COMMON TERN (*STERNA HIRUNDO*) HATCHING SUCCESS RELATED TO NESTING PATTERN ON POPLAR ISLAND

by

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ABSTRACT

This study serves to understand how location within a colony may impact the successful hatching of a common tern nest. Previous research has shown that returning breeding birds will choose areas on the periphery of a colony near the water's edge to nest, and that nest density and parental protection from predation are positively correlated. Research was conducted on Poplar Island, Maryland in a common tern colony to examine nesting patterns and changes throughout the nesting season. These data were then analyzed to determine if successful nests were randomly distributed throughout the colony or showed a clustered pattern. Results show that both failed and successful nests were distributed in clusters within the colony. This research can be used to understand the factors that contribute to breeding success in vulnerable water bird populations, as well as recognize potential areas for further research.

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INTRODUCTION

As of August 2016, the common tern (*Sterna hirundo*) has been listed as endangered by the Maryland Department of Natural Resources after a population decline of 86% since the 1990s (Maryland Natural Heritage Program, 2016). It is classified as a species of least concern on the IUCN Red List due to a large stable global population, but it faces declining population rates in many Atlantic coastal regions due to many threats (Palestis, 2015; BirdLife International, 2016). These threats include habitat loss due to sea level rise, pollution, development, disturbance of breeding birds, and predation of nests (Nisbet, 1984; Erwin et al., 2011; Palestis, 2015). My study focuses on the Paul S. Sarbanes Ecosystem Restoration Project at Poplar Island (hereafter Poplar Island) in the Chesapeake Bay, which has the highest nesting population of common terns in Maryland.

The common tern is a small, migratory waterbird with biparental care throughout the breeding season (Wendeln & Becker, 1999; Riechert et al., 2014). The common tern has an average mass between 130 – 140 g. The average clutch size is three eggs, and one to two chicks typically survive to fledge (Wendeln, 1996; Wendeln, 1999). The first successful breeding attempt occurs between three and four years old, with birds as old as 18 being observed breeding (Nisbet, 1984; Wendeln, 1999). Due to their longevity, age at first breeding, and low output, the common tern is the ideal study subject for how reproductive success impacts lifetime survival rates. Tern chicks hatch asynchronously, which may be an adaptation to varying food supplies. This means that parents will first feed the first hatched and largest nestlings, and only when these chicks are satiated, will younger and smaller chicks be fed. If food supply is limited, younger chicks will soon starve, as food will not be provided to weaker chicks (Langham, 1972). On average, the second egg in a clutch will hatch within half a day of the first, but if there is a clutch of three, the third egg will hatch about two days after the first two (Langham, 1972).

The Chesapeake Bay is the largest estuary in the United States and was at one time regarded as one of the most productive estuaries in the world (Erwin et al., 2011). Unfortunately, several factors including pollution and sea level rise have caused this once-complex landscape made up of a variety of islands to decrease in production and available habitat (Kemp et al., 2005). The loss of smaller islands is detrimental to migratory water birds, including the common tern, as these islands provide optimal habitat while hosting a small number of predators. While larger islands do provide suitable habitat, they have a higher probability of being inhabited by mammalian predators. As a result, these larger islands may become a “sink” for species such as the common tern (Erwin et al., 2011). Nesting habitat and island decline throughout the Chesapeake Bay region contribute to difficulties experienced by migratory common tern populations. Stabilization and preservation of rapidly eroding islands are critical to ensure the sustainability of migratory water bird communities.

The goal of this study is to visualize nesting pattern changes and hatching success on Poplar Island during the 2014-2017 nesting seasons. By understanding how nest location may affect hatching success, or if eggs survive to hatch, we may better propose methods for habitat preservation and predator control to aid in conservation efforts.

Poplar Island

Poplar Island, located in the mid-Chesapeake Bay (GPS point 38.7617° N, 76.3840° W), is an international model of environmental restoration (Poplar Island Restoration, 2017). It was reduced in size from about 1,100 acres in 1847 to about 5 acres in 1993 (Poplar Island Restoration, 2017). This loss is due to various natural processes, including sea level rise and severe storms. The reversal of this degradation is a multi-phase process using clean dredged material from the approach channels of the Port of Baltimore. To restore the island's original footprint, about 68 million cubic yards of dredged material has been placed, shaped, and planted within a dike that approximates the 1847 original shape of the island (Poplar Island Restoration, 2017). This restoration project includes the creation of diverse wildlife habitats for many species within the Chesapeake Bay. These wildlife components are designated as "beneficial use" by the U.S. Army Corps of Engineers to ensure the support of natural resources throughout the island. These include requirements for vegetation and the creation of habitats on the island, including small nesting islands, open water, high marsh, low marsh, and uplands. The priority species for these habitats are the common tern (*Sterna hirundo*), least tern (*Sternula antillarium*), American black duck (*Anas rubripes*), cattle egret (*Bubulcus ibis*), snowy egret (*Egratta thula*), and osprey (*Pandion haliaetus*) (Erwin et al., 2007). There are several other research or monitoring projects currently underway on Poplar Island, including terrapin nesting surveys, avian surveys, population monitoring of least and common terns, invertebrate and fish monitoring, development of gull deterrent methods, avian influenza sampling, and marsh elevation studies. Special focus has been on the protection of suitable tern nesting habitat, as many areas previously used throughout the Chesapeake Bay have been lost due to predation and erosion (Erwin et al., 2011).

Nesting site selection

Habitat selection during the breeding season is important for common terns since they are partially confined to their nest during incubation and the early chick period (Burger & Gochfeld, 1988). Most common terns will choose nesting sites characterized by flat sand nearby or surrounded by vegetation (Burger, 2016). This vegetation allows for protection of chicks from overhead predation. Some studies show that a peripheral nesting preference may exist (Becker, 2015). Elevation is important to nesting site selection as well, with most nests being built within zero to five meters above the high-water mark. The highest sites are occupied first, with late arriving birds settling at or below the high-water mark (Nisbet et al., 1984). Early arriving birds, usually experienced breeders, will select nesting sites towards the island's edge (Becker, 2015). Common terns typically colonize stable, well established breeding areas. The typical age of reproduction is between 2 and 5 years, and about 83% of individuals recruit at ages 3 and 4 (Ludwigs & Becker, 2002; Kharitonov & Siegel-Causey 1988). New breeders fill nest sites between returning breeders. The perimeter of the habitat island will fill with nest sites until late-arrival breeders, usually inexperienced, nest in the center. With advancing age, common terns will move their nesting territories towards the periphery of the colony (Becker, 2015).

Nesting site selection includes several factors that influence the patterns of settlement within the colony. These factors are sites at which there is little risk of flooding, appropriate substrate makeup, low predation risk, and sufficient space to the spatial edge of the colony (Nisbet et al., 1984; Becker, 2015). With age, experienced breeders tend to move their nests closer to the periphery of the colony (Becker, 2015). Birds that nest at the "biological center" of the colony are older, heavier, and more likely to use aggressive displays to attack intruders (Kharitonov & Siegel-Causey 1988; Becker, 2015). The biological center of the colony is not necessarily the geographic center of the colony, but it is the most densely populated area within the colony (Becker, 2015). One explanation for preferred peripheral nesting is a reduced number of neighbors on the periphery, with open access to the water's edge for hunting or foraging (Becker, 2015).

Reproductive recruitment is one of the most important steps in the life cycle of the common tern, and it carries consequences both for the individual's fitness and the dynamics of the population (Newton, 1998). Extrinsic factors such as population density, colony size, predators, and past reproductive success and intrinsic factors such as the individual's early life experiences can affect an individual's reproductive success (Newton, 1998; Oro & Pradel, 2000; Serrano et al., 2003; Crespin et al., 2006). Common terns spend 1 to 2 years prospecting before recruitment to breeding colonies. Most return to their home colony after the prospection period, done on the wintering grounds, during which several other colonies are visited (Dittmann & Becker, 2003). Prospectors typically arrive to the colony later in the breeding season than experienced breeders (Dittmann & Becker, 2003). As a common tern has more breeding experience, it has improvements in body mass, reproductive performance, and reproductive success (Ezard et al., 2007; Limmer & Becker, 2007). It is advantageous for recruits to mate with experienced breeders. Male and female recruits show greater reproductive success when paired with a mate with two or more years of breeding experience (Ludwigs & Becker, 2005).

The selection of suitable breeding and nesting sites is extremely important for the tern's reproductive career (Serrano et al., 2003). New recruits into a colony are usually forced to arrive later than experienced breeders, lay later, and select nesting sites in either highly populated areas or undesired areas at the periphery of the colony (Becker, 1995; Coulson, 2002). Mates at initial recruitment are typically of similar age, and they separate in the year following the first breeding success (Ludwigs & Becker, 2005). First time breeders have been found to use gaps in the established colony to establish their nests (Becker, 2015). These gaps are both spatial gaps between established nests and gaps in time between established breeders' first laying and replacement laying (Becker & Zhang, 2011).

Parental nest defense and predation

Parental effort increases with increased breeding success. Parental year and body condition have been found to be significant factors affecting the growth rate of chicks, with good female condition being the highest indicator of high chick growth rate (Wendeln, 1999). Defensive aggression has been well-studied in the common tern. This is defined as birds circling overhead and diving at the highest point of the intruder in the colony (Burger, 1988). Aggressive behavior has been found to be positively correlated with nest density, with more birds displaying diving behavior as nest density increases (Burger, 1988).

During some years, common terns have suffered high predation on Poplar Island from both red fox (*Vulpes vulpes*) and great horned owl (*Bubo virginianus*) (Erwin et al., 2011). Past presence of predators in colonies has caused colony failure, with numbers of hatching failures exceeding 95% in the years 2003 and 2004 (Table 1; Erwin et al., 2007). In 2008, the common tern colony had a near total colony failure believed to be due to high rates of great horned owl predation. Great horned owl predation was found to cause nocturnal nest desertion during the nesting season in 2005, leading to a reduced number of nesting adults and successful eggs (Table 2). Nocturnal nest desertion due to great horned owl predation has been seen in other colonies throughout the east coast of the United States (Nisbet, 2002). Following an effort in late 2008 to eliminate the great horned owl population, the common terns had a marked improvement in nesting success, resulting in a growth from <0.5 young produced per pair prior to predator removal to about 1.5 young produced per pair (Table 3; Erwin et al., 2011). For most nocturnal predators, the defense response of common terns involves temporary or permanent nest desertion (Arnold et al., 2006). While nocturnal nest desertion reduces adult mortality, egg and chick mortality is a high risk, mainly if adults do not return to the nests until dawn. Eggs and chicks left unattended are at risk of predation and hypothermia, especially on cold or rainy nights (Arnold et al., 2006).

Table 1. Estimated number of common tern fledglings at Poplar Island, Maryland, for the years 2003-2005. Data from Erwin et al. (2007).

Species	**2003**	**2004**	**2005**
Common tern (*Sterna hirundo*)	0	0	ca. 75

Table 2. Estimated number of nesting pairs of common terns at Poplar Island Environmental Restoration Project, Maryland, for the years 2001-2005. Data from Erwin et al. (2007)

Species	**2001**	**2002**	**2003**	**2004**	**2005**
Common tern (*Sterna hirundo*)	398	380	827	809	ca. 500

Table 3. Estimated number of nesting pairs and fledglings of common terns on Poplar Island, Maryland, before (2008) and after (2009) Great Horned Owl removal. Data from Erwin et al. (2011)

	Number of Nests (Fledglings)	
Species	**2008**	**2009**
Common tern (*Sterna hirundo*)	361 (20+)	244 (115-130)

Adult terns display both fleeing and mobbing behaviors when a perceived predator is present, giving alarm calls when a predator enters the colony (Burger & Gochfeld, 1988). They will flee the nest if the predator is a perceived danger to themselves, and they mob the predator if it is a perceived danger to the chicks or eggs (Clode et al., 2000).

Nocturnal predation by great horned owls and black crowned night herons (*Procyon lotor*) has been noted in other tern colonies, notably in a Massachusetts Common Tern colony (Nisbet, 1975). The synchronous departure of almost all adult common terns has also been noted to occur without the presence of predators. Long term nocturnal desertion contributes to a reduction in reproductive success (Marshall, 1942; Nisbet 1975). Studies have shown that eggs and chicks that are lost due to predation contribute significantly to overall reproductive loss of the colony (Langham, 1968;

Hunter, 1976). Predation is not the only factor influencing nocturnal desertion, as research has shown that some periods of nocturnal foraging may occur (Marshall, 1942). Eggs and chicks are not lost completely due to direct predation, but the extended interruption of incubation of eggs and nesting care of chicks due to these nocturnal desertions are an important factor. Because of this, it is important to include nocturnal monitoring in the monitoring of vulnerable water bird communities.

Clustered nesting site selection

Breeding in large colonies or clustered territories offers protection against predators (Burger, 1974; Stokes, 2000; Hernández-Matías, 2003). While it is advantageous for terns to nest close to other nests due to mobbing behaviors, large clusters of nests may serve as an attractant to predators. Some studies have shown that larger colonies are visited by predators more than smaller colonies, and that nest aggregations are more conspicuous to predators than solitary nests (Clode, 1993; Stokes, 2000). Smaller distances between nests offer opportunities for adherence and communication between adults, which may mean that adults are more likely to nest in clustered patterns (Becker, 2015). Nesting in clusters also may help the terns to detect, defend, and even confuse predators, which will lower the risk of predation for the colony (Hernández-Matías et al., 2003). The “selfish effect”, in which prey animals will attempt to reduce predation risk by placing other conspecifics between themselves and the predator, may also impact nest clustering (Hamilton, 1971). This also reduces the risk of predation to clustered nests.

There is a trade-off that occurs between nesting in clusters to ensure group protection and avoiding colonies that are too large and may attract predators.

Poplar Island has been divided into a series of six containment cells for building island habitat. Of these cells, the eastern portion of the island has been divided into a series of 14 “sub-cells” in various stages of wetland creation and management (Droter, 2013). Historically, terns have nested on the eastern portion of the island in sub-cells 1D, 2C, 3B, 4B, 4C, as well as Jefferson Island (Figure 1). Nesting site changes could be due to a variety of factors, including past predation, outside disturbances such as construction or other human intervention, and differing nesting habitat.

Due to existing research and the background information given above, I expect to find that the nests in clustered patterns have higher hatching rates when compared with nests randomly distributed throughout the colony. Nests that are isolated from the nearest neighbor are more easily predated due to being easily found and not having the benefit of multiple adults mobbing predators nearby (Heath, 2004).

Figure 1. Map showing division of cells on Poplar Island, Maryland.

MATERIALS AND METHODS

This study took place on Poplar Island, Maryland, on the northwest side of cell 2 (hereafter 2C-NW). This is a cell that contains vegetation, gentle incline of sand to a water's edge, and rocky substrate. Efforts have been made to designate this cell as acceptable tern nesting territory, and once terns arrive and begin nesting, it is sectioned off from various construction traffic, including dredging machinery and trucks, from the rest of the island as to not disturb the nesting birds. Decoys and call sounds were in use prior to nesting season in an effort to attract the breeding terns to the area. This cell contained the majority of nesting common terns during the 2017 season on the island.

Walking nest checks occurred every two to four days in the mornings, with a maximum time in the colony about 45 minutes to reduce the amount of disturbance caused to the nesting birds. In this linear colony, terns often returned to nests after observers passed through their section of the colony, thus terns were not off nests the entire time. To cover ground without double counting nests, teams of three to six people formed a line, walking at a fixed distance through the colony. When a nest was found, it was marked with a paint stick displaying a nest number, and GPS coordinate data were taken. On subsequent visits, nests were monitored for any changes, including predation, new eggs, lost eggs, and hatched eggs.

Nests were determined to be successes or failures based on egg hatch. If one egg from the nest survived to hatch, the nest was designated as a success. This study does not examine fledgling success of the tern chicks post-hatch. Of the nest failures, there are three classifications of nest fate: washed out due to a heavy rain event, predation event, and undetermined cause of mortality. Included within the classification of undetermined cause of mortality are unattended nests, cracked or crushed eggs, and bug infested nests. However, these undetermined classifications are ones that I attributed to each nest based on existing field notes and are not proven as the cause of egg failure, as the exact cause of mortality is often hard to determine. A nest was determined to be washed out if eggs were found unattended outside of the nest area. This would often be the result of heavy rains where an egg would be pushed out of the nest. A nest was considered predated if eggs were cracked in half, had peck marks or holes, or had obvious animal tracks around the nest. Of the nests of undetermined cause for mortality, a nest was determined to be unattended if eggs were found buried, meaning they were not actively being turned by the parent, or if they were overly cold or hot. “Cold” or “hot” designations were made by comparing the eggs to other egg temperatures by hand. The cause for mortality, which would result in the unattendance, or nest abandonment, could be due to a number of factors that we were not able to determine such as flooding from rain event or mortality from low temperatures during all-night nest abandonment following nocturnal predator. Nests that contained eggs that showed cracks were designated as cracked- again, the cause for mortality is unknown, but at times whether tended or not, dead eggs will typically begin to crack. Nests containing eggs that were completely crushed were designated as crushed. This cause of mortality was due to one volunteer who inadvertently could not see certain nests; the volunteer’s actions during surveys were adjusted to only move through the parts of the colony with more visible nests. Few nests showed bug infestations and were designated as such. This cause of mortality could have been due to multiple factors such as flooding, nighttime nest abandonment during nocturnal predation, cracks forming in the egg, or other reasons. Nests that failed without obvious reason were designated failures with no reason found. Nests that had an unknown fate of success or failure were not included in this study.

Esri ArcMap™ 10.3.1 was then used to determine if nests that were predated, unattended, and hatched showed clustered patterns or were randomly distributed in the colony. As this study is only focused on cell 2C-NW, nests found elsewhere on Poplar Island are not included in this map. The analysis used to determine if the failed nests showed a clustered pattern within the colony is the nearest neighbor analysis tool on ArcMap™. The nearest neighbor analysis tool measures the distance between each feature point location and its nearest neighbor's feature point location for each nest within the colony area. These nearest neighbor distances are then averaged and compared to the average for a hypothetical complete spatial randomness distribution. If the average observed distance between nests is less than the expected random distribution distance, these feature points are considered clustered. If the average distance between feature points is greater than the hypothetical random distribution average, the feature points are considered dispersed.

ArcMap™ and Google Earth Pro were used to visualize colony distribution changes on Poplar Island for the years 2014-2017. GPS coordinate data for the nest locations were collected by USGS technicians during the nesting season on Poplar Island. These maps show the location of common tern nests on all cells of Poplar Island, Maryland.

RESULTS

There were 240 found nests on cell 2C-NW on Poplar Island, Maryland, during the 2017 nesting season. Of these 240, 29.6% were found to be failures, 54.2% were found to be hatched, and 16.3% had unknown fates (Figure 2). Of the 71 nest failure events, 22.5% were due to being washed out from heavy rain events, 9.9% due to predation, and 67.6% due to undetermined causes of mortality (Figure 3).

The nearest neighbor analysis found that the nearest neighbor ratio for failed nest clusters was 0.16 (Table 4); this was the same for successful nests. Since it is less than 1, the pattern exhibits clustering and is not randomized. In this analysis, both failed and successful nests exhibit a clustered pattern and were not randomly distributed on the island.

Table 4. Results from the nearest neighbor analysis run on the failed and successful nests in the 2C-NW COTE colony

Nearest Neighbor Ratio	0.16
Observed Mean Distance	4.61 m
Expected Mean Distance	28.7 m
Z score	-36.62

The mapping analysis for the locations of common tern nests for the years 2014-2017 shows various changes in nest locations (Figure 4). In general, cells 4B and 4C were always occupied in surveyed years. In years 2014, 2015, and 2016, Jefferson Island contained common tern nests. On average, there were four sub-cells occupied by nesting terns during the surveyed years. The most notable of these changes is the new nesting location on cell 1D in 2017.

Within cell 2C-NW, the nests that had successful hatches and those with failed hatches are shown in Figure 5.

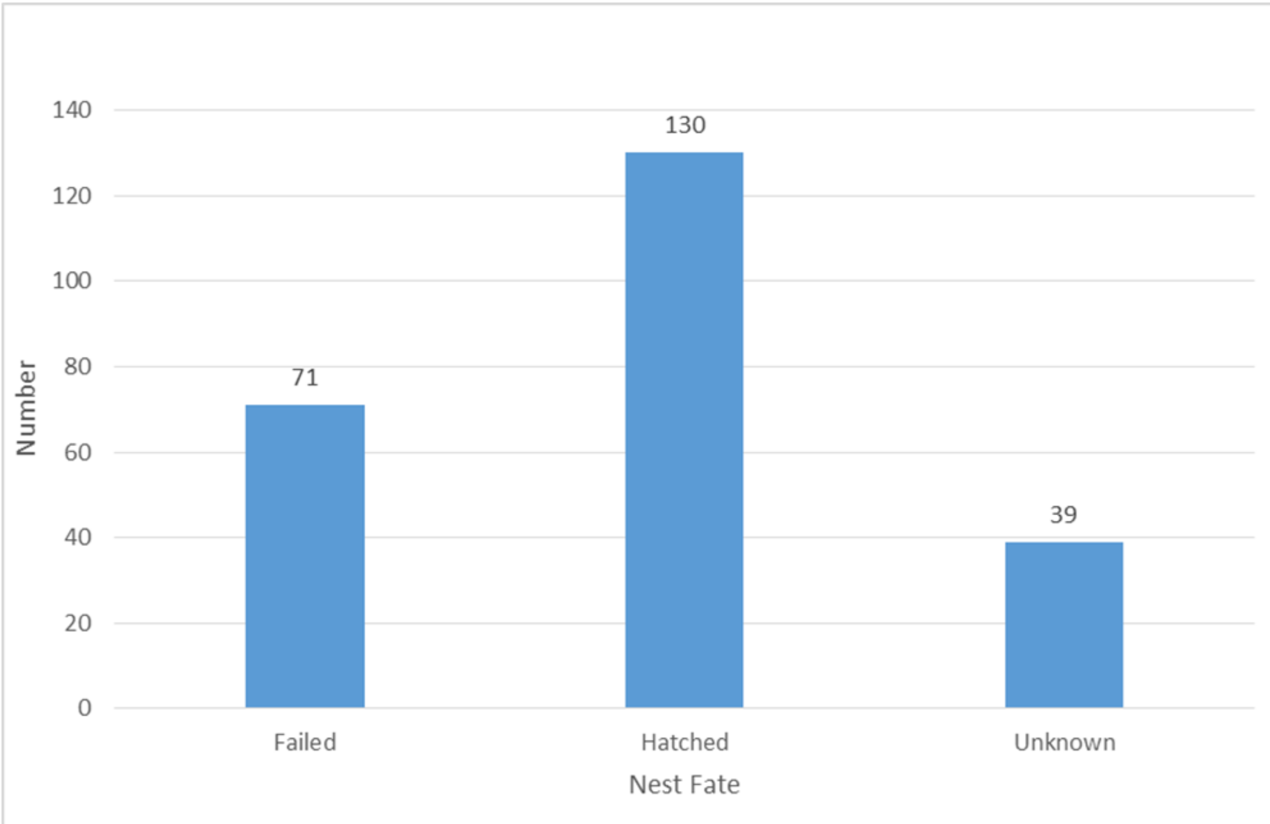


Figure 2. Overall nest fates for common tern nests on cell 2C-NW on Poplar Island during the nesting season 2017. Includes nests that were failures, hatched (successful), and unknown fate. N= 240

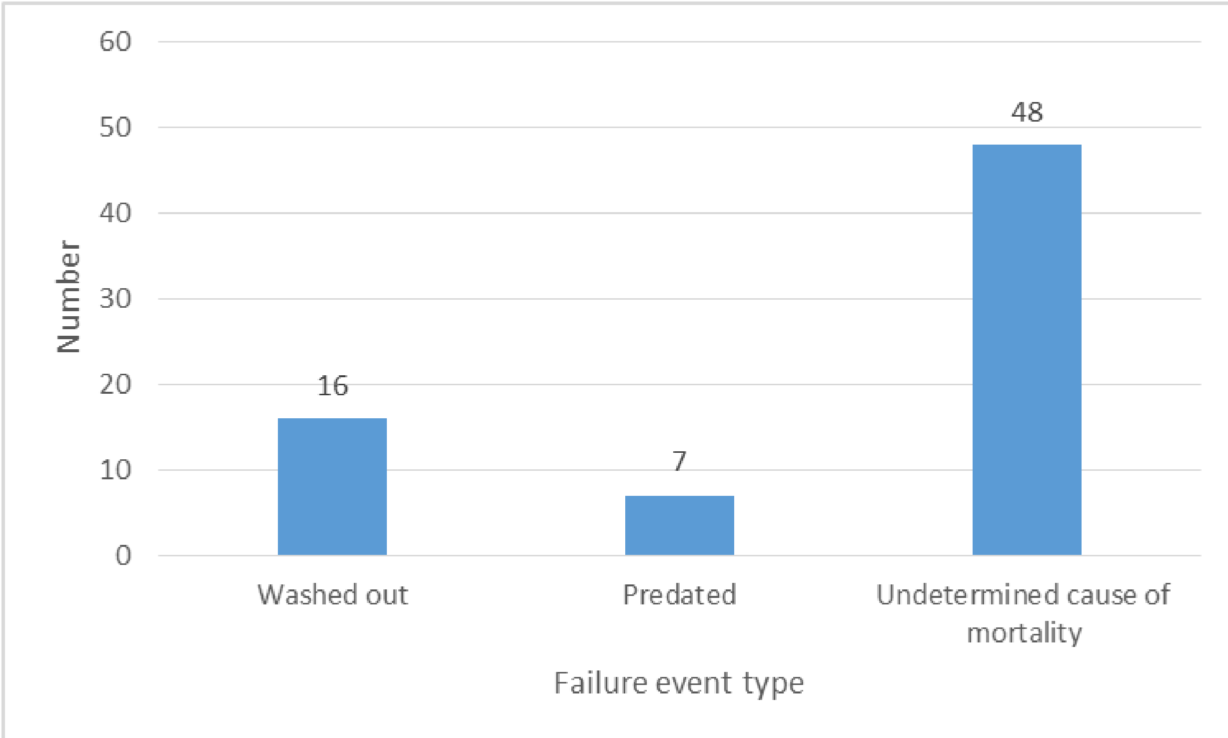


Figure 3. Nest failure event types for common tern nests on cell 2C-NW on Poplar Island, Maryland during the 2017 nesting season. Reasons noted in the field categorized into washed out, predated, and undetermined cause of mortality. N=71

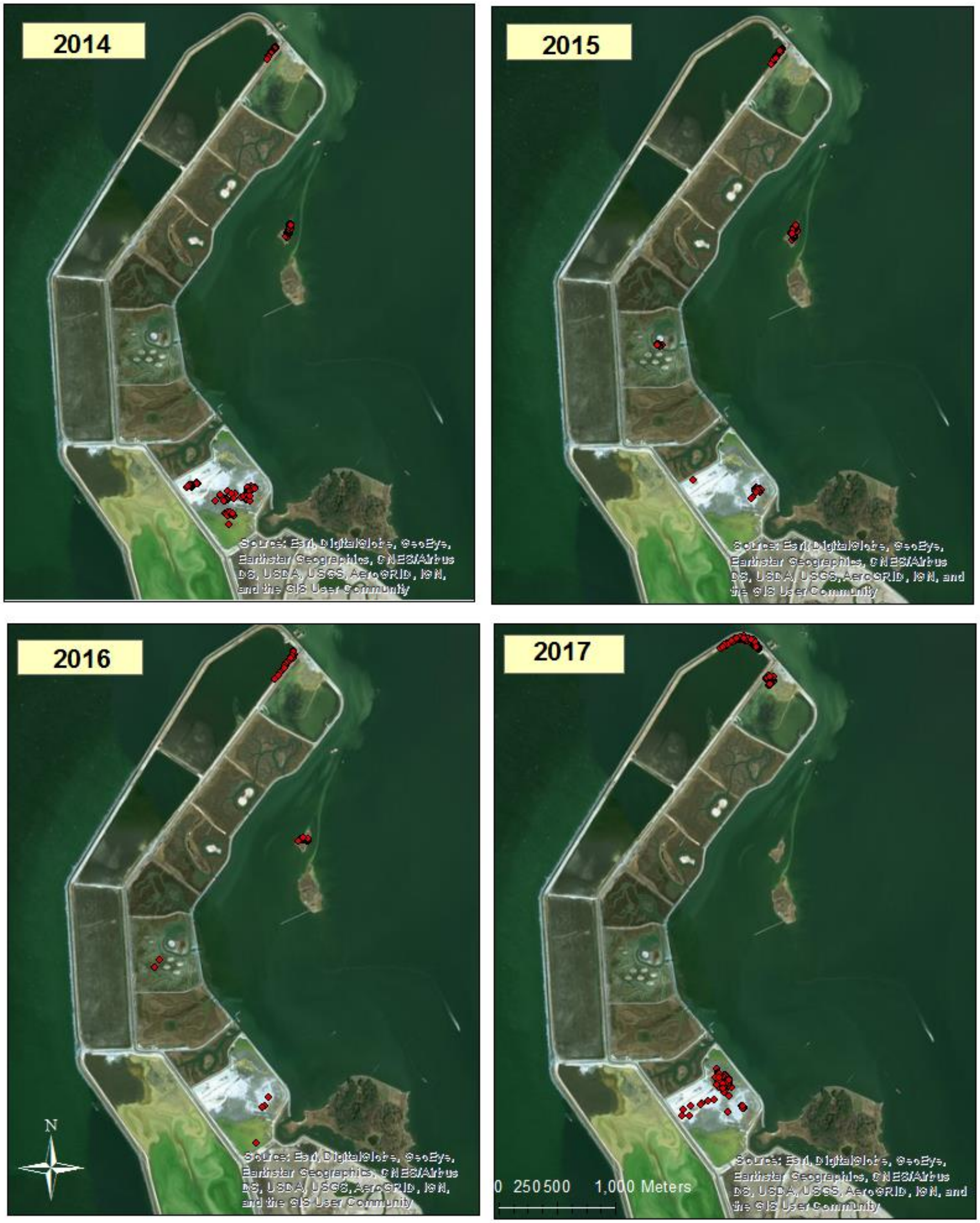
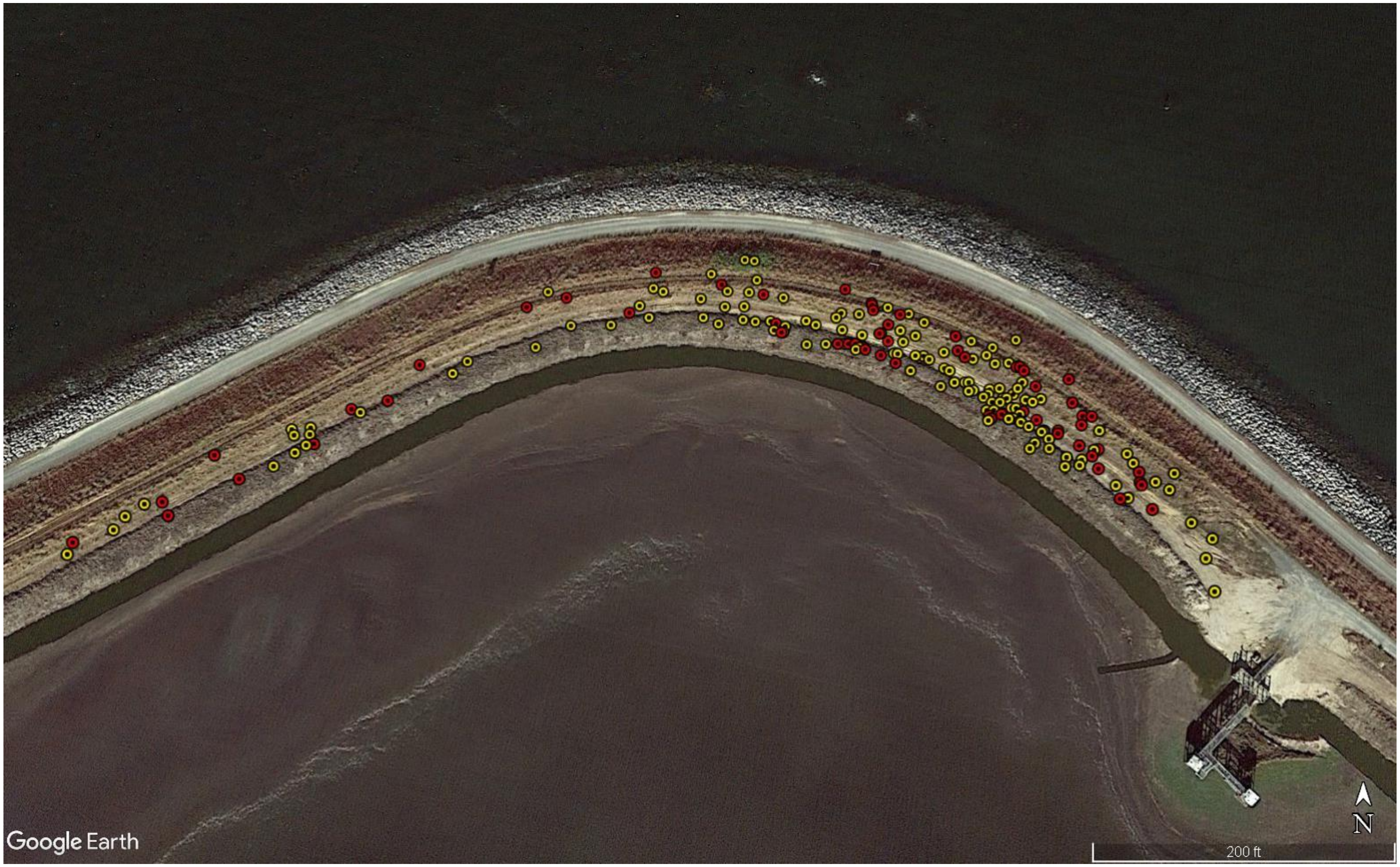


Figure 4. Maps showing common tern nesting location differences on Poplar Island by year. Nest locations are shown in red dots, and vary each year between different cells.



Legend	
(yellow marker)	Nests with hatching success
(red marker)	Nests with hatching failures

Figure 5. Map displaying the common tern nests on cell 2C-NW during nesting season 2017.

DISCUSSION

This study examined how nesting pattern relates to nest success in the common tern on cell 2C-NW on Poplar Island. The results show that nesting pattern does not appear to influence survival rate of tern nests in the colony, as both failed and successful nests displayed a clustered pattern, in that the average nearest neighbor distance is less than a randomized distance, rather than a randomized one. Because of the distance used by ESRI to define the distances between nests for clustered versus randomized patterns, the hypothesis that nests in clustered patterns have higher survival rates when compared with nests randomly distributed throughout the colony is not supported at this time. If nesting pattern had a large impact on nest survivability, a difference in the location of failed nests versus successful nests would be clearer in that failed nests would be more scattered than their successful counterparts.

The clustered pattern of nests can be due to a variety of factors, including protection against predators. There was a high rate of survivability of nests in this colony during this breeding season, something that may be due to the adult tern mobbing behavior. This mobbing behavior was observed during this study when researchers were in the colony conducting nest checks. Aggressive nest defense behavior has been found to be positively correlated with nest density, with more birds displaying diving behavior with an increase in nest density (Burger, 1988). Predation was not a huge factor in nest failure during this breeding season, with only seven nests (9.9%) appearing predated, something that could be due to the clustered pattern of nests providing more nest protection. This predation did not appear to be a result of great horned owl or fox presence but rather the presence of avian predators such as crows (*Corvus spp.*) or redwinged blackbirds (*Agelaius phoeniceus*). Since all nests displayed a clustered pattern, there is no comparison to be made between clustered and randomly placed nests. This is a limitation of the study, as there is no control group in place here to compare how clustered or randomized density may have an impact on nest survivability.

Of the nest failure events, the majority (67.6%) were due to undetermined causes of mortality. Within this category, the majority (32.4%) were due to eggs being buried or left unattended. This could be due to adult nocturnal nest desertion, a phenomenon previously studied and found to be a result of nocturnal predation. Great horned owl predation is a huge influence on nocturnal nest desertion, with common tern adults in predated colonies leaving the nest at dusk and not returning until dawn (Nisbet, 2002). This results in cold eggs, leading to egg death. While great horned owl predation was not a huge factor during this nesting season due to successful control efforts, it has been a problem in past seasons (Table 3). Another reason for nocturnal desertion could be due to extended foraging periods, which may explain this occurrence during a season low in nocturnal predation (Marshall, 1942).

The next most significant nest failure reason, eggs being washed out due to heavy rain (22.5%), is due to weather events or parental egg rejection. Parental effort increases with increased breeding success, and first time breeders may choose to reject or abandon their nest if perceived effort is greater than perceived reward, in this case a successful hatch (Crespin et al., 2006). Further research can be done on banded birds to determine what differences exist in the nesting behaviors of first time versus returning nesters.

The movement of nesting terns between sub-cells can be due to a variety of factors, from predation on cells of previous years to new habitat becoming available. The use of decoys and call boxes on cell 2C-NW for the 2017 nesting season may have had an impact on the nesting terns, as the majority chose that cell to nest on during the season. The new nesting on cell 1D may be largely due to new construction projects on the cell which resulted in suitable nesting habitat, although they were not designed to do so.

This study has a variety of limitations. These include small study area, small sample size, and only one season of nesting data. The area of study was on one cell of Poplar Island, a small island located in the Chesapeake Bay. Within the cell was one colony of common tern. If a larger study area and sample size were utilized, more data could be collected and used to understand nesting site selection and protective behaviors of the adults. The study focused on the 2017 nesting season, between the months of May and August. Ideally, the study would include more than one season, to capture more of the natural nesting behaviors of the common tern. With more seasons being examined, perhaps a clearer pattern of nesting clusters could be observed and researched. More research can be done using game cameras set up in the colony to monitor nocturnal nest desertion to understand the significance of the phenomenon and how much it may impact nest survivability.

The limitations in this study open up a wide variety of future research related to this topic. These include studies with the above limitations eliminated, such as a multi-year study on the same topic or a study of all common tern nesting sites in Maryland. Further research to understand mobbing behavior of the common tern could be conducted, as could more research into nesting site and mate selection.

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