Use of Artificial Eelgrass Mats by Saltmarsh-Nesting Common Terns (*Sterna hirundo*)

By

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Abstract

Terns and skimmers nesting on saltmarsh islands often suffer large nest losses due to tidal and storm flooding. Nests located near the center of an island and on wrack (mats of dead vegetation, mostly eelgrass *Zostera*) are less susceptible to flooding than those near the edge of an island and those on bare soil or in saltmarsh cordgrass (*Spartina alterniflora*). In the 1980's Burger and Gochfeld constructed artificial eelgrass mats on saltmarsh islands in Ocean County, New Jersey. These mats were used as nesting substrate by common terns (*Sterna hirundo*) and black skimmers (*Rynchops niger*). Every year since 2002 I have transported eelgrass to one of their original sites to make artificial mats. This site, Pettit Island, typically supports between 125 and 200 pairs of common terns. There has often been very little natural wrack present on the island at the start of the breeding season, and in most years natural wrack has been most common along the edges of the island. The terns readily used the artificial mats for nesting substrate. Because I placed artificial mats in the center of the island, the terns have often avoided the large nest losses incurred by terns nesting in peripheral locations. However, during particularly severe flooding events even centrally located nests on mats are vulnerable. Construction of eelgrass mats represents an easy habitat manipulation that can improve the nesting success of marsh-nesting seabirds.

Introduction

Common terns (*Sterna hirundo*) are colonially-breeding birds that live in a variety of habitats near water[1-3]. Although they are typically thought of as nesting on sandy and rocky beaches, in New Jersey most barrier beaches have been developed and terns nest most frequently on small saltmarsh islands[2,4,5]. Common terns appear to be adapted to nesting in marsh habitat[2,6-8], and saltmarsh islands have important advantages over mainland and barrier island locations, such as a lack of mammalian predation and less frequent human disturbance[7]. However, these islands are vulnerable to tidal flooding and storms, and large numbers of nests are frequently lost[2,7,9-11]. Rising sea levels are expected to exacerbate this problem[10,12,13].

Preferred nesting substrate on saltmarsh islands is wrack, mats comprised mainly of dead eelgrass (*Zostera*) or other dead vegetation deposited by flooding prior to nesting. Nests on wrack are better able to survive flooding than nests on bare soil or in saltmarsh cordgrass (*Spartina alterniflora*), because eelgrass mats provide additional elevation, provide structure, and can float[2,4,5]. The availability of wrack is limited, however, as hundreds of terns may nest on a small island and wrack covers only a small percentage of an island's area. Nests on wrack therefore occur at a higher density than those in other habitat[2,4,9,14]. Nests located in the center of an island are also less likely to experience flooding than those along the edges, but during severe floods an entire island can be under water and complete nesting failure of a colony can occur[2].

Although global populations are large and probably stable, the common tern is listed as "Species of Special Concern" by the New Jersey Division of Fish and Wildlife and is also a focal species for conservation in other states and provinces along the Atlantic coast[15]. In the area where this study took place, the Barnegat Bay ecosystem in New Jersey, the common tern population has decreased since the 1980's in both number of individuals and number of colonies[12,16,17]. This decline may be in part due to increased flooding and lower availability of wrack[16,17]. Other contributing factors include nest site competition with herring and great black-backed gulls (*Larus argentatus* and *L. marinus*)[12,16,17], which can also act as nest predators, and disturbance by personal watercraft[16,18]. These factors do not act in isolation. For example, gulls can increase the effects of flooding by causing terns to nest on lower sites[16,19], and flooding can increase susceptibility to nest predation by gulls[19]. Tern colonies are often actively managed by controlling gulls, limiting human disturbance, and modifying habitat to increase or improve nesting substrate[3,10,15,20,21].

In the 1980's, Burger and Gochfeld[2,22] constructed mats of eelgrass on several saltmarsh islands in Barnegat Bay and documented use of these artificial mats by common terns and black skimmers (*Rynchops niger*), a state endangered species. Because of a lack of large natural mats, the only skimmers to nest successfully in Barnegat Bay in the late 1980's did so on artificial eelgrass mats[12,16,22]. That tern and skimmer nests survive flooding better on wrack than on other substrates[2,4,5,22], also suggests that these mats could be used as a conservation tool to improve nesting success. Both Safina *et al.*[7] and Rounds *et al.*[10] have proposed placing or manipulating wrack on saltmarsh islands to encourage common terns to nest at higher elevations. The effect of adding artificial mats would be particularly important if suitable wrack becomes less available than in the past, which may have already occurred in Barnegat Bay[17].

I have studied the common terns at one of Burger and Gochfeld's original sites, Pettit Island, in most years since 1996. Skimmers abandoned this site several years before my study began and have not returned, except for one pair that nested unsuccessfully in 2001. In 2002 I began transporting eelgrass annually to this site to create artificial mats. Here I document usage of artificial eelgrass mats by common terns nesting at Pettit Island from 2002 through 2008, document the effects of flooding in this colony from 1996 through 2008, and examine whether the terns benefited from the presence of artificial eelgrass mats.

Methods

This study took place on Pettit Island (39°40'N, 74° 11'W), a 0.3 hectare saltmarsh island in Manahawkin Bay in Ocean County, New Jersey that has been the site of a common tern colony for decades[2]. Manahawkin Bay is part of the larger Barnegat Bay ecosystem, south of Barnegat Bay proper and north of Little Egg Harbor. Excluding permanent and tidal pools, the island is covered almost entirely with *S. alterniflora*.

I collected dead eelgrass in Bayville and Surf City, New Jersey and transported it in large trash bags by boat to Pettit Island annually since 2002. Mats of eelgrass were then constructed, usually near the center of the island. To create a mat I simply dumped eelgrass out of the trash bags and evened out the pile by hand, approximating the height of natural mats. In addition to eelgrass transported to the island, small natural mats located close to the edge of island were occasionally pulled back closer to the center of the island, either alone or to add to an artificial mat. (Pulled-back mats are analyzed together with artificial mats.) The mats were typically placed at a minimal distance of 5 to 20m from the nearest edge of the island, with the majority greater than 12m from the edge. From 2002 through 2007 the artificial mats ranged in size from approximately 2 to 5m^2 and ranged in number from one to four. Total area occupied by artificial mats ranged from approximately 5 to 13m^2 (Table 1). In 2008 I constructed larger mats, measuring 8.4 and 14.4m^2, for a total area of 22.8m^2. Whenever possible, eelgrass mats were constructed in mid-May before terns began nesting (typically late May) and were added to early in the nesting period.

I recorded the number of nests on these mats and estimated the total number of nests in the colony. Flooding events were also documented, as well as loss or survival of nests after flooding, including four years prior to construction of artificial mats in which I also studied the Pettit Island terns (1996, 1997, 1999, 2001). In most years the colony size estimate comes from a nest census before hatching, but in 2003 and 2004 is a minimum estimate based on the number of terns flying overhead during disturbance. In this colony there are often two distinct waves of egg-laying, one in late May and early June and one in late June and early July[23]. Colony size estimates exclude nests appearing in the second wave or later to avoid counting the same breeding pairs twice, because terns losing nests early in the breeding season often re-nest[1-3].

The level of detail recorded varies among years, depending on the focus of my research activity in a given year. The best data is from 1999, 2001, 2002, 2007, and 2008, when nests were individually marked with numbered craft sticks and checked regularly, with information recorded on individual index cards. The cards could include such information as the location of the nest, fate of each egg, date of hatching and fate of each chick (individually marked with metal bird bands), and nesting substrate. Although I constructed mats in 2004, there is little data from this year, because I visited the island only once after mat construction, late in the breeding season.

Results

The total number of nests on the island varied from over 110 nests to approximately 210 nests (Table 1). In 2002 and 2008 I recorded the nesting substrate for a large number of nests (N = 79 and 81, respectively). In 2002 81% of nests were built on wrack (including both natural and artificial eelgrass mats), with 16.5% on *S. alterniflora* and 2.5% on bare soil. In 2008 75.3% of nests were built on wrack, with 14.8% on *Spartina* (including 2 nests on *S. patens*), 4.9% on clumps of root mat and soil, 2.5% on bare soil, and 2.5% on wooden boards. In five of eight years there was little wrack present early in the breeding season, and what was present tended to occur along the edges of the island (Table 2).

Terns used artificial mats in every year in which they were constructed, and the number of nests on artificial mats ranged from 5 in 2002 to 22 in 2003 (Table 1). In five of six years with data, an additional one to four nests were present in *S. alterniflora* immediately adjacent to the artificial mats (within approximately 1m). When constructed prior to the start of nesting, nests on artificial mats were among the first nests on the island (Table 2). With the exception of 2002, when terns began nesting before artificial mats were constructed, all of the nests recorded on artificial mats were present during the first wave of egg laying, with no late nests.

There is a significant correlation between the area of individual artificial mats and the number of nests on the mats (Spearman Rank Correlation, Z = 2.45, P = 0.014, Rho = 0.66). The correlation is not significant if total area

Table 1. Estimated common tern colony size and usage of artificial mats (AM)			
Year	Total Nests	Nests on AM	Total Area of AM (m^2)
1999	160	N/A	N/A
2001	150	N/A	N/A
2002	200	5	9
2003	>110	22	13
2004	>120	No data	No data
2005	200	8	9
2006	200	13	7
2007	210	13	5
2008	125	17	23

Table 3. Effects of flooding in the colony and on artificial mats			
Year	Date	Losses to Flooding	Nests on Artificial Mats
1996	2-Aug	Island abandoned after flooding late in season	N/A
1997	5-Jun	Perimeter flooded	N/A
1999	mostly 10-Jun	13% of eggs lost to flooding	N/A
2001	mostly 19-Jul	27% of eggs at peripheral nests lost	N/A
2002	6 and 15-Jun	32% of eggs and 22% of chicks lost, affecting 59 of 111 marked nests	First nest lost; 4 of 4 late nests survive
2003	9-Jun	NE side of island flooded	18 of 19 nests survive
2003	14-Jun	>14% of nests lost to flooding	All 21 nests survive (3 lose an egg)
2004		No data	No data
2005	23 and 30-May	13 of first 16 nests lost	First nest lost
2005	20-Jun	Perimeter flooded	7 of 8 nests survive
2005	7-Jul	Some flooding	All remaining nests survive
2006		No significant flooding	No losses to flooding
2007	8-Jun	All 54 SW peripheral nests lost	All 13 nests survive
2007	12-Jun	Some flooding along NE side of island	All 13 nests survive
2007	14-Jun	Island under water, >75% of nests lost	8 of 13 nests lost
2008	21-May	Nesting delayed ~one week	Nesting delayed ~one week
2008	13-Jun	Approx 15% peripheral nests lost	All 17 nests survive
2008	18 and 25-Jun	Approx 10% peripheral nests lost	All 17 nests survive

Table 2. Status of natural mats and presence of nests on artificial mats early in the breeding season			
Year	Date study began	State of natural mats early in season	Early nests on artificial mats (AM)
2001	23-May	Little wrack, mostly along edges	No AM this year
2002	20-May	Wrack abundant and in from edge	Terns already nesting when AM created
2003	15-May	No wrack present	First 3 and 18 of first 32 nests on AM; 8 of first 9 chicks on AM
2004	4-Jun	Large mats present	Terns already nesting when AM created; 3 nests on remnants of AM from 2003 AM
2005	10-May	Large central mat, little else	1 of first 16 nests on AM
2006	10-May	Little wrack, except narrow mat along edges	2 of first 19 nests on AM
2007	7-May	Little wrack, mostly along edges	2 of first 5 nests and 2 of first 5 chicks on AM
2008	15-May	Little wrack, small clumps along edges	8 of first 23 nests on AM

Figure 1. A nest on an artificial mat of eelgrass (a) and in nearby *Spartina alterniflora* (b) are shown during a flood.

of artificial mats is used rather than considering each mat separately ($Z = 0.99$, $P = 0.33$, Rho = 0.44), but the two years with the largest number of nests on artificial mats were also the two years in which artificial mats occupied the largest total area (Table 1).

Flooding was a major cause of nest loss in most years; flooding events are summarized in Table 3. In most cases flooding affected nests near the edge of the island to a much greater extent than nests near the center of the island (Table 3). Nests on artificial mats tended to survive flooding (Table 3), except in 2007, when flooding was so severe that the entire island was under water. Figure 1 shows a surviving nest on an artificial mat surrounded by water and a nearby flooded nest in *S. alterniflora*.

Discussion

As has been previously reported[2,4-11], common terns nesting on saltmarsh islands clearly prefer wrack, in this location largely comprised of eelgrass mats, as nesting substrate. Approximately 75 to 80% of nests were on wrack, even though *S. alterniflora* occupies a much larger proportion of the island's area[2,4,22]. Terns readily used artificial mats of eelgrass: nests were present on artificial mats in every year of the study and were often among the first nests on the island. That the terns began nesting on the artificial mats so quickly suggests that eelgrass mats are a limiting resource in the colony. Observations across several years (see Table 2) support the suggestion that naturally occurring wrack is less abundant than in the past[17].

Nests on artificial mats typically survived normal flooding, likely due to both their central location and increased elevation. However, few nests survived unusually severe flooding, such as in 2007, regardless of location. In that year the entire island was under water and at least 75% of nests were lost. It is likely that many terns abandoned Pettit Island after this flood, as there was a large decrease in the number of nests on the island between 2007 and 2008 (see Table 1). Effects of flooding were apparent in most years, particularly among nests close to the edge of the island. Losses to flooding were unpredictable, though, as all nests along one side of the island could be washed out while the opposite side of the island was largely unaffected (see Table 3), depending on the direction a storm happened to take.

Burger and Lesser[4] studied habitat selection of common terns nesting on 34 saltmarsh islands in Ocean County, NJ, including Pettit Island. They reported that the terns usually avoided nesting on wrack that was within 5m of the edge of an island, but in my study that is typically where most nests were located. That terns chose nest sites close to the water's edge seems maladaptive, but it is often where eelgrass mats were most abundant. The terns appear to be suffering from an "ecological trap"[24]. They may be trapped by competing characteristics of good nesting sites: a good location may not match with a good substrate because of a recent change in the environment - decreased availability of wrack, particularly in the center of the island. Previous authors have also found that characteristics of good nest sites for marsh-nesting common terns can conflict with one another[10,11].

One of the major benefits of providing artificial eelgrass mats is that preferred nesting substrate becomes more available away from the edges of an island. In addition to transporting additional eelgrass to an island, pulling back eelgrass from the edge, which I did on a small scale, may enhance this benefit. The positive effects of artificial mats may also extend beyond the borders of the mats if they attract terns to form subcolonies closer to the center of the island: some terns built nests in *S. alterniflora* immediately adjacent to the artificial mats. Although these nests were likely to survive most flooding due to their central location, anecdotal evidence suggests that they were less likely to survive major floods than those on the eelgrass mats (Figure 1). For example, in 2007 five of thirteen nests on an artificial mat survived the major flood, while all three neighboring nests were washed out. During the same flood a large natural mat floated nearly 3m inland from its original location largely intact, with several nests surviving.

Artificial mats seemed to be particularly important in years when little wrack was present on the island early in the breeding season. Years with substantial wrack early in the season not only have more substrate available, but what is there is safer from flooding, as it would include material deposited by the highest winter storm tides above the reach of normal tidal flooding[2,4,22]. 2003 is an extreme example, but shows the potential value of artificial mats as a conservation tool. In this year there were no natural mats present in mid-May – it appeared that, rather than creating mats, winter storms were so severe that they washed over the island and removed what was previously present[17]. The first three nests and 18 of the first 32 nests were built on artificial mats, and eight of the first nine chicks hatched on artificial mats. This was also the year with the largest total number of nests on artificial mats, 22. Only one of these nests was lost to flooding, despite substantial losses elsewhere in the colony. The improvement in tern nesting success caused by the presence of artificial mats is probably underestimated by the proportion of nests surviving flooding, because many previous studies have shown that terns that nest early are consistently more successful in raising chicks to fledging[25-27].

The loss of a large number of nests to flooding in a given year does not necessarily mean that the overall population will be affected, because terns are long-lived and have many opportunities to breed[1-3]. Similarly, because flooding does not directly affect adult survival, that fewer terns nested on Pettit Island in 2008 does not mean that the population has decreased, but instead suggests that many adults chose to nest in a different location within the same metapopulation. On the other hand, if flooding increases in frequency and intensity, which may have already occurred in Barnegat Bay due to the dredging of Barnegat Inlet and reconfiguration of a jetty[12,16] and is predicted to increase further due to rising sea levels[10,12,13], then the Barnegat Bay common tern population will continue the downward trend reported in the late 1990's[12,16,17].

I plan to continue to construct mats in the future, particularly large mats, to increase usage by terns and to possibly attract skimmers, which require larger mats than do terns[2,4,16,22]. Construction of eelgrass mats represents an easy method to modify habitat in a manner that can increase reproductive success of terns and skimmers and may help prevent or slow down further population declines.

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