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ENGINEERING WITH NATURE

Creating Nesting Habitat for the Common Tern (*Sterna hirundo*) on the Repaired Ashtabula Breakwater: Lessons Learned 2014 – 2016

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PURPOSE: The U.S. Army Engineer Research and Development (ERDC), Environmental Laboratory (EL) developed this technical note to summarize data collected during avian monitoring efforts on a repaired breakwater in Ashtabula Harbor, Ashtabula, OH. The repaired breakwater included a modified design that provided nesting habitat for the state-listed (Ohio) Common Tern (*Sterna hirundo*). The purpose of the nesting structure was to demonstrate simple design changes, executed during repairs to an existing breakwater, that increases environmental benefits consistent with the Engineering With Nature (EWN) initiative (U.S. Army Corps of Engineers [USACE] 2012). The U.S. Environmental Protection Agency (USEPA), Great Lakes Restoration Initiative (GLRI), and the Dredging Operations and Environmental Research Program (DOER) funded this project. The Nature Conservancy (TNC), with expert consultation from the Ohio Department of Natural Resources (ODNR) and the New York Department of Natural Resources (NYDNR), assisted with the implementation of this project. Elements of this work included (1) specific features of the repaired breakwater utilized to attract terns to the structure, (2) development and implementation of a monitoring program to assess the use of the structure by terns, (3) description of media coverage of this effort, and (4) final results and lessons learned from the project and future efforts to monitor the breakwater.

BACKGROUND: The EWN initiative utilizes natural and engineering processes to enhance the economic, social, and environmental benefits associated with water resource projects (Fredette et al. 2016). Application of EWN principles through numerous demonstration projects is a necessary component to transfer developed technologies and approaches beyond local environments. The Ashtabula Tern Nesting Habitat Project is intended to provide and demonstrate a viable option during repairs of similar breakwaters throughout the Great Lakes Region.

The Common Tern was considered a suitable target species for this project because this species experienced significant declines due to the millinery trade during the late 19th century. However, in the 1930's, the Audubon Society's Common Tern recovery efforts led to the implementation of a Migratory Bird Treaty with Canada, and ultimately, the Migratory Bird Treaty Act that allowed the species to recover. However, by the 1970's, the species had declined again due to pesticides and toxins, including Dichlorodiphenyldichloroethylene (DDE), in the environment that reduced reproductive output (Nisbet 2002). Moreover, there was a corresponding surge in predation by gulls (*Larus* spp.), plus competition for nesting sites with Ring-billed Gull (*Larus delawarensis*) populations that likely contributed to the decline (Nisbet 2002, New York Department of Environmental Conservation [NYDEC] 2013). Currently, populations have recovered since the 1970's, but are still well below historical population numbers (Cuthbert et al. 2003). A breeding

population in the Ashtabula area has been extirpated for about 40 years; however, individual Common Terns are still observed periodically as migrants or transients. The largest colonies of this species are located about 75 miles east in the Buffalo Harbor, New York, and approximately 105 miles west near Sandusky, OH. Despite the distance from source colonies, this species is often limited by lack of suitable nesting habitat. In the Great Lakes Region, this species is now largely dependent upon man-made structures to provide suitable nesting sites that are isolated away from predators and protected from human disturbance (Karwowski et al.1995, Riveredge Associates 2012). There are significant data to show that Common Terns regularly nest on navigation structures and man-made islands that are constructed or modified specifically for nesting birds (Karwowski et al. 1995, Cuthbert et al. 2003, Riveredge Associates 2012). Therefore, in the development phase of this demonstration project, the potential for reestablishing a breeding colony in this area seemed appropriate. Likewise, TNC staff that was consulted before designing the repair structure recommended reestablishing a breeding colony in this area. By demonstrating the value of repaired breakwaters for nesting tern habitat, it is expected that similar harbor restoration efforts in the future may provide significant nesting habitat leading to the eventual recovery of Common Tern populations in the Great Lakes Region.

NESTING SITE DESIGN: Specific details on the breakwater nesting habitat design can be found in Fredette et al. (2016). Briefly, a major feature of the breakwater is that it is not connected to land (Figure 1), which greatly reduces access to the site by mammalian predators. The breakwater crest was repaired with a double row of pre-cast cement blocks laid end-to-end. There are two types of blocks: (1) a toe block (8 ft x 8 ft x 4 ft) used to anchor the base of the structure, and (2) modified blocks on top that have a 6 in. deep recess filled with gravel to serve as a suitable substrate for tern nesting (Figures 2 and 3). When completed, the blocks were placed end-to-end and side-to-side on the breakwater. Each eight-block section provides approximately 250 ft^2 of nesting area (Figure 3). Once the blocks were in place, fence posts were erected in pre-cast holes in the blocks. Cabling was attached to the posts along the sides and over the top of the nesting substrate to protect the habitat from avian predators. Metal-mesh side fencing was also placed around the bottom edge of the nesting structure to prevent mammals from accessing the site while also preventing young Common Terns from potentially falling (Figure 3).

FEATURES USED TO ATTRACT/PROTECT TERNS: Six to twelve wooden decoys were placed on the gravel substrate to attract birds (Figure 3), and two solar powered Murremaid® call boxes were used to broadcast calls during the day (Figure 4). Wooden covers and driftwood were added to provide cover and shield young Common Terns from exposure. Three to six motion-activated cameras were placed on the structure to visually capture use of the site by terns or other birds not detected during regularly scheduled manned surveys. In addition, cabling (5/32 in. PVC clothesline) along the sides and over the top of the nesting structure was used to deter avian predators, particularly gulls, from preying on eggs and chicks (Fredette et al. 2016). The cabling was spaced about 1.5 ft to 2.0 ft to provide access to the nesting substrate by terns; however, it was narrow enough to discourage or prevent gull access. In the initial construction of the site, ¼ in. to ½ in. #9 pea stone gravel was used as nesting substrate. However, these stones were washed away during winter months in 2014 and 2015. In April 2016, 2.5 in. to 3.0 in. of #3 gravel was used as a base layer and covered with ½ in. to ¾ in. #67 pea sized gravel. It is expected that the #3 gravel will remain in place during the winter months and that the #67 gravel will be more efficiently replaced, if needed.

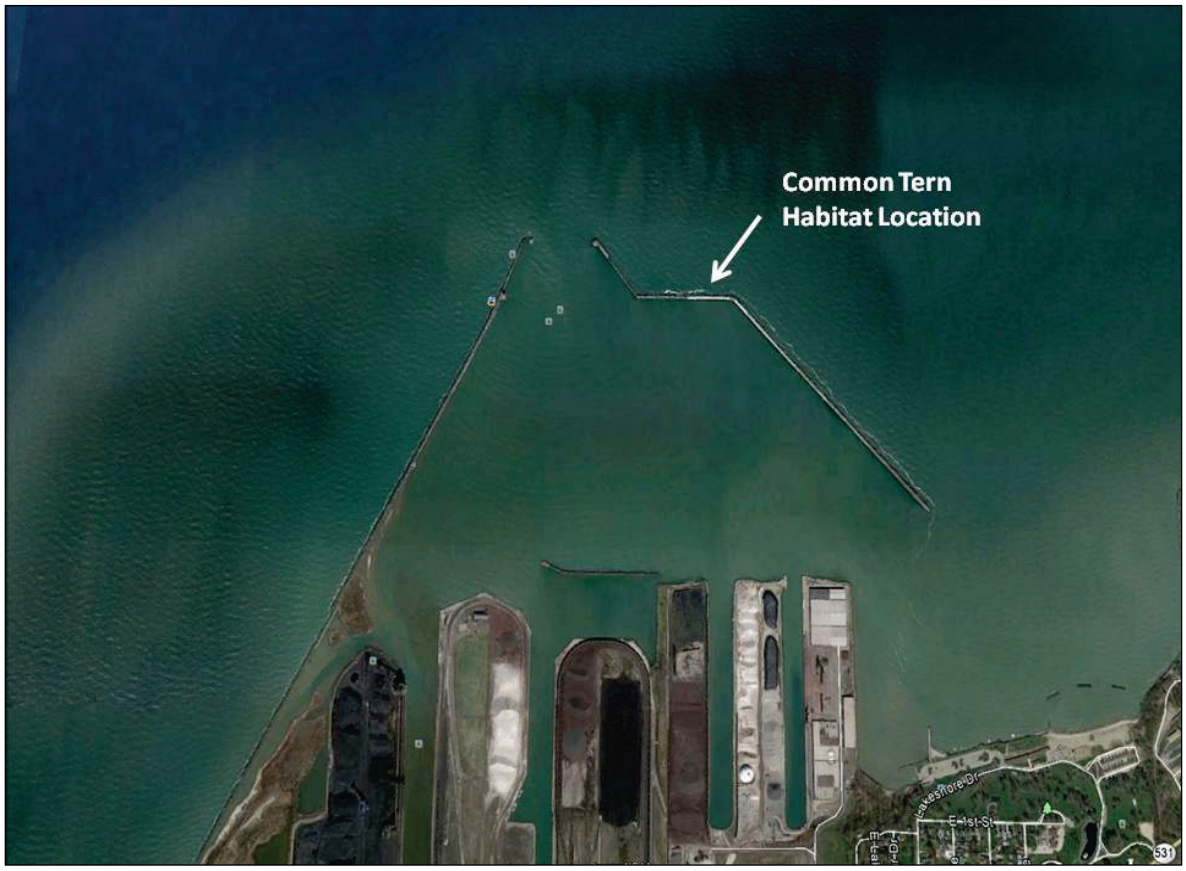

Figure 1. Location of the repaired breakwater in the Ashtabula Harbor, OH.

Figure 2. Blocks established on the Ashtabula breakwater were designed to create nesting habitat for the state-listed (Ohio) Common Tern (Photo Credit: Michael Guilfoyle, ERDC-EL).

Figure 3. Nesting habitat created for the Common Tern on the repair breakwater in the Ashtabula Harbor (Photo Credit: Michael Guilfoyle, ERDC-EL).

Figure 4. Murremaid® call boxes were placed on both ends of the repaired Ashtabula breakwater. In 2016, the call boxes were elevated above the structure to protect them from over washes during storms (Photo Credit: Michael Guilfoyle, ERDC-EL).

MONITORING PROTOCOL FOR COMMON TERNS: The purpose of monitoring Common Terns on the repaired breakwater in Ashtabula Harbor was to document the success of the structure in attracting breeding terns to the site. In addition, it was expected, upon evidence of nesting by the birds, to provide an index of reproductive success of the colony. To meet these objectives, the authors developed a scientifically sound monitoring protocol based on the Department of Defense (DoD) Coordinated Bird Monitoring effort (Bart el al. 2012). As part of this effort, all data were uploaded on the Coordinated Bird Monitoring Database (CBMD) maintained by the U.S. Geological Survey (USGS) and made available through eBird (*http://ebird.org*).

Originally, the protocol specified biweekly visits to the breakwater; however, travel logistics, adverse weather conditions, and boat repairs often made this difficult. Surveys were scheduled for the periods when terns establish nesting sites and during the period when breeding typically takes place in early May to mid-July (Nisbet 2002). During a typical monitoring event, an observer would conduct a 10-minute survey, usually between 0800 – 1100 EDT, looking over the breakwater. All bird species observed while approaching and leaving the site were noted. In general, documented birds were noted only if they were near the breakwater or adjacent breakwaters, piers, and open water areas, or flying overhead. To minimize disturbance on potential breeding terns, surveys were conducted approximately 80–100 ft away from the nesting platform. Because the nesting platform was raised, it was not possible to stand at that distance and observe any nesting birds; therefore, the surveyor used a small 6 ft stepladder to gain a better view of the nesting area (Figure 5). In addition to regular adult surveys, regular nest/egg/chick surveys were planned upon verified breeding activity of terns at the site, as determined through the regular adult surveys. However, no terns initiated nesting behavior during the monitoring effort.

Beginning in 2015, access to the property of Kinder-Morgan, Inc., a mining and energy infrastructure company with a base along the Ashtabula Harbor shoreline, provided a location with an excellent vantage point of the breakwater via a spotting scope (Leica® Televid 65 mm angled spotting scope) (Figure 6). From this vantage point, 30-minute counts were conducted in May and June of 2015 and 2016. The survey focused on the upper portion of the nesting area and any birds flying or landing within the scope's view were counted. The nesting area was also visually surveyed without a spotting scope to detect birds in the area that were not specifically in the scope's view. As with the 10-minute surveys on the breakwater, the spotting scope surveys would also record all birds utilizing the adjacent breakwaters, open water habitat, and any flyovers in the vicinity of the breakwater.

OUTREACH AND MEDIA COVERAGE OF ASHTABULA BREAKWATER PROJECT: As part of a concerted outreach effort, the U.S. Army Corps of Engineers (USACE) and TNC sought local media coverage to more broadly communicate to stakeholders and the local community about the project team's effort to attract the Common Tern back to Ashtabula Harbor. In an article posted on 27 May 2014 titled *Army Corps Tries to Lure Common Terns Back to the Nest*, Julie Grant of Michigan Radio discussed the background and overall objectives of the project (*http://michiganradio.org/post/army-corps-tries-lure-common-terns-back-nest#stream/0*).

Figure 5. A 6-ft stepladder was used to observe any nesting terns at the created habitat on the Ashtabula repaired breakwater (Photo Credit: Michael Guilfoyle, ERDC-EL).

The project team also collaborated with TNC on the construction of the wooden shelters and the collection and placement of locally collected driftwood placed in the structure to attract terns. An article appeared in the *Ashtabula Star Beacon* on 2 March 2014 that highlighted this collaboration. Jeff Frischkorn, a local outdoor writer, posted a story about the project on his blog *Outdoors with Frischkorn* (posted 4 March 2014).

Another part of the outreach effort was a post on the USACE Buffalo District website. The summary posted on 5 May 2016 provided additional information about various aspects of the project that the District was initiating during that time. (*http://www.lrb.usace.army.mil/Media/News-Stories/Article/752444/usace-buffalo-district-biologists-repair-common-tern-nesting-habitat/*).

Figure 6. Placement of spotting scope on the Kinder-Morgan property with view of the restored Ashtabula breakwater for weekly spotting scope surveys and biweekly surveys on the breakwater (Photo Credit: Michael Guilfoyle, ERDC-EL).

RESULTS: During the 2014 to 2016 field seasons, 23 surveys of the breakwater were made between May and June (2014: 6 visits; 2015: 9 visits; 2016: 8 visits). During 2015 and 2016, four 30-minute spotting scope surveys were conducted on the Kinder-Morgan property (2015: two surveys; 2016: two surveys). Data from both the 10-minute breakwater counts and the 30-minute spotting scope counts yielded a total of 906 birds representing 23 species during the monitoring period (Table 1). During the 2014 breeding season, only one Common Tern was observed, while 11 terns were observed in 2015 and 7 in 2016 (Table 1). The seven terns observed in 2016 were detected during early May while the nesting site was being established; no more terns were observed during the rest of the season. Over the course of the 2015 season, multiple Common Terns were observed foraging beyond the western breakwater on several occasions. During a spotting-scope survey, one tern was observed foraging in the water directly in front of the nesting structure. Eight additional terns were detected during maintenance visits on the breakwater in May 2015; however, these terns were not recorded during the timed counts. In total, these observations represent a significant increase in detection of Common Terns in 2015; nevertheless, in 2016, counts declined and no terns were observed after 5 May 2016.

Table 1. Birds detected during 10-minute surveys on the repaired breakwater and 30-minute spotting-scope surveys on the Kinder-Morgan property in the Ashtabula Harbor, May – July 2014–2016.

Species	Year	On Breakwater	On Water	On Adjacent Breakwaters/Piers	Flyovers	Annual Total	Overall TOTAL
American kestrel *Falco sparverius*	2014	0	0	0	0	0	1
	2015	0	0	0	1	1	
	2016	0	0	0	0	0	
Bald eagle *Haliaeetus leucocephalus*	2014	4	0	0	4	8	40
	2015	21	4	3	1	29	
	2015	1	0	1	1	3	
Bank Swallow *Riparia riparia*	2014	0	0	0	0	0	4
	2015	0	0	0	0	0	
	2016	0	0	0	4	4	
Barn swallow *Hirundo rustica*	2014	0	0	0	8	8	39
	2015	0	0	0	23	23	
	2016	2	0	1	5	8	
Canada goose *Branta canadensis*	2014	0	0	0	0	0	90
	2015	11	70	0	0	81	
	2016	0	5	4	0	9	
Caspian tern *Sterna caspia*	2014	0	0	0	1	1	13
	2015	0	0	0	0	0	
	2016	1	0	1	10	12	
Chimney swift *Chaetura pelagica*	2014	0	0	0	0	0	19
	2015	0	0	0	19	19	
	2016	0	0	0	0	0	
Cliff swallow *Petrochelidon pyrrhonota*	2014	0	0	0	0	0	2
	2015	0	0	0	2	2	
	2016	0	0	0	0	0	
Common loon *Gavia immer*	2014	0	1	0	0	1	1
	2015	0	0	0	0	0	
	2016	0	0	0	0	0	
Common Tern *Sterna hirundo*	2014	0	0	0	1	1	19
	2015	0	1	0	10	11	
	2016	7	0	0	0	7	
Double-crested cormorant *Phalacrocorax auritus*	2014	21	5	1	0	27	402
	2015	123	4	5	14	146	
	2016	34	190	3	2	229	
Great Blue Heron *Ardea herodias*	2014	5	0	0	3	8	11
	2015	1	0	0	0	1	
	2016	2	0	0	0	2	
Herring gull *Larus argentatus*	2014	0	0	0	12	12	237
	2015	33	0	2	24	59	
	2016	73	3	66	27	166	
Killdeer *Charadrius vocierus*	2014	0	0	0	0	0	3
	2015	2	0	0	0	2	
	2016	0	0	1	0	1	

Species	Year	On Breakwater	On Water	On Adjacent Breakwaters/Piers	Flyovers	Annual Total	Overall TOTAL
Mallard *Anas platyrhynchos*	2014	0	0	0	0	0	2
	2015	0	0	0	0	0	
	2016	0	2	0	0	0	
Northern Shoveler *Anas clypeata*	2014	0	0	0	0	0	5
	2015	0	0	0	0	0	
	2016	0	5	0	0	5	
Ring-billed gull *Larus delawarensis*	2014	0	1	0	30	31	125
	2015	10	1	0	23	34	
	2016	9	15	5	31	60	
Red-winged blackbird *Agelaius phoeniceus*	2014	0	0	0	0	0	16
	2015	2	0	0	1	3	
	2016	6	0	5	2	13	
Ruby-throated Hummingbird *Archilochus colubris*	2014	0	0	0	0	0	1
	2015	1	0	0	0	1	
	2016	0	0	0	0	0	
Ruddy Duck *Oxyura jamaicensis*	2014	0	1	0	0	1	1
	2015	0	0	0	0	0	
	2016	0	0	0	0	0	
Song sparrow *Melospiza melodia*	2014	0	0	0	0	0	2
	2015	0	0	0	0	0	
	2016	0	0	0	2	2	
Spotted Sandpiper *Catties maculation*	2014	5	0	0	0	5	5
	2015	0	0	0	0	0	
	2016	0	0	0	0	0	
Turkey vulture *Cathartes aura*	2014	0	0	0	0	0	4
	2015	0	0	0	0	0	
	2016	0	0	0	4	4	
TOTAL	2014	35	9	1	59	104	906
	2015	204	76	30	117	427	
	2016	141	61	86	87	375	

During the monitoring effort, the most common species detected was the Double-crested Cormorant (*Phalacrocorax auritus*) (402), followed by the Herring Gull (*Larus argentatus*) (237), Ring-billed Gull (*Larus delawarensis*) (125), Canada Goose (*Branta canadensis*) (90), Bald Eagle (*Haliaeetus leucocephalus*) (40), Barn Swallow (*Hirundo rustica*) (39), Chimney Swift (*Chaetura pelagica*) (19), and the Common Tern (19) (Table 1). The mounted motion-activated cameras did detect Common Terns, but only in 2014 (see Figure 8 below); however, numerous Red-winged Blackbirds (*Agelaius phoeniceus*) were captured by the cameras, along with one juvenile Bald Eagle (Figure 7), a Snowy Egret (*Egretta thula*), and a Herring Gull. In 2015, only one Red-winged Blackbird was detected during surveys, but many more apparently landed on the nesting site during the afternoon and evening hours. All survey data from 2014 to 2016 are now available on the ebird website (http://ebird.org) (User Name: USACE-EWN Common Tern Project; Password: Ashtabula).

Figure 7. A juvenile Bald Eagle (*Haliaeetus leucocephalus*) investigates a possible meal at the Ashtabula breakwater, as captured by one of the motion-activated cameras in 2016.

DISCUSSION: Since the completion of the Ashtabula Harbor breakwater nesting habitat, no Common Terns were observed nesting on the site. In some respects, this result was not surprising since recently created habitats, especially in an area like Ashtabula that is isolated from larger established colonies, often take more than one season to attract nesting terns (Dave Sherman, Ohio Department of Nature Resources [ODNR], pers. comm., May 24, 2014; Connie Adams, New York Department of Environmental Conservation [NYDEC], pers. comm., June 30, 2015). In fact, given the isolation of Ashtabula, at least five or more years may likely be needed to successfully attract nesting terns (Connie Adams, NYDEC, pers. comm., June 30, 2015). The ODNR created artificial nesting habitat on floating pontoon islands in the Willow Point Wildlife Area, OH, that did not attract nesting terns right away. These islands took several seasons to attract nesting terns (Dave Sherman, ODNR, pers. comm., May 24, 2014). Another example can be found along the Atlantic coast. Great Gull Island, located 20 km northeast of Montauk Point, was once known as the world's largest breeding colony for the Common Tern and the endangered Roseate Tern (*S. dougallii*). The terns were extirpated from the island in 1898 when military fortifications were constructed. The island was unused after World War II and was handed to the American Museum of Natural History in 1948 (Ginzburg 1994). Despite efforts to create nesting habitat for the terns, it took seven years for terns to begin nesting on the island again. Currently, the island once again supports one of the largest breeding colonies for these two tern species (Ginzburg 1994).

Common Terns nest approximately 40 km from Ashtabula on Gull Point Natural Area at the Presque Isle State Park, Erie County, Erie, PA. Terns attempted to nest at this park in 2012 after a 40-year absence (Patricia Barber, Pennsylvania Game Commission [PGC], pers. comm., September 15, 2016; and Sarah Sargent, Audubon Pennsylvania, pers. comm., September 12,

2016). In 2014 and 2016, only two pairs attempted to nest. In 2015, approximately 25 to 30 adults were observed during the breeding season, and 8 birds nested. Since 2012, terns have not nested successfully; all nests were lost to predation or high water levels (particularly in 2015). The terns are nesting on beach habitat that is accessible to mammals and avian predators. No structures or enclosures are used to attract and/or protect the nesting terns. The 2016 season is the only season where the tern eggs were actually thought to have hatched, but it is believed that the chicks were predated shortly thereafter. The 2016 season is also the first season where motion-activated cameras were used to monitor the nests; however, the cameras did not capture the predation of the young Common Terns (Patricia Barber, PGC, pers. comm., September 15, 2016). While it is unfortunate that the Common Tern nesting attempts at Presque Isle State Park have so far been unsuccessful, it is revealing that the terns are nesting in relative close proximity to the Ashtabula breakwater. Terns were observed on the breakwater (Figure 8) and foraging near the nesting habitat. Therefore, it is believed to be only a matter of time before the terns attempt to nest on the Ashtabula breakwater habitat.

Figure 8. Common Terns were observed visiting the Ashtabula breakwater in June 2014 (left: picture from motion-activated camera) and in April 2016 (right: Photo Credit: Richard Ruby, USACE).

At the Ashtabula nesting site, several factors may have prevented documenting the presence of terns. During the 2014 and 2015 seasons, repeated boat repairs reduced the monitoring conducted. Several opportunities to conduct surveys in 2014 were lost because of adverse lake conditions. This problem was remedied in 2015 when access to the Kinder-Morgan, Inc. property was obtained, which created a vantage point to observe the Ashtabula breakwater (see Figure 6). The procurement of a more reliable boat during the 2016 season aided monitoring efforts that year.

Other factors may have acted to inhibit the terns from nest attempts on the breakwater. The nesting habitat that ODNR created attributed to the success in attracting terns to the Willow Point Wildlife Area, OH, site by continually broadcasting calls during the breeding season (Dave Sherman, ODNR, pers. comm., May 24, 2014). However, for much of the 2014 season, the call box malfunctioned and did not broadcast calls. While the solar power panel appeared to successfully

recharge the enclosed battery, the system was unable to restart the MP3 player once the battery power had been drained (e.g., during the night or during overcast periods). During the 2015 season, a newly purchased call box performed as designed until a storm in late May damaged both call boxes via wave action. As a result, for the remainder of the breeding season in 2015, no broadcast calls occurred. In late 2015, USACE Buffalo Distract purchased a new Murremaid® call box, and a second functioning call box was constructed by utilizing the parts from the two flooded call boxes. Therefore, two functioning call boxes were in operation in 2016. Moreover, the two call boxes were elevated above the nesting site (see Figure 4) to protect them from high water during any spring storms.

While the nesting habitat on the Ashtabula breakwater should be attractive to Common Terns because of the size and distance from mainland (e.g., generally safe from mammalian predators), the loss of eggs and/or young due to storms remains an unavoidable possibility. Nesting failure for an entire colony due to storms has impacted ODNR colonies in the past (ODNR colonies also experienced significant loss of eggs/young during the same May 2015 storm that damaged the Ashtabula habitat call boxes; Laura Kearns, ODNR, pers. comm., July 17, 2015). Moreover, avian and mammalian predators have the potential to disrupt nesting success for an entire colony. Common Tern nesting colonies in Buffalo, NY, experienced significant losses in 2015 because of a red fox (*Vulpes vulpes*) that traveled to the colony over the ice during the winter only to feed on eggs and young during the breeding season (Connie Adams, NYDEC, pers. comm., June 30, 2015). In addition, the nesting colonies in Buffalo harbor do not currently use cabling to protect terns from avian predation; gull predation is an ongoing problem on the Buffalo, NY tern colonies (Connie Adams, NYDEC, pers. comm., June 30, 2015). During the 2016 season, the team felt that the cabling used to discourage avian predators might also discourage terns from attempting to nest at the site. Consequently, the top cabling was removed on the nesting structure with the plan of restoring the cabling if/when the terns nested on the structure. While no terns nested in 2016, the motion-activated cameras captured gull usage of the site.

Currently, there are no plans to continue maintenance or monitoring of the breakwater. USACE is interested in locating other partners to assist with surveys and nesting site maintenance, including re-establishing the solar-powered call boxes, and regular gravel substrate applications. If successful in attracting nesting terns in an area as isolated as Ashtabula Harbor, it would demonstrate a useful proof-of-concept of EWN principles, which could potentially provide incentives for other areas in the Great Lakes Region to initiate similar efforts. Such actions could significantly increase available nesting habitat for the Common Tern and could contribute to recovery of populations in the Great Lakes Region.

LESSONS LEARNED: The application of this EWN concept through the redesign of an armor stone repair of the Ashtabula Harbor breakwater yielded the following lessons learned. It is hoped that these lessons can be used to make any necessary adjustments before this approach is applied at other breakwater and navigation structures in the future:

1. Attracting the Common Tern to isolated breeding habitat takes time (up to seven years) and patience.

2. Access to a reliable boat is a necessity for this type of project.

3. Expect the unexpected: the initial design was intended to minimize overwash during storms based on wave modeling predictions prior to design and construction of the habitat (Fredette et al. 2016). Factors may need to be built into the design to account for increasing storm severity.

4. Gravel may need to be augmented or replaced if waves reach the habitat.

5. Possessing backup call boxes and other cameras is recommended for this type of project.

6. If possible, having a shoreline vantage of the created nesting habitat is preferable to monitor site during adverse weather conditions. Incorporating off-site spotting scope surveys will also be useful to minimize disturbance when monitoring nesting terns.

7. Use of predator exclusion cabling may not prevent predatory activity.

8. Use of motion-activated cameras is helpful to document use of the site by birds not detected during monitoring surveys. The cameras could also help document hatching and predation rates on the site once terns begin nesting.

9. Time and labor costs for placement of gravel substrate can be significant, especially when winter storms wash the gravel away every year. Use of a larger stone base that is thinly covered with smaller stones may be an effective way to retain more gravel during the winter months and lower the costs of site setup during subsequent breeding seasons.

10. Communicate with potential collaborators and stakeholders early and often for help with local scientific expertise and assistance.

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