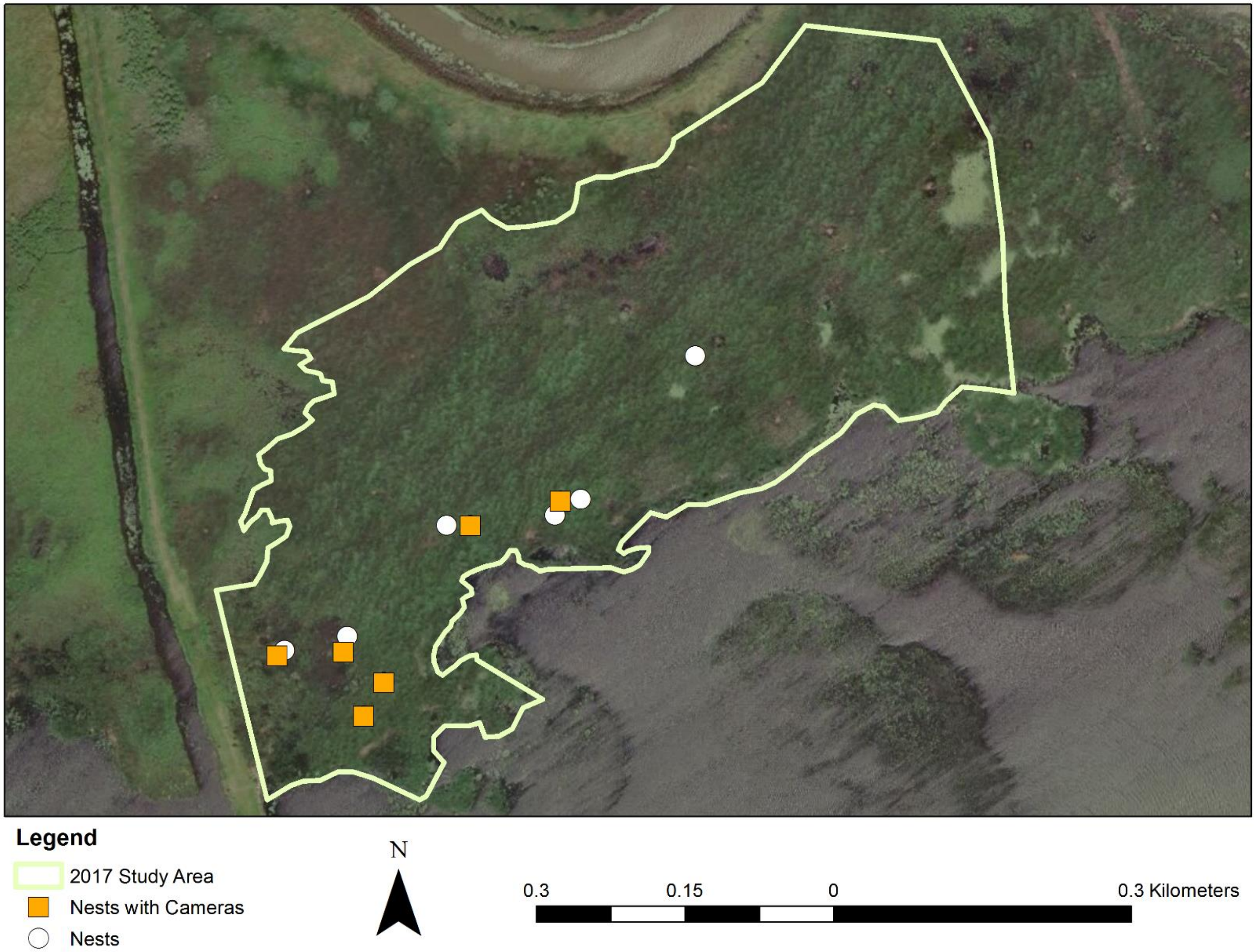

Figure 2.3 Locations of nest cameras throughout the Black Tern colony monitored in the Munuscong State Wildlife Management Area, Michigan in 2017.

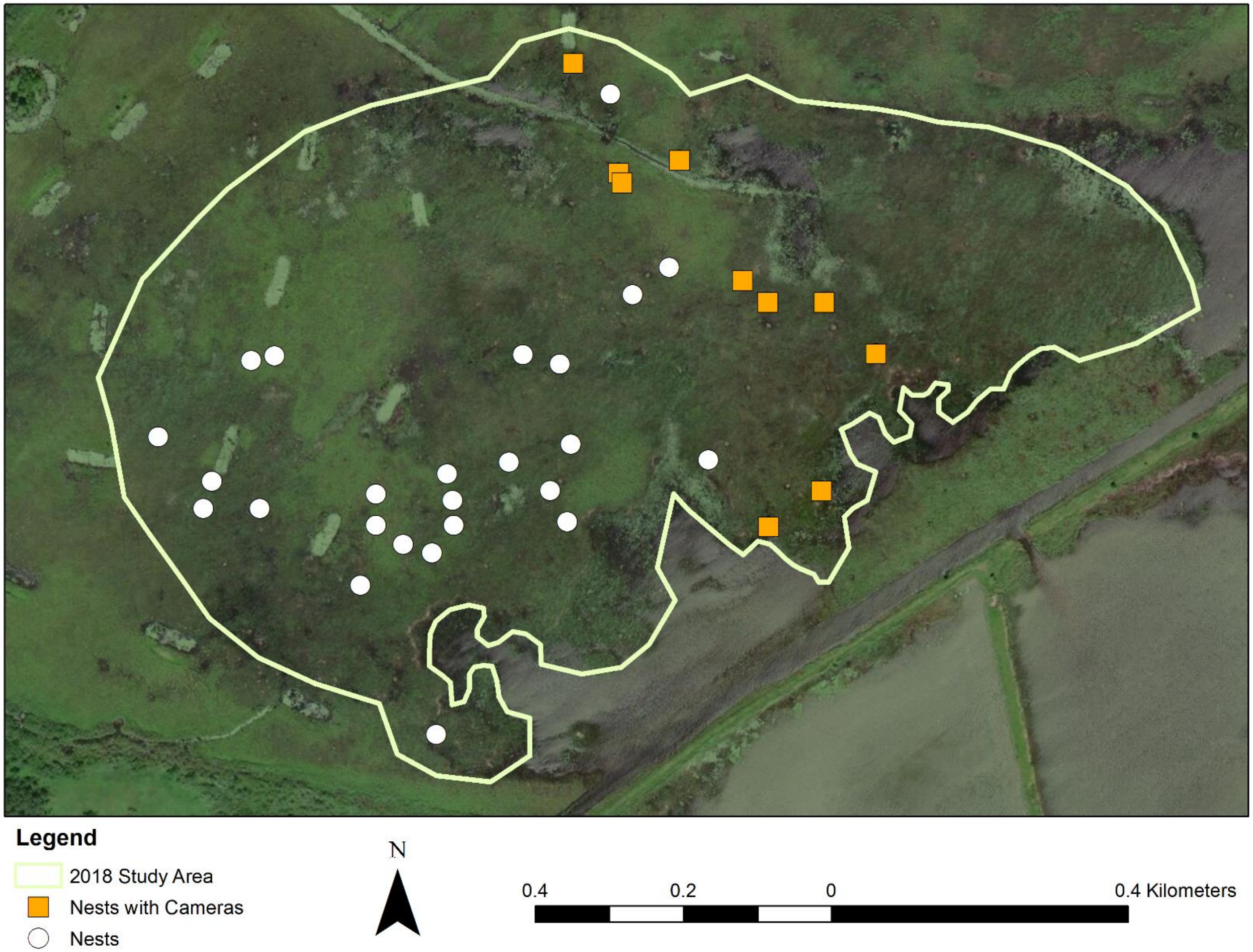

Figure 2.4 Locations of nest cameras throughout the Black Tern colony monitored in the Munuscong State Wildlife Management Area, Michigan in 2018.

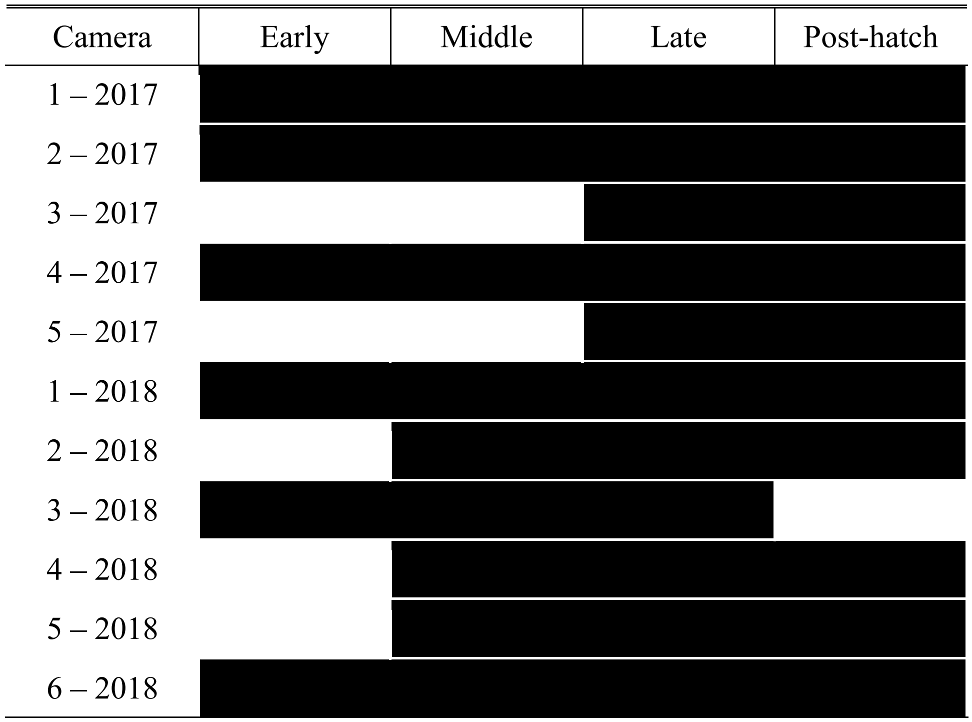

Figure 2.5 Incubation stages documented by individual nest cameras installed near nest sites in the Munuscong State Wildlife Management Area, Michigan in 2017 and 2018.

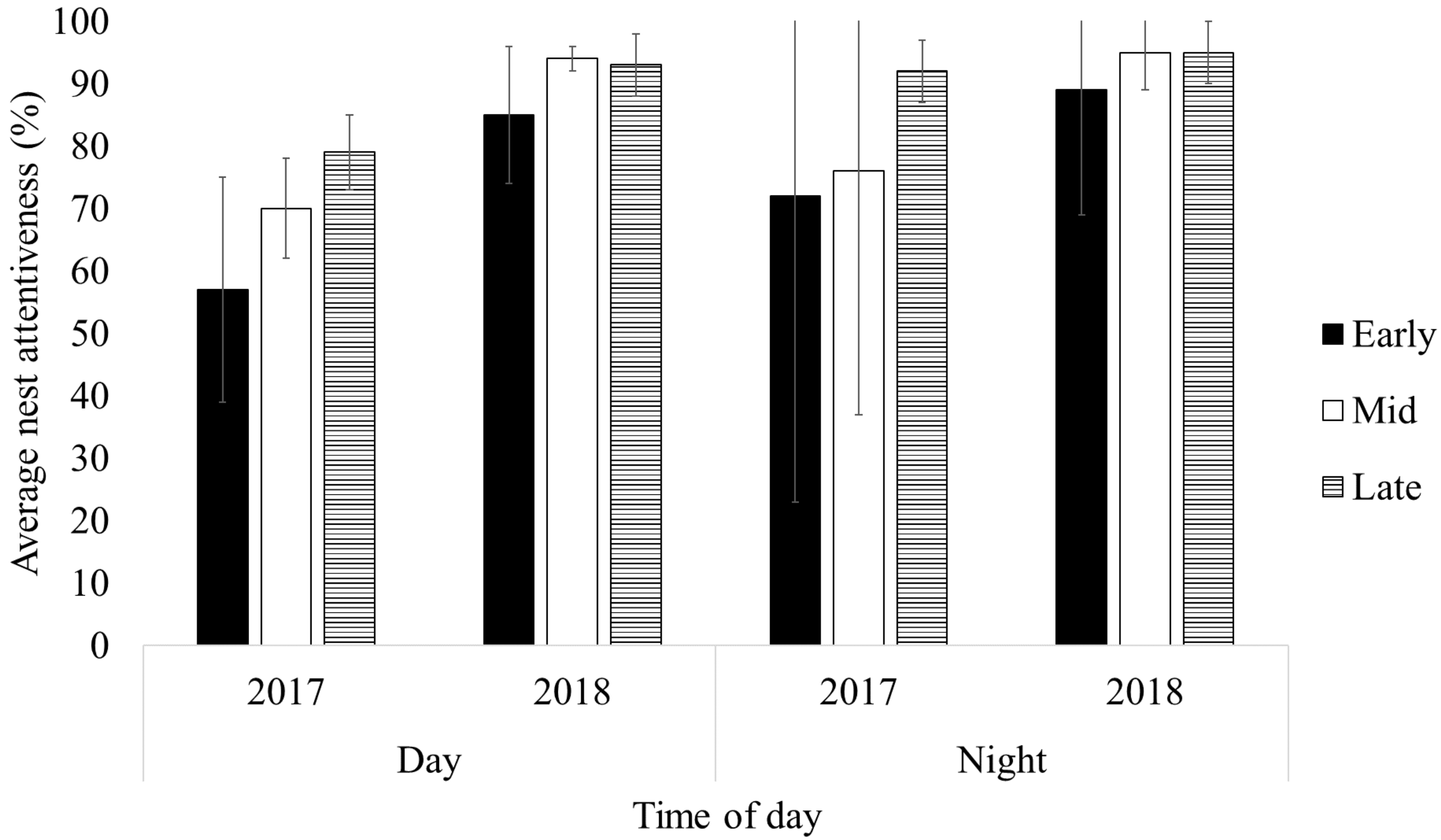

Figure 2.6 Average percentage of time when at least one adult Black Tern was present at the nest site during early, middle, and late incubation stages in 2017 (*n* = 5) and 2018 (*n* = 6) during daylight hours (06:00–22:00 hr) and night hours (22:00–06:00 hr) in the Munuscong State Wildlife Management Area, Michigan. Confidence intervals (95% CI) are included.

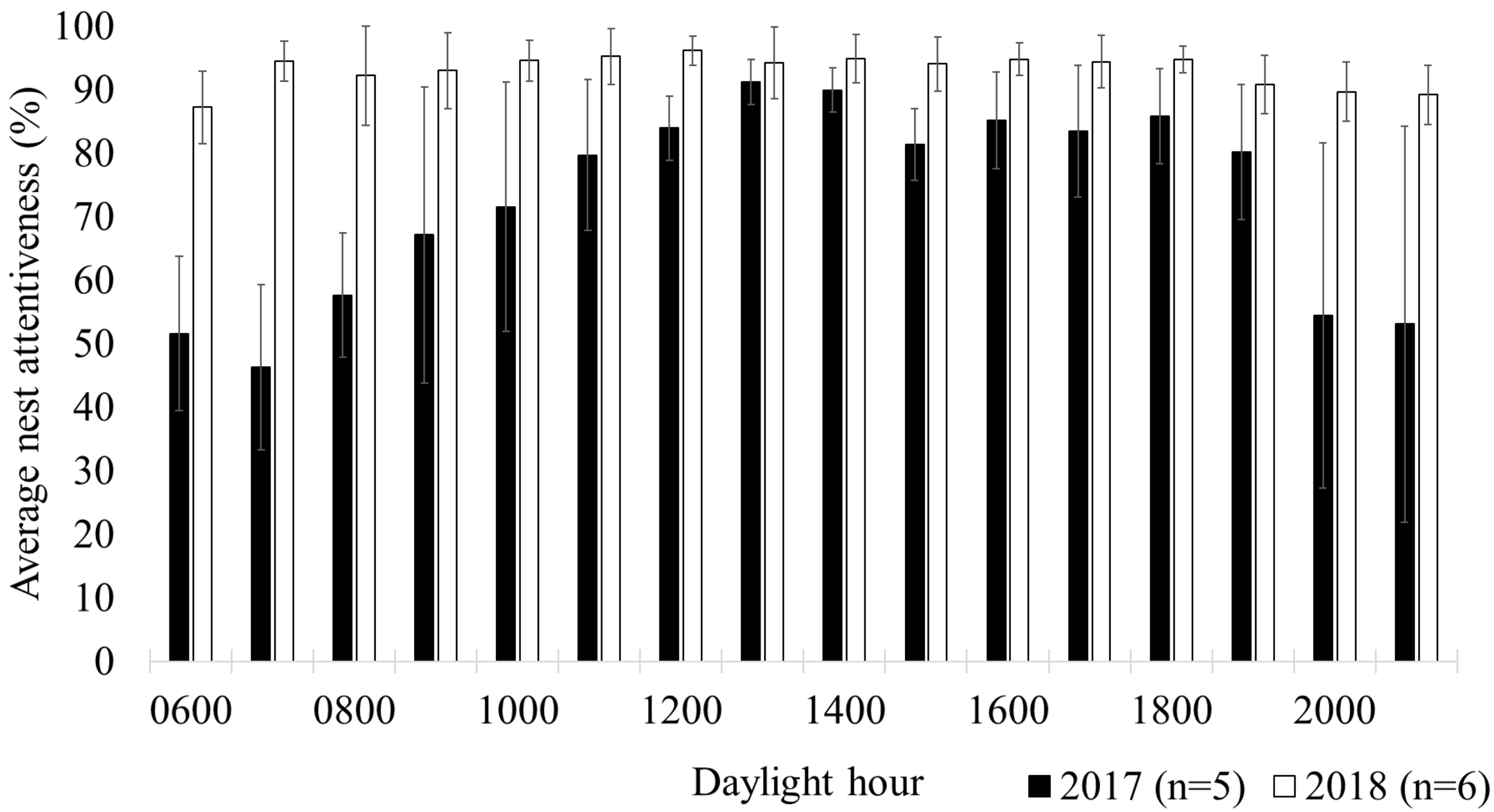

Figure 2.7 The average percentage of time when at least one Black Tern adult was present at the nest site during combined early, middle, and late incubation stages in 2017 (*n* = 5) and 2018 (*n* = 6) during daylight hours (06:00–22:00 hr) in Munuscong State Wildlife Management Area, Michigan. Confidence intervals (95% CI) are included.

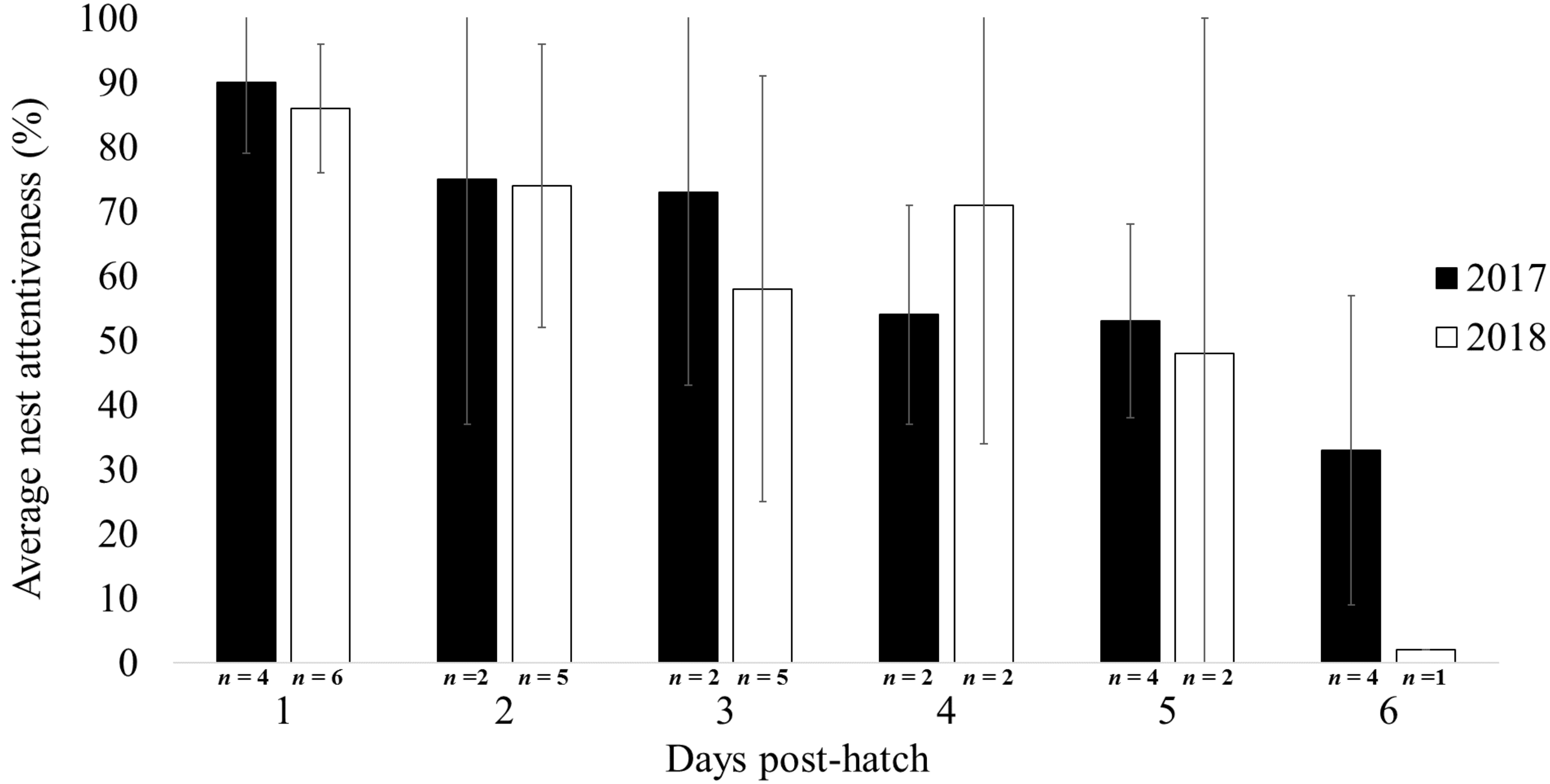

Figure 2.8 The average percent of time adult Black Tern spent at nest post-hatch in 2017 (*n* = 5) and 2018 (*n* = 5) during daylight hours (06:00–22:00 hr) for nests found in the Munuscong State Wildlife Management Area, Michigan. Confidence intervals (95% CI) are included.

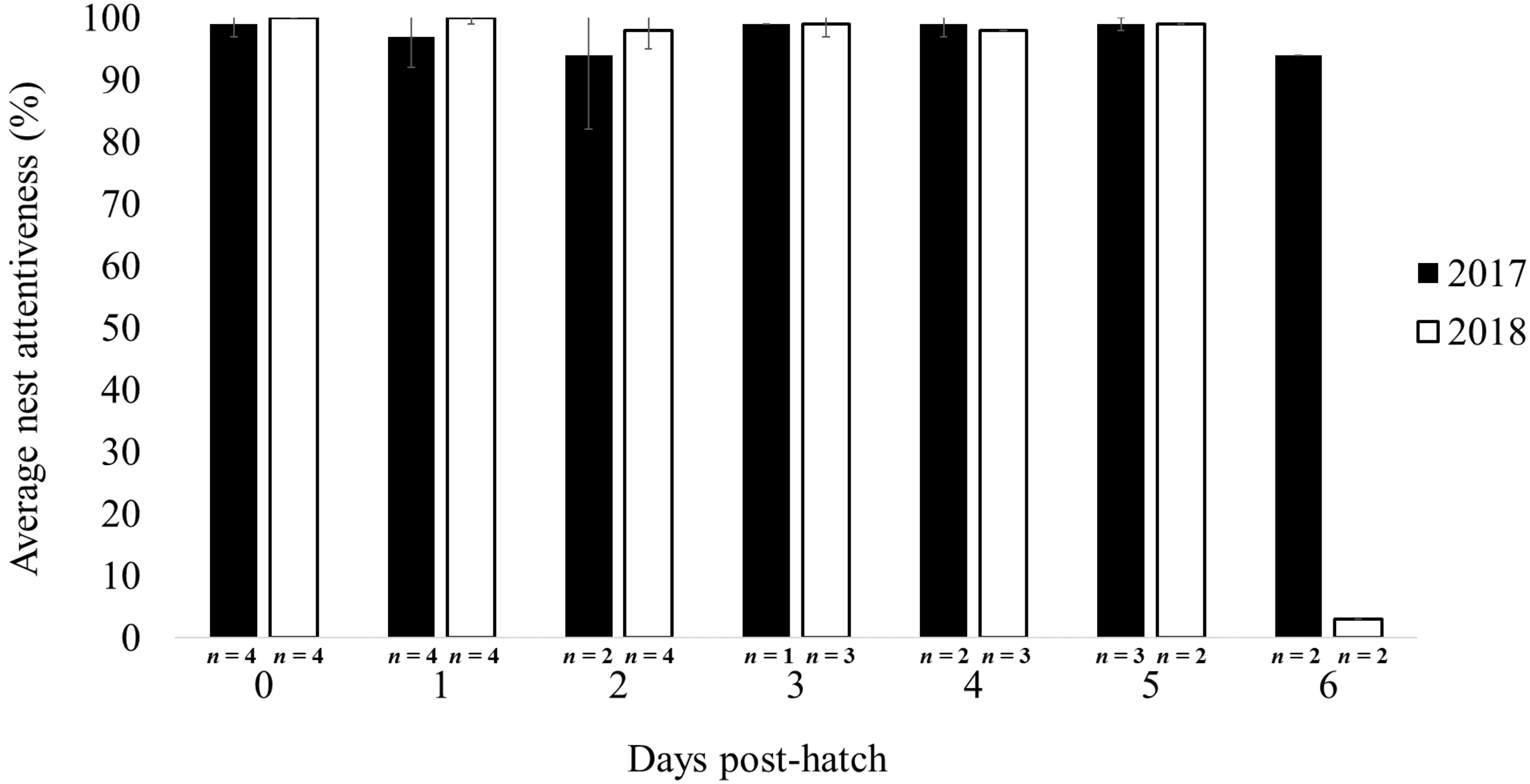

Figure 2.9 The average percent of time a Black Tern adult was present at the nest with chicks post-hatch in 2017 (*n* = 4) and 2018 (*n* = 5) during nighttime hours, (22:00–06:00 hr) for nests monitored in the Munuscong State Wildlife Management Area, Michigan. Confidence intervals (95% CI) are included.

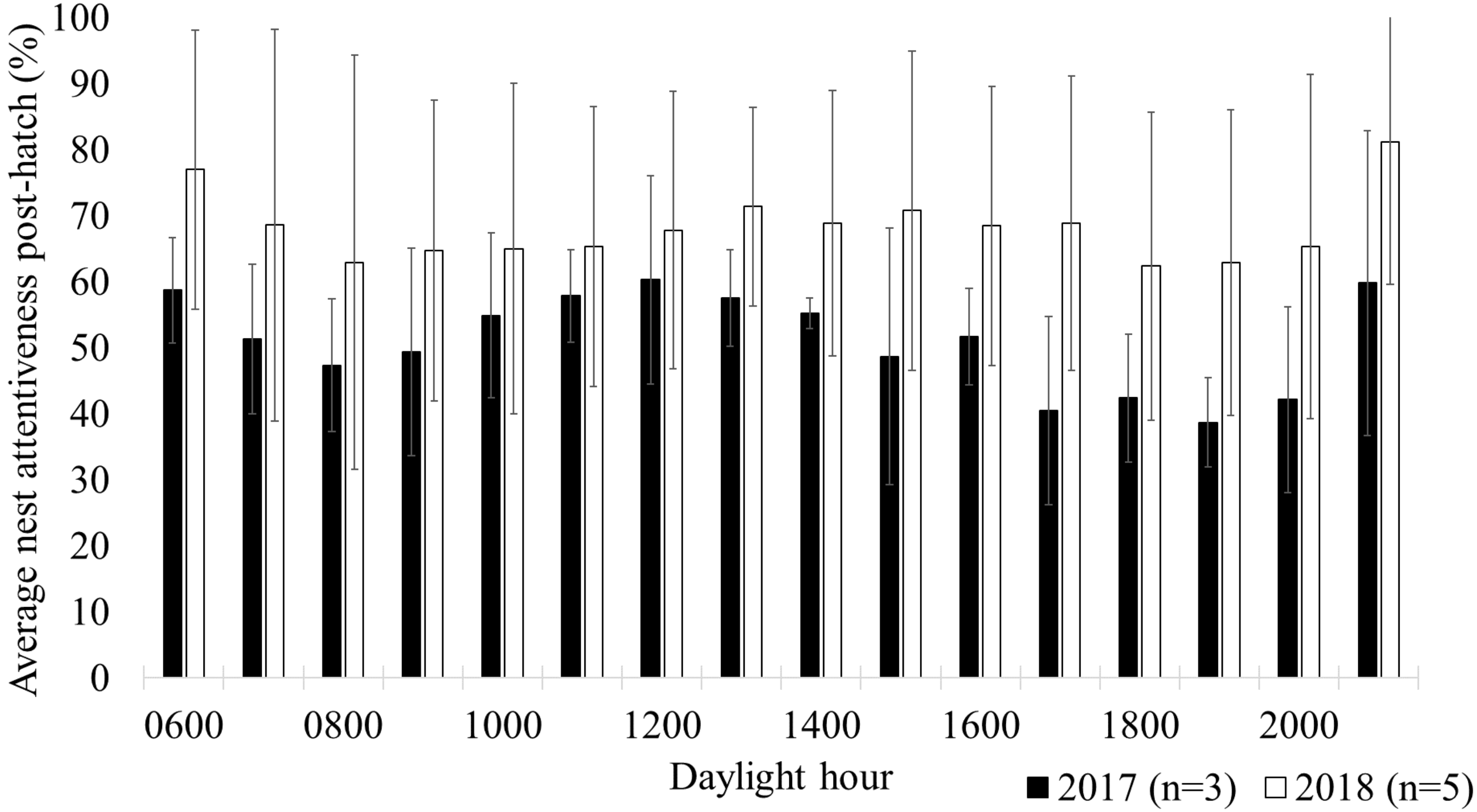

Figure 2.10 The average percentage of time when at least one Black Tern adult was present at the nest site post-hatch in 2017 (*n* = 3) and 2018 (*n* = 5) during daylight hours (06:00–22:00 hr) for nests monitored in the Munuscong State Wildlife Management Area, Michigan. Confidence intervals (95% CI) are included.

Figure 2.11 Clockwise beginning with the upper left photo, *a)* Black Tern (*Chlidonias niger*) mobbing a Great Blue Heron (*Ardea herodias*) at the nest site, *b)* Mallards (*Anas platyrhynchos*) swim by the nest site with no response from the incubating Black Tern, *c)* Muskrat (*Ondatra zibethicus*) disturbing a nest site, and *d)* Common carp (*Cyprinus carpio*) thrashing next to a nest site and causing a wave of water to soak the chicks.

APPENDIX A

INSTITUTIONAL ANIMAL CARE AND USE COMMITTEE (IACUC) APPROVAL

Application to Use Vertebrate Animals in Research, Testing or Instruction

Northern Michigan University

Project Title (If using external funds, enter the title used on the grant application):

Black Tern (*Chlidonias niger*) Nest Success and Response to Invasive Species in Great Lakes Wetlands

Shaded area for IACUC use only.

Application Number: 305
Date Application Received: 2/3/2017
Approved on: 2/27/2017
Denied on:

General Instructions
Please check the IACUC website to ensure you are using the current version of the form. All parts of this form *must be submitted electronically* to the Institutional Animal Care and Use Committee (email: IACUC@nmu.edu) and the relevant Department Head or other departmental designee. Review of this application will commence upon receiving the electronic application, but the project may not begin until all required approval signatures are obtained via Right Signature. Please contact the IACUC chair (email: IACUCChr@nmu.edu) if you have any questions.

Review Dates:
Designated Member Review of applications (appropriate for USDA Use Categories B and C) will be completed within two weeks after receipt of the electronic application.

Full Committee Review of applications will take place on the last Friday of every month. Applications for Full Committee Review must be electronically received by the first Friday of the month. Full Committee Review is required for applications that fall under USDA Use Categories D and E. Applications that fall under USDA Use Categories B and C will receive Full Committee Review if requested by an IACUC member. Detailed procedures on the IACUC review processes are located at the IACUC website.

I. **Principal Investigator** (Must be a faculty member or Department Head): Dr. Patrick Brown

Co- Investigator: Dawn Marsh

Department: Biology

Phone number: (906) 227-2227

II. **Funding Sources/Course Information and Dates**
If the proposed work is for a course, please include the number of the course and title of the course
N/A

Funding Sources (External & Internal, if applicable) Departmental funds
Additional Funding Pending (click on the correct box)? ☐Yes ☒No

Project/Course Start Date: 5/1/2017
End Date (three year maximum): 8/31/2018

This application is (check one) ☒New ☐ Modification of an application currently approved by the Institutional Animal Care and Use Committee (a **new** protocol must be submitted after three years)