Guidance and Best Practices for Coordinated Predator Management to Benefit Temperate Breeding Shorebirds in the Atlantic Flyway

2020 Supplement:
2019 Demonstration Project Reports & Camera Guidance

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ATLANTIC FLYWAY
SHOREBIRD
INITIATIVE

RECOMMENDED CITATION

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DOCUMENT DESIGN

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COVER PHOTO CREDITS

Female adult collared red fox, Matt Kynoch; American Oystercatcher caught on camera, TNC; Camera setup, TNC; Least Tern adult and chicks, ©Ray Hennessey, rayhennessy.com

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Piping Plover chick, ©Ray Hennessey, rayhennessy.com

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DOCUMENT OVERVIEW

In summer 2019, the National Fish and Wildlife Foundation (NFWF)-funded Guidance and Best Practices for Coordinated Predation Management to Benefit Temperate Breeding Shorebirds in the Atlantic Flyway (Guidance and BPs) was published on the Atlantic Flyway Shorebird Initiative website (https://atlanticflywayshorebirds.org/).

The Guidance and BPs synthesized published and gray literature along with interviews of managers and scientists on all aspects of predation management. The current version (v.1.1) of the document was developed over the course of nearly two years, with input from over 50 individuals. It includes case studies from six demonstration projects from Florida to Massachusetts, which tested novel predator management methods or unique hypotheses related to predation management, and integrated findings into the Guidance and BPs as it was being drafted. Primary authors and contributors to this original version of the document recognized early on that it would ideally be a 'living document,' from which managers could continuously implement, test, adapt and recommend future guidance and best practices.

Given that intent, three new demonstration projects were funded by NFWF for the shorebird breeding season of 2019 to implement and evaluate the Guidance and BPs in the field. The following supplement to the Guidance and BPs reports on how these demonstration projects, performed at sites in North Carolina, Virginia and Massachusetts, utilized information found in the Guidance and BPs. Demonstration project partners also share lessons learned from implementing the Guidance and BPs and suggest next steps that are widely applicable to those involved in predation management for temperate breeding shorebirds in the Atlantic Flyway.

Each of the three 2019 demonstration projects also utilized camera technology related to their implementation of Best Practice 1: Identifying Beneficiary Species and Predators for Management and Best Practice 2: Identifying Strategies, Triggers and Priorities for Lethal and Nonlethal Management. Use of cameras is supported in the Guidance and BPs by information from literature review and expert knowledge, and broad guidance is provided in the document on using the technology to improve management. However, no comprehensive and synoptic resource currently exists that provides specific methodological details on how to design, implement and analyze a camera-based project to benefit shorebird predation management programs. Such a resource has been identified by a number of shorebird managers in the Atlantic Flyway as a priority. As part of their work, demonstration project leads, in partnership with Virginia Tech and the US Fish and Wildlife Service worked together to outline and begin to compile information for a "Supplemental Guidance" document, which if completed could serve as a complement to the Guidance and BPs if additional funding can be found. This outline and associated information derived from on-the-ground field experiences with cameras at each demonstration site is provided here, following the three demonstration project reports.
Efficient and effective predation management is species-, site-, and project-specific. Therefore, these BPs aim to provide users with a suite of potentially viable management options that have been developed and/or implemented elsewhere, and the associated details that will inform effective management decisions specific to unique sets of circumstances and constraints encountered at individual sites.

In the following sub-sections of this introduction, we introduce the AFSI beneficiary species, describe in more detail the steps taken to develop this document, and provide a suggested roadmap for use of this BP by stakeholders.

2019 Demonstration Project, North Carolina

PROJECT TITLE: Using guidance and best practices to inform and assess predator removal efforts to support nesting success of American Oystercatchers on Masonboro Island, North Carolina

PROJECT LEAD: Hope Sutton, North Carolina National Estuarine Research Reserve (suttonh@uncw.edu)

SITE DESCRIPTION

Masonboro Island is a 13.5 km long uninhabited barrier island located in the southeastern portion of North Carolina (Figure 1). It is part of the Masonboro Island Reserve, a component of the NC Coastal Reserve & National Estuarine Research Reserve (NERR), as well as a dedicated state nature preserve. Covering 20.4 km^2, the Masonboro Island Reserve is the largest site within the NC NERR. The habitats within the Reserve boundary are comprised of a combination of inter- and subtidal soft bottoms, tidal mud flats, oyster reefs, salt marshes, shrub thicket, maritime forest, dredge spoil areas, grasslands, sand dunes, and ocean beaches. The Masonboro Island Reserve includes suitable nesting, foraging, and roosting habitat to provide for the needs of American Oystercatchers. The barrier island areas are used for breeding and nesting while the adjacent marsh, embayment, and ocean beach areas allow for forage of shellfish and marine worms. Several species listed as endangered, threatened, or of special concern at the state or federal level utilize the site, including American Oystercatcher (Haematopus palliatus), Least Tern (Sternula antillarum), Piping Plover (Charadrius melodus), Wilson's Plover (Charadrius wilsonia), and loggerhead (Caretta caretta) and green sea turtles (Chelonia mydas). The site served as a National Fish and Wildlife Foundation-funded demonstration project in 2017, associated with development of the , "Guidance and Best Practices for Coordinated Predation Management for Focal Temperate Breeding Shorebirds in the Atlantic Flyway"(2019; 'Guidance and BPs'). Characteristics of the site and occurrence of species of interest remain as previously described in the Guidance and BPs document.

SPECIES DESCRIPTION

Coordinated breeding season surveys since 2013 have consistently shown that Masonboro Island hosts approximately 10% of North Carolina's American Oystercatcher nesting population, ranging from 33 - 40 nesting pairs each year. As suggested in Best Practice (BP) 1 of the Guidance and BPs, survey data were used to identify the American Oystercatcher as the key beneficiary species of the predation management program.

Between 2012 and 2018, intensive nesting season monitoring at the site revealed that productivity varied from zero fledglings per pair (2012) to 0.97 fledglings per pair (2016) with an average of 0.15 fledglings per pair, falling below rates needed to meet conservation goals as stated in the American Oystercatcher Conservation Action Plan (2010) and the Atlantic Flyway Shorebird Business Plan (2018). As suggested in BP1, this low average annual reproductive rate was used as a trigger to determine that predator management should be implemented to support conservation goals.

Given the protected status of the site, the high-quality nesting and foraging habitats available, and human disturbance levels kept low by inaccessibility of much of the site, predator activity was identified as the major cause of nest failure. Predator management began in 2013 and has been conducted annually during winter months based on funding availability. Anecdotally, higher reproductive success has occurred in years where predator management has been completed three to six weeks prior to the initiation of the nesting season, while low reproductive success has frequently occurred when no or limited predator management has been conducted. As suggested in BP 5, average clutch initiation dates have been used to inform timing for the predator management program, focusing efforts in late February and early March before the onset of AMOY nesting.

Selective use of wildlife cameras on American Oystercatcher nests during the 2017 project improved understanding of causes of nest failure and resulted in more accurate identification of predator species. Bushnell Trophy Cam HD Camo Model 119973C cameras were installed at nests following nest identification. Cameras were locked to anchored steel u-posts approximately 3 meters from nests and set to high sensitivity on still image mode. Through the pilot deployment, settings were adjusted from single image capture to multi-image capture. Camera failure and inappropriate settings resulted in mixed results, however images were collected that allowed for some documentation of cause of nest failure and identification of several mammalian predator species. As suggested in BP1, these results were used to inform the target species for predator removal and management for the 2019 project. Although several predator species were preliminarily identified from tracks and activity patterns, wildlife camera documentation supported a final target species list of nest predators that included Vulpes vulpes (red fox), Procyon lotor (raccoon), Didelphis virginiana (opossum), and Canis latrans (coyote).

GOALS AND EXPECTED OUTCOMES

- Improving identification of causes of nest failure due to predation
- Increase effectiveness of predator management and protection of nesting shorebirds
- Develop a site-specific approach to assessing causes of nest failure informed by comparisons of camera results with field observations and comparison of camera types and settings
- Contribute to development of a supplemental camera guidance document with partners from other 2019 Demonstration Projects in VA and MA (To include: recommendations on study design, equipment types, field installation, camera maintenance, data management, data interpretation, and adaptive management informed by results)
- Support conservation goals for shorebirds within the Atlantic Flyway
- Prepare for data analysis to support assessment of predator management efforts

METHODS - GENERAL DESCRIPTION

Reproductive success of 35 pairs of American oystercatchers was monitored between 4 April and 19 September, 2019. A single technician monitored the territories on foot 2-3 times weekly, depending on weather and the timing of high tide, with most pairs being monitored two times per week on average. Cause of nest failure was assessed and recorded in the field based on observed tracks and sign and informed by training provided by a contracted trapper familiar with the site.

Predator removal was conducted prior to the initiation of nesting during the week of March 3, 2019. Additional removal was conducted during the weeks of June 2 and August 25 based on documented predation and predator presence. During each management operation, the contracted trapper stayed on site 3-5 days, deploying between 16 and 29 padded foothold restraining traps selectively to focus on the target predator species. Traps used were Bridger 1.65 padded jaws for red fox, MB 650 for coyote, and K.O. 1.5 double jaw for raccoon. Target animals trapped were euthanized on site. All trapping and euthanizing was conducted in line with state laws and informed by American Veterinary Medical Association guidelines and using U.S. Fish and Wildlife Service and NC Wildlife Resources Commission approved methods.

Wildlife cameras were deployed at 17 nests to support assessment of causes of nest failure and document predator presence and activity levels between 1 May and 31 July, 2019. To allow for side by side comparison of images and video collected at a single nest, two-camera arrays were deployed 2 feet above ground level 3 meters from each nest with one Reconyx HC500 Hyperfire camera on top and one Bushnell Trophy Cam HD (model 119973C) camera below (Figure 2). Reconyx cameras were set to 1080 pixel resolution, at high sensitivity, three pictures per trigger with a one second interval, and no delay between triggering events.

Bushnell cameras were set to full screen HD video with resolution size of 1280 X 720, at high sensitivity, with a five second recording interval. Cameras were removed from the field immediately following failure of a nest.

Images were manually processed in the lab and cataloged per nest with cause of nest failure assigned based on photo documentation. Field observed causes of nest failure were compared with photo documented causes of nest failure.

METHODS - BEST PRACTICES IMPLEMENTATION

BP1 - Identifying Beneficiary Species and Predators for Management: Information in BP 1 guided the selection of American Oystercatcher as the primary beneficiary species for the predator management effort in North Carolina. Breeding season surveys of American Oystercatchers revealed a number of breeding pairs that warranted attention (>10% of the breeding pairs in the state).

BP 2 - Identifying Strategies, Triggers, and Priorities for Lethal and Nonlethal Management: Guidance in BP 2 was used to define the trigger and the priority for predator management. Productivity data falling below levels suggested in the Business Plan for the American oystercatcher was used as the trigger to initiate management with the priority being achieving a productivity level above 0.39 fledglings per pair.

BP 3 & BP 4 - Methodological Considerations for Lethal & Non-lethal Predation Management: As discussed in BP 3, lethal techniques were determined to be the approach needed to achieve productivity goals, and trapping methods were selected to maximize effectiveness while reducing potential for accidental capture of non-target species. Non-lethal methods such as exclosures were eliminated from consideration due to resource limitations that do not allow for the intensive installation and maintenance effort that would be required across the spatial extent throughout the nesting season. An experienced, certified private predator control contractor was selected to perform predator management activities. Trapping with foot-hold traps was selected due to the type of predators known to be present (raccoon, red fox, coyote) and to reduce the likelihood of animals developing trap shyness. Placement of traps avoided areas of human use. Traps were set during the early evening and checked and fired during early morning to avoid active trapping during daylight hours. Animals trapped were humanely euthanized on site. State wildlife personnel were consulted regarding methods and notified each time a management operation was conducted; the required state depredation permit was obtained from the NC Wildlife Resources Commission.

BP 5 - Timing of Predation Management and Unintended Secondary Impacts: BP 5 was used to inform decisions regarding the timing of predator management efforts. No data was available to help understand dispersal patterns of target predator species, but several years of average date of clutch initiation for American Oystercatchers was available, so this guided the timing for predator management activities. The initial operation was conducted approximately four weeks prior to the average clutch initiation date for the four previous years. This proactive approach resulted in no predation of early nests by red fox or raccoon. Unfortunately, an evasive coyote continued to predate nests despite two additional removal attempts later in the season. No secondary effects or unintended consequences of predator removal were detected during the 2019 season. Although this was not a focus of study at this site in 2019, field technicians took note of predator activity in nesting areas and no unusual patterns or unexpected changes were documented. Predator numbers are generally low on Masonboro Island and recruitment appears to be slow and seasonally influenced. Additional study is needed to fully explore secondary effects and predator return rates. As BP 5 suggests, additional effort to quantify and understand these effects would help inform management goals and define the acceptable level of predator activity.

BP 6 - Community Engagement, Outreach, and Communications: As suggested in BP 6, providing information to the public regarding predator removal operations is important but can be challenging to manage. The approach used at Masonboro Island in 2019 and prior years was for staff to be prepared to answer questions based on talking points developed in conjunction with Wildlife Resources Commission staff. No broad public notification of the predator management work was made; however, signs were strategically placed to inform the small number of visitors to the site that the effort was being conducted. Separate from predator management operations, outreach activities have been opportunistically utilized to discuss human behaviors that can increase predator populations and influence choices accordingly.

BP 8 - Monitoring, Measuring, and Reporting Effectiveness: BP 8's recommendations were used to inform standardization of data collection and handling in order to allow for adaptive management, spatial and temporal comparisons, and sharing of data between agencies and organizations to benefit species management strategies at the regional or flyway level.

RESULTS

Predator management activities were conducted prior to the initiation of nesting from 7-11 March, 2019. Five raccoons, one opossum, and one red fox were trapped and euthanized. Predation of nests by mammalian predators during the early nesting season (April-May) was documented through field observations and wildlife camera use at nests. Species documented predating nests were red fox, raccoon, crow, and coyote. As a result, additional predator management activities were undertaken 2-7 June, 2019. One red fox was trapped and euthanized during this second period. Predation continued to occur during the later portion of the nesting season and wildlife cameras documented the continued presence of a coyote and a raccoon. As a result, a final predator management effort was conducted 25-29 August, 2019. The contracted trapper characterized the level of raccoon activity as being very low during this period. Due to the tendency of the coyote to travel greater distances and the greater potential for impact to nests, the coyote was the primary target for the third management effort. No predators were trapped during the third management effort. A summary of predation management efforts during 2019 is shown in Table 1.

During 2019, thirty-five pairs of American oystercatchers were monitored through the nesting season to document nesting success, determine causes of nest failure, and assess effectiveness of predator management. The overall hatching success for monitored pairs on Masonboro Island was 39.6%, and the fecundity was 0.57 fledglings per pair (Table 2). Results are divided into “north” and “south” as habitat characteristics and human activity levels vary across the site, with the north having higher levels of disturbance, less favorable nesting habitat due to higher vegetation density, and better cover and denning habitat for mammalian predators. The 2019 season was the second most productive season since monitoring began at the site in 2012 (Table 3). In the years since predation management and more intensive shorebird monitoring were initiated in 2013, results have varied. Although nests have occasionally failed due to disturbance or weather-related impacts, years with successful pre-nesting season predation management appear to have increased fecundity, suggesting that predation management plays a key role in reproductive success. During most seasons, red fox were the most effective predators, in part due to their tendency to regularly visit much broader spatial extents than either raccoons or opossums. During 2019, a single coyote was documented to be present throughout the season; however, wildlife camera documentation showed that it may have been a less effective predator than previous red foxes as it was documented several times in the area of a nest but not actually locating the nest. Additional analyses are needed to more fully understand the relationships between variables.

Of the 48 nests located, 60.4% failed during incubation. Predation was identified as the cause of nest failure for 29% of failed nests. A combination of field observation and wildlife camera documentation was used to assign the cause of nest failure for each nest to identify whether nests failed due to predation or other factors (Table 4). Similarly, both field observation of tracks and sign and wildlife cameras were used to identify predators per nest to enable a comparison between the field technician's ability to identify types of predation and camera documentation of predation (Table 5). Raccoon, red fox, coyote, snake, and crow were identified as predators. Based on wildlife images, spatial and behavior patterns, and tracks, a single coyote appears to have predated many the predated nests; however, wildlife camera results showed that correctly assigning nest predation sources is complex and the potential for mistakes exists (Table 6).

Wildlife cameras were deployed successfully in a two-camera arrangement on 15 nests, with one camera set to capture still images and the other set to capture video. Reconyx cameras collecting still images were set to capture 3 pictures per trigger with a one second interval between pictures and no delay between triggering events. Bushnell cameras collecting video were set to capture 5 seconds of video for each trigger with no delay between triggering events. Both still and video cameras were set to high sensitivity. The number of images and videos collected per camera varied based on activity levels and capture of accidental false targets. Two cameras, one Bushnell and one Reconyx failed during deployment and resulted in no image or video capture. A total of 3,962 images and 4,435 videos (approximately 370 minutes) were collected, reviewed manually, and cataloged. Predators were captured on 2.0% of still images collected and 0.5% of video files collected (Table 6). The majority of the remaining images captured AMOY adults and chicks, wind-blown vegetation, and the occasional human visitor. Unfortunately, these results point to challenges with determining the best settings to use to capture depredation events. Further study, including additional side-by-side comparisons utilizing the same camera model with different settings, altering camera set-ups, and a greater number of deployments on depredated nests will help to assess factors involved in failure to capture predators on camera during predation events.

Of nests with cameras, seven hatched and produced fledglings, seven failed due to predation, and one failed for unknown reasons, as no predators were documented on camera. Wildlife cameras allowed nest predators to be conclusively identified for all seven depredated nests monitored by cameras (Table 6). Camera results were compared with causes of nest failure assigned by the monitoring technician based on field observation. The field assigned cause of nest failure matched the camera assigned cause of nest failure for only two failed nests (28% of cases).

An experienced field technician with strong observational skills can identify signs of predators and use these to assign causes of nest failure. Environmental factors can complicate this process if wind, rain, or high tide wash overs have obscured tracks and other sign. Further challenges in using field sign to identify causes of nest failure can result if multiple predators visit a nest between monitoring events. In several cases, our field technician assigned the cause of nest failure to coyote based on fresh tracks at the nest. In three cases, camera results showed that the coyote visited the nest after predation by a raccoon or crow. Still images identified the crow, while still images and video identified the raccoons. In one case, ghost crabs were incorrectly assigned as the nest predator, but camera results showed that ghost crab presence followed coyote predation. In one case coyote was assigned as the predator and still images confirmed this to be correct. In one case red fox was assigned as the predator and video documentation confirmed this to be correct. In the final case, coyote was assigned as the predator but still images revealed that a coachwhip originally disturbed the nest and removed but abandoned the eggs, while coyote later took the abandoned eggs (Table 6).

LESSONS LEARNED

Monitoring of reproductive success and predator management activities were accomplished as planned and the resulting fecundity rate of 0.57 fledglings per pair is above the goal of 0.50 fledglings per pair as stated in the Business Plans related to the American Oystercatcher. These results reinforce the current management approach at the site and suggest that continued management of predator populations should continue to support the conservation goals for this species.

The Guidance and BPs supported our efforts by helping us clarify the beneficiary species and triggers for management action. It also improved the efficiency of our predator management efforts by supporting a focus on specific target species and identifying the most effective timing for management action. Recommendations and examples provided in the document, coupled with references from peer-reviewed scientific studies, support the science-based decision-making approach our program relies on and looks to for justification when requesting funds for predator management and biological monitoring activities.
We have used fecundity as both a trigger for our management efforts and a metric for measuring the effectiveness of our efforts. The Guidance and BPs has offered several other options and metrics that we are

evaluating to determine what will be most efficient and cost effective for a long-term program. Particularly given the challenges of identifying funds to conduct these types of efforts, efficiency needs to be a major consideration and determining how to get the desired results effectively with limited resources will continue to be a priority for our program, as it is for most agencies and organizations. The Guidance and BPs has also led us to discuss and incorporate consideration of potential secondary effects in our management decision making.

Our predator management and shorebird monitoring programs have been influenced by the combined experiences we had during the initial 2017 and 2019 Demonstration Project efforts. The use of wildlife cameras clearly has value for informing and supporting both shorebird productivity monitoring and predator management programs. However, the financial and staff resources needed to broadly utilize cameras are beyond what our operational budget can support on a regular basis. Based on our experiences during these projects, we are most likely to continue to use cameras to prepare for and target predator management activities. The hours spent to deploy cameras to identify predator species, provide some indication of population densities, and isolate spatial extent for management efforts produced measurable results in the form of fecundity rate increases. While the use of cameras on nests produced some interesting and enlightening results in terms of increasing our understanding of the various causes of nest failure, the predominant finding was that without camera documentation, identification of nest predators can be complex. More importantly, correct identification of nest predators does not equate to successful predator management. Hours spent deploying cameras to identify nest predators may yield interesting (and often useful) findings, and exciting images or videos that can provide educational benefit, but nest predation caught on camera still results in lower fecundity rates, unless resources are invested in control. For this reason, we are likely to limit our use of cameras on nests unless we have specific questions that can be best answered through capturing images. For example, cameras on nests may be considered important if changes to predation patterns occur and the presence of a new species of predator needs to be confirmed or the percentage of nests abandoned rather than predated changes and new management strategies need to be considered.

Since the 2017 project, we have also been moving toward more coordination with partner agencies and organizations working in the Atlantic Flyway, as recommended in BP 9. We intend to be active participants in the development and implementation of activities recommended in the Guidance and BPs including workshops and meetings, databases and data sharing tools, and pursuit of funding to continue working toward shared conservation goals. In particular, participation in these projects has encouraged us to seek opportunities to increase our involvement in projects working to achieve the goals set out in the business plans for the Atlantic Flyway and for the American Oystercatcher. One of the recommendations we would be enthusiastic about supporting is the development of broader data management tools or databases that allow for data sharing and analysis across regions or ranges.

As previous noted, there is great value in implementing the Guidance and BPs including the summarized findings of scientific literature in the document. References that support recommendations and best practices should continue to be built out in the document as additional studies are published. Making these reference documents available and searchable through an online database could further support the implementation of best practices by increasing efficiency for resource managers planning management approaches and seeking funding.

Following this season, we do have some next steps we will still need to address. We were not able to accomplish all the original objectives of the project due to complications with staffing and purchasing. Through the season, personnel issues resulted in two different monitoring technicians being involved with productivity monitoring and implementation of various portions of the wildlife camera study. Gaps were covered by two seasonal staff who had other priority activities to attend to and could not devote as much attention to the activities associated with this project as would have been ideal. Both monitoring technicians received appropriate training and the seasonal staff were familiar with shorebird nesting, predator management, and use of wildlife cameras. However, having a single, dedicated technician to complete monitoring and oversee wildlife camera work would produce better results. In addition, despite attempts during the pre-award period to purchase the more expensive cameras with quicker triggering times we had planned to use for the camera study this year, internal permission to complete the purchase was not received until much of the nesting season had passed. As a result, camera deployments were reduced in number and scope from what was originally intended.

FIGURES & TABLES

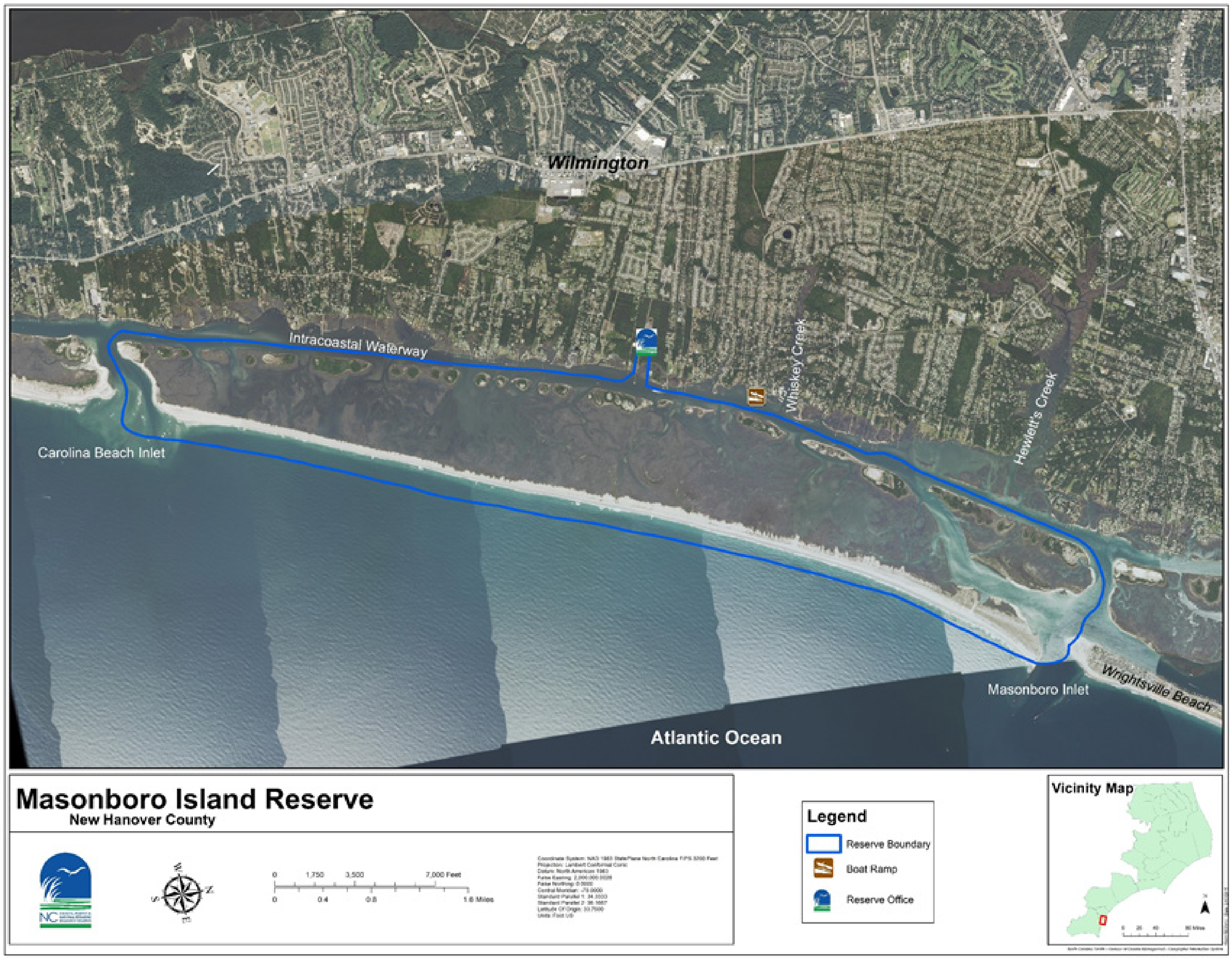

Figure 1. The Masonboro Island Reserve – American Oystercatcher pairs nest along the full length of the barrier beach.

Figure 2. Typical two-camera nest monitoring system, deployed 0.6 meters above ground level, 3 meters from each nest. A Reconyx HC500 Hyperfire camera is on top and a Bushnell Trophy Cam HD (model 119973C) camera is below.

Fox in live trap. R. Colona

Table 1. Summary of predation management efforts for 2019.

Date	# traps set	Fox caught	Coyote caught	Raccoon caught	Opossum caught
3/7/19	10	1	0	1	0
3/8/19	17	0	0	3	0
3/9/19	19	0	0	1	0
6/3/19	13	0	0	0	1
6/4/19	19	1	0	0	0
6/5/19	23	0	0	0	0
6/6/19	27	0	0	0	0
8/25/19	5	0	0	0	0
8/26/19	12	0	0	0	0
8/27/19	16	0	0	0	0
8/28/19	19	0	0	0	0
	TOTALS	2	0	5	1

Table 2. Summary of nesting data for 2019.

Area	# Pairs	# Nests	Nests Hatched	Chicks Fledged	Hatching Success (%)	Fecundity (fledglings/pair)
North	10	20	5	5	25	0.50
South	25	28	14	15	50.0	0.60
Total	35	48	19	20	39.6	0.57

Table 3. Summary of nesting data and predation management effort for 2012 – 2019.

Year	# Pairs	# Nests	Nests Hatched	Chicks Fledged	Hatching Success (%)	Fecundity (fledglings/pair)	Predators removed preseason**	Predators removed during season**
2012	10*	8	0	0	0	0	-	-
2013	34	49	12	9	24.5	0.265	3 V; 1 D	
2014	33	63	12	5	19.1	0.152	1 V	-
2015	34	52	6	5	11.5	0.147	-	-
2016	38	47	27	37	57.4	0.973	1 V; 5 P; 3 D	-
2017	35	49	5	6	10.2	0.170	2 V; 6 P; 2 D	1 V
2018	43	49	5	0	10.2	0	-	-
2019	35	48	18	15	39.5	0.710	1 V; 5 P	1 D

**monitoring of a select portion of the site only*

***V=Vulpes vulpes; P=Procyon lotor; D=Didelphis virginiana*

Table 4. Summary of causes of nest failure for 2019.

Area	Nests	Nests hatched	Nests failed	Predation	Abandonment	Flooding/ storms	Unknown
North	20	5	15	7	1	0	7
South	28	14	14	7	0	0	7

Table 5. Summary of predation for 2019.

Area	Nests predated during incubation	Nests predated after hatching	Raccoon	Red Fox	Coyote	Coachwhip	Avian	Unknown
North	7	2	0	2	3	1	1	2
South	7	3	1	0	3	0	3	3

Table 6. Results of nest camera deployments and comparison with field observation for predator identification.

Territory #	Nest #	# Images	# Images w/ predators	# Videos	# Videos w/ predators	Suspected Predation Type	Confirmed Predation Type
27	19	65	0	77	6*	Coyote	Raccoon
21	20	155	0	597	3*	Fox	Fox
15	33	78	3*	59	0	Coyote	Avian (crow)
13	35	215	6*	867	0	Coyote	Coachwhip & coyote
10	42	231	25*	315	0	Coyote	Coyote
12	44	131	32*	74	16*	Coyote	Raccoon
21	45	280	15*	867	2	Ghost crabs	Coyote

** Denotes source of confirmation of nest predation*

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2019 DEMONSTRATION PROJECT, VIRGINIA

PROJECT TITLE: Using cameras as essential tools for managing American Oystercatcher and Piping Plover at Metompkin Island

PROJECT LEAD: Alexandra Wilke, The Nature Conservancy Virginia Coast Reserve (awilke@tnc.org)

SITE AND SPECIES DESCRIPTION:
The coastal barrier island/lagoon system along the Eastern Shore of Virginia is among the most important breeding, staging and wintering areas for shorebirds along the Atlantic Flyway. The region supports significant populations of at least five of the 15 focal species identified in the Atlantic Flyway Shorebird Initiative (AFSI) Business Plan, according to thresholds defined by the Western Hemisphere Shorebird Reserve Network (WHSRN). For example, the approximately 80 miles of coastal barrier island/lagoon system supports 455 pairs of American Oystercatchers (*Haematopus palliatus*; 'AMOY') and over 250 pairs of Piping Plovers (*Charadrius melodus*; 'PIPL'). The AMOY population in Virginia is the largest nesting congregation of this species along the Atlantic and Gulf Coasts of the U.S.

The region is characterized by several factors that make it significant to shorebirds and other migratory birds relative to other coastal areas along the Atlantic Flyway. Eighty-five percent of the state's barrier island coastline is under conservation ownership by The Nature Conservancy (TNC), the U.S. Fish and Wildlife Service (USFWS) or the Commonwealth of Virginia. A long-standing multi-agency partnership between these federal, state and NGO entities guides and implements conservation strategies for the barrier islands, including shorebird conservation and management, at a meaningful scale. Additionally, the majority of the saltmarsh system adjacent to the barrier island chain is owned by the state and managed by the Virginia Marine Resources Commission which considers migratory bird management as a priority and works closely with barrier island landowning partners. Lastly, most of the region is remote and only accessible by boat, making it an unmatched coastal wilderness that is critical for supporting and ensuring the resiliency of some of our most imperiled shorebird species along the Atlantic Flyway. The significance of the barrier island chain for shorebirds is recognized through a WHSRN site of International Importance and nomination for Hemispheric Importance and an Audubon Important Bird Area of Global status. The region is also recognized as a Biosphere Reserve by the United Nations Educational, Scientific and Cultural Organization, a U.S. Department of Interior National Natural Landmark and a National Science Foundation Long Term Ecological Research Site.

Over the past two decades partners within this landscape have recognized and prioritized predation management as an essential strategy for ensuring the resiliency of nesting shorebird and colonial waterbird populations. Coordinated predation management has previously resulted in great successes. However, managers have recently recognized the need for a re-evaluation of coastal Virginia's predator communities and the extent to which they are limiting reproductive success of shorebirds relative to other factors (i.e., flooding and habitat loss related to island change, sea-level rise, storms) at some sites. This information is essential for managers to effectively implement adaptive predation management in a highly dynamic and complex coastal system where conditions and variables that impact nesting shorebirds change over time.

Metompkin Island

Metompkin Island, located within the Virginia barrier island chain, presents a scenario where this adaptive management approach is needed to guide current and future management activities (Figure 1). The 6-mile long island supports over one hundred pairs of breeding AMOY, sixty pairs of PIPL and has typically been a reproductive hotspot for both species, both locally and regionally. Monitoring efforts over the past several years, however, have documented unexplained poor reproductive success for AMOY (Figure 2). This apparent decline in productivity has occurred despite successful removal of raccoons (*Procyon lotor*) and red fox (*Vulpes vulpes*) prior to each nesting season, and despite relatively low visitor use. Metompkin is remote and difficult to access. Consequently, shorebird monitoring typically is conducted on a weekly basis, which does not allow for precise documentation of all the factors limiting reproductive success. We propose that a current assessment of other potential predators at the site is needed to benefit nesting shorebirds, as well as colonial waterbirds and other wildlife such as diamondback terrapins.

Figure 1. Metompkin Island study area, Accomack County, Virginia. Inset map shows location of Metompkin Island relative to other barrier islands located on the Virginia portion of the Delmarva Peninsula.

Existing predation management needs on Metompkin Island, provided an ideal opportunity for us to directly utilize and evaluate the [Guidance and Best Practices for Coordinated Predation Management for Focal Temperate Breeding Shorebirds in the Atlantic Flyway]" (2019; 'Guidance and BPs') developed under the AFSI. Our project aligned directly with the AFSI priority of reducing the impact of predation on nesting shorebirds on the Atlantic Coast. At a site and program scale, our project aimed to evaluate factors influencing nest success at an important shorebird nesting site in coastal Virginia, with a focus on the role of predators. The project also aimed to provide information on the predator community present at the site, shorebird hatching success rates, and causes of nest and chick failure. Finally, we anticipated that a synthesis of the information would allow us to reevaluate current assumptions that guide monitoring and management at the site and inform, adapt and improve our existing program to maximize reproductive success and increase the breeding population size of AMOY and PIPL.

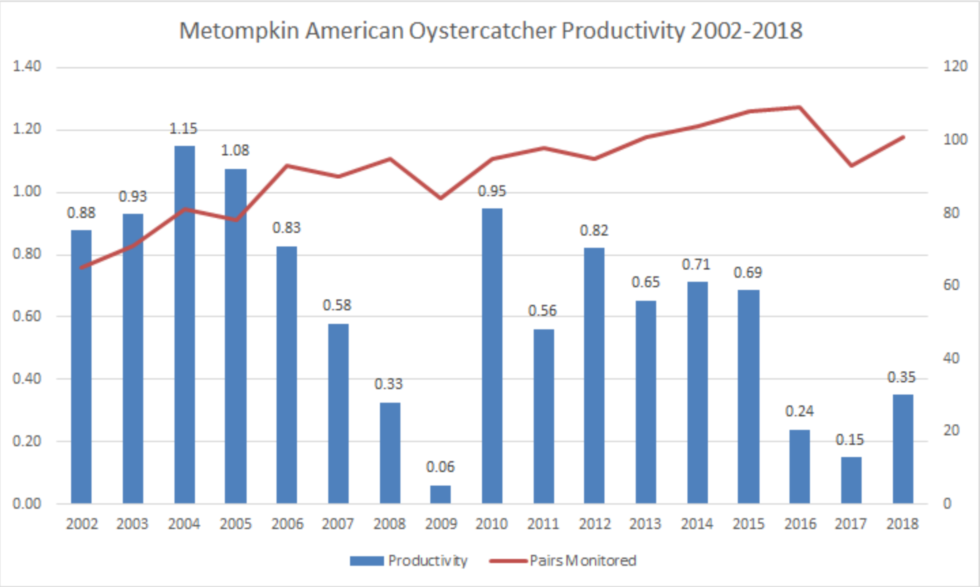


Figure 2. Number of pairs monitored and productivity of American Oystercatchers nesting on Metompkin Island, Virginia, 2002-2018.

The project also provided us an opportunity to collaborate with similar projects taking place in Massachusetts and North Carolina in order to synthesize information and lessons learned from our work to supplement to the Guidance and BPs. Our collective efforts will ideally add to the utility of the Guidance and BPs by providing detailed, technical recommendations on specific tools available to managers working to develop or improve predation management programs. At a Flyway scale, preliminary information we provide here lays the framework for a 'Supplemental Guidance on Camera Use', with the goal of providing detailed information from a variety of perspectives that will be valuable for managers considering the use of cameras at their sites.

Overall, we anticipate that the information gained, lessons learned, and recommendations developed as part of our demonstration project will not only advance site-specific protection of nesting shorebirds, but also result in a significant advancement in the tools available to managers across the Atlantic Flyway seeking to inform, adapt and/or improve predation management efforts.

GOALS AND EXPECTED OUTCOMES

Implementation of Guidance and Best Practices

Development of our demonstration project was guided by recommendations included in "Best Practice 1: Identifying beneficiary species and predators for management" and "Best Practice 8: Monitoring, measuring, and reporting effectiveness". Our primary objectives were to: 1) characterize the predator community impacting nest success of AMOY and PIPL, 2) calculate hatching success using field observations and camera observations and evaluate the differences, 3) document causes of nest failure, and 4) test two novel techniques for using cameras to identify causes of chick loss for AMOY.

Supplemental Guidance on Camera Use

We also worked collaboratively to synthesize lessons learned and recommendations from two other demonstration projects (Massachusetts and North Carolina) into a framework that can guide future development of a supplemental guidance document, pending additional funding. This document would provide detailed, technical recommendations to guide managers considering the use of cameras in their programs.

Using the Guidance and Best Practices

Finally, we used our project to report out on our process using the Guidance and BPs as a resource to guide adaptive predator management. Specifically, we aimed to provide recommendations to other managers about how to best use the document and maximize its ability to inform and guide an active predation management program.

METHODS

To achieve our goals, we deployed cameras at: 1) 27 active AMOY nests ('nest cameras'), 2) 28 active PIPL nests, 3) 11 AMOY brood-rearing areas ('brood cameras'), and 4) one transect location (7 cameras) allowing for wide-angle visual monitoring of known oystercatcher brood-rearing areas ('transect cameras'). All field work took place between 1 April 2019 and 31 August 2019 on Metompkin Island.

Nest Camera Placement And Settings

Nest cameras were deployed as soon as active nests with full clutches were located and as site visits allowed. Due to the intervals of time between site visits and logistics of site coverage, cameras were deployed at a variety of points during the incubation phase for both species. Nest cameras were set to motion trigger for still images, capturing three images per trigger with a 5s reset speed. Blaze Video brand 16-megapixel cameras with 'no glow' infrared 940 nm flash were used. Cameras were mounted on steel U-posts pounded into the sand approximately 3-6m from each nest, with a DIY mounting bracket that allowed for rotation of the camera angle (Figure 3). Cameras sat approximately 0.3m above the ground and no camouflage or anti-perching devices were used.

Figure 3. Top left, field installation of nest cameras. Top middle, DIY mounting bracket mounted on U-post (cambushcamo.com – note that our methodology used a single mounting bracket as opposed to double bracket shown). Right, deployed nest camera with solar panel. Lower left, deployed nest camera with nest. Lower middle, beach cart system for transporting equipment.

Brood Camera Placement And Settings

Brood cameras were deployed strategically at marsh edge locations where field observations (i.e. chick visuals, presence of tracks, empty mussel shells, adult behavior) indicated the presence of an active AMOY brood. 'Brood' cameras were deployed to test the idea that cameras trained on specific brood rearing locations at the site could successfully capture chick predation events. Prior observations at the site noted a high density of nesting pairs and relatively restricted brood territories, suggesting that stationary cameras have the potential to capture predation of highly mobile chicks. Brood cameras were mounted in the same fashion and with the same settings as nest cameras except the height was approximately 1m above the ground. To allow for maximum coverage, we deployed cameras as far from the marsh edge as possible to allow for increased field of view while still in range for the motion trigger threshold and flash range and to provide maximum potential for identifying predators. This objective followed suggestions in BP 1. Field tests suggested a 15m motion detection range and camera manufacturer specifications suggested a flash range of 20m.

Transect Camera Placement And Settings

Transect cameras were deployed systematically along a section of marsh/beach interface that was chosen based on a high likelihood that several AMOY broods would be located there. Exact locations were chosen based on the proximity to known AMOY nesting territories and identification of typical brood rearing areas during previous nesting seasons. Similar to the brood cameras, our intent was to test the efficacy of deploying cameras to capture chick depredation events, in this case using a transect configuration. In contrast to the brood cameras, the transect cameras were deployed to capture the entire marsh edge, perhaps increasing the chance of observing specific depredation events. Seven cameras were placed approximately 40m apart, running parallel to the marsh/beach interface approximately 50-75m away and angled to capture the entire edge. Transect cameras were mounted in the same fashion as brood cameras but were set on time-lapse with 1s intervals and did not record night images.

Batteries And SD Cards
We used a combination of solar panel kits (solar panel, battery box, 6V acid sealed battery), 6V batteries alone, and AA alkaline batteries to power all cameras. We used PNY 128GB SD cards formatted from xFat to FAT32 in all cameras.

Camera Deployment And Checks
Information related to each camera deployment was collected using Collector for ArcGIS. All cameras and SD cards were labeled with individual ID numbers which were recorded during all deployments and checks. For nest camera deployment we recorded total deployment time and time until bird resumed incubation. Our baseline threshold for abandoning a deployment attempt because birds would not resume incubation was 30-45 minutes. This threshold varied considerably, however, due to factors we present in our results below. During maintenance checks, we recorded camera status information such as general condition, battery life, and SD card storage capacity. All cameras were checked approximately once per week, with some variation due to logistical constraints. All SD cards were replaced during each camera check and batteries were replaced generally when they were at 50% capacity or less.

Traditional Reproductive Success Monitoring
TNC and VA Department of Game and Inland Fisheries staff conducted weekly monitoring of the reproductive success of AMOY and PIPL pairs concurrent with camera deployment. Monitoring consisted of searching all suitable nesting habitat for nests or broods of both species, recording the locations of each nest/brood, and checking the status of previously known nesting attempts. Monitoring efforts recorded apparent hatching success (success defined as at least one egg hatching) and causes of nest and chick loss when possible. Young were considered fledged at 25 days for PIPL and 35 days for AMOY. Information related to each nest/brood check was recorded using Collector for ArcGIS with attributes informed by BP 8. All nest attempts were followed until hatched or failed and all broods were followed until fledged or failed.

Data Review And Analysis
All photos retrieved from the cameras were carefully cataloged on an external hard drive. Each photo was reviewed by an observer and for nest cameras all disturbance events (resulting in bird leaving the nest due to an observable cause) and predation events were recorded. We did not record researcher disturbance as an event. For brood cameras, our objective was to record predation events, however no such events were captured on the cameras.

We used the nest camera photos to: 1) characterize the predator community at the site, 2) calculate hatching success, and 3) document causes of nest failure. We then compared results from the two different monitoring techniques (nest cameras vs. direct observations) to assess and evaluate errors and assumptions associated with quantifying nest success and identifying predators based on evidence in the field.

Photos from the transect cameras were not yet processed at the time of this report and are not reported in results.

RESULTS
Implementation of Guidance and Best Practices
The Nature Conservancy has implemented predation management on Metompkin Island since the late 1990s. Therefore, our experience with utilizing and implementing the Guidance and BPs for this demonstration project was in the context of guiding and adapting a well-established, long-term predation management program, as opposed to building a program from the ground up. As a result, we focused specifically on two Best Practices within the document that we believed would inform specific aspects of our existing program - "Best Practice 1: Identifying beneficiary species and predators for management" and "Best Practice 8: Monitoring, measuring, and reporting effectiveness"

Best Practice 1: Even for long-standing management programs, the Guidance and BPs stresses the importance of assessing present-time interactions between predators and beneficiary species so that management strategies are geared towards the appropriate targets. We recognized the fact that our current predation management on Metompkin Island is guided primarily by indirect evidence of predator impacts on shorebirds and would benefit from a more direct assessment of the factors influencing AMOY and PIPL reproductive success. This was particularly important for management at Metompkin Island since we have observed relatively low AMOY productivity at the site in recent years due to unknown causes of chick loss. Due to the remote nature of the site and relatively infrequent visits, the recommendation in BP 1 of using game cameras to identify predators and other causes of nest and chick loss was deemed the most appropriate for this project. Basic details provided in BP 1 related to using game cameras at nests were informative, however we note that more specific guidance and recommendations of using cameras in the field would have been very useful. Fortunately, one of the anticipated outcomes of this and the two other demonstration projects in Massachusetts and North Carolina will lay the groundwork for future development of such a product.

Best Practice 8: We also referenced BP 8 when implementing our project. Specifically, we followed recommendations on reporting apparent estimates of nest success and productivity when monitoring AMOY and PIPL pairs and cross-checked our monitoring metrics with those provided in the Supplemental Material for BP 8. We did not consider any of the suggested existing standardized data collection platforms or repositories (e.g. PIPLODES, NestStory) for our project. The current availability of multiple platforms and tools for collecting data can be overwhelming from a management perspective. We have focused on developing data collection tools in Collector for ArcGIS as it is integrated into our organization and provides flexibility for integrating with other platforms when and if needed. We recommend that more emphasis be placed on defining the metrics themselves since standardizing the actual tools used for collection is likely more difficult to standardize across a broad range of agencies and organizations.

Nest Cameras

We deployed cameras at a total of 27 AMOY nests and 28 PIPL nests (Figure 4).

Although we attempted to deploy cameras as early in the incubation phase as possible, deployment timing varied due to logistical constraints. When possible, we recorded the set-up time for nest camera deployment and the time between deployment and resumed incubation. Set-up time (both species, n=55) ranged between 2 and 18 minutes and averaged 7 ±

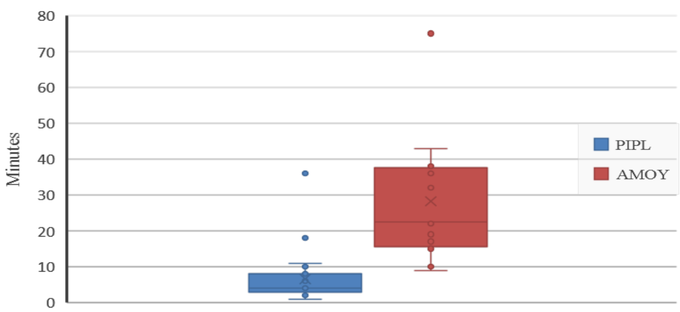


Figure 5. Box and whisker plots of the amount of time between next camera deployment and resumed incubation for AMOY and PIPL.

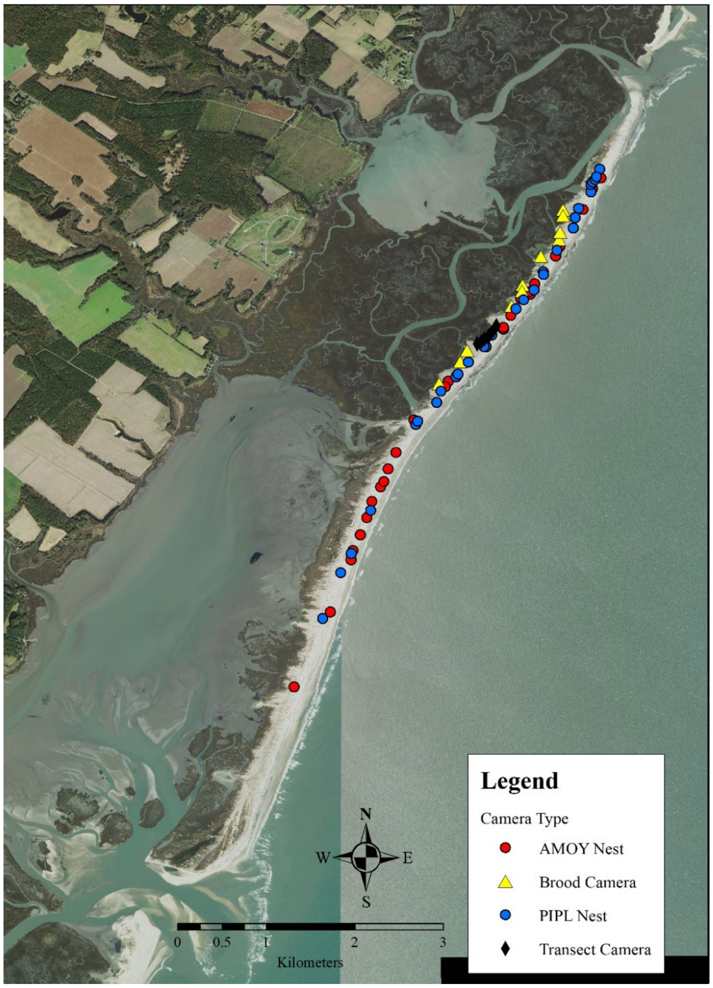


Figure 4. Nest, brood and transect camera deployment on Metompkin Island, Accomack County, Virginia, 2019.

3 minutes. The time before incubation resumed at AMOY nests (n=12) ranged between 9 and 75 minutes and averaged 28 ± 18 minutes. The time before incubation resumed at PIPL nests (n=23) ranged between 1 and 36 minutes and averaged 7 ± 7 minutes (Figure 5). On seven occasions (AMOY, n=6; PIPL, n=1), we abandoned our attempt to deploy cameras because the adults would not resume incubation in what we determined to be a reasonable amount of time. Although our baseline threshold for this was 30-45 minutes, we amended the threshold based on nest-specific variables such as environmental conditions, potential predators or other disturbance in the area, and other nearby nesting birds or other wildlife. In one case, we made the decision to pull the camera before the 30-minute mark (25 min), two cases within the 30-45 minute window (36 min and 44 min) and three cases after the 45-minute mark (57, 68, 72 min).

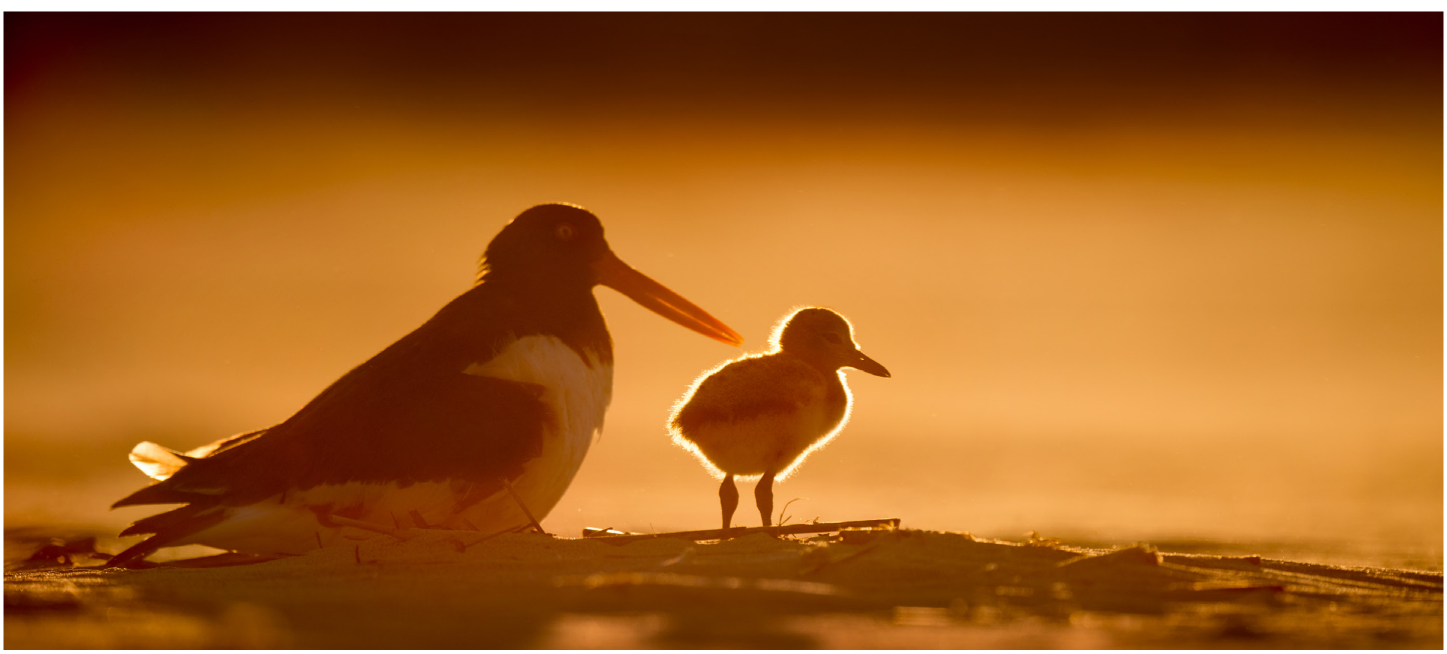
Of the 27 AMOY nests and 28 PIPL nests, we experienced five and six cases of camera failure, respectively. In most cases, we believe that complications with deployed solar panels were to blame and photos were not collected to document hatch success or reasons for failure. Hatch success information from those nests are not included in the summaries of hatch success provided below.

Twenty-two species were observed on nest cameras either causing a disturbance event, defined as causing the incubating bird to leave the nest, or a predation event, defined as the loss of one or more eggs in a clutch, or young (Table 1; Appendix 1).

In all cases where field observations documented at least one egg hatching, camera observations matched accordingly (AMOY, n=18; PIPL, n=11). Camera observations documented hatch success for eight attempts for which field observations were unable to confirm hatching (AMOY, n=2; PIPL, n=6) (Table 2). Six of those attempts were successful and two failed.

Hatch success for AMOY and PIPL based on field observations and camera observations was 82% vs. 91% and 50% vs. 68%, respectively.

Camera observations documented causes of clutch depredation (at least partial) for five nest attempts where field observations were inconclusive (AMOY, n=1; PIPL, n=5). Those causes included: Herring Gull depredation of an AMOY clutch (partial), ghost crab depredation of a PIPL clutch (partial), Laughing Gull depredation of PIPL clutches (twice) and Canada Goose crushing a PIPL clutch. A Laughing Gull was also documented depredating an already abandoned PIPL clutch with an active camera. Field observations of both species did not record any clutch or egg loss events attributed to predation with which we could compare camera observations.



American Oystercatcher adult and chick. ©Ray Hennessey, rayhennessy.com

Table 1. Species documented causing either a disturbance (resulting in bird leaving the nest) or predation (resulting in complete or partial loss of clutch or brood) event on nest cameras deployed at active American Oystercatcher (indicated with an "A") and/or Piping Plover (indicated with a "P") nests.

SPECIES (COMMON NAME)	SPECIES (SCIENTIFIC NAME)	DISTURBANCE EVENT	PREDATION EVENT
AVIAN			
Canada Goose	*Branta canadensis*	A, P	P[1]
American Oystercatcher	*Haematopus palliatus*	A, P	P[2]
Black-bellied Plover	*Pluvialis squatarola*	P	
Willet	*Tringa semipalmata*	A	
Shorebird sp.		A, P	
Laughing Gull	*Leucophaeus atricilla*	P	P[3]
Herring Gull	*Larus argentatus*	A, P	A
Least Tern	*Sternula antillarum*	A, P	
Bald Eagle	*Haliaeetus leucocephalus*	A, P	
Great Horned Owl	*Bubo virginianus*	A	
Peregrine Falcon	*Falco peregrinus*	P	P[4]
Red-winged Blackbird	*Agelaius phoeniceus*	P	
Grackle sp. (Boat-tailed/Common)	*Quiscalus major/Q. quiscula*	A, P	
MAMMALIAN			
Muskrat	*Ondatra zibethicus*	A	
Red Fox	*Vulpes vulpes*	A	
Raccoon	*Procyon lotor*	A	
White-tailed Deer	*Odocoileus virginianus*	A	
Domestic Dog	*Canis lupus familiaris*	A	
Human	*Homo sapiens*	A, P[5]	
OTHER			
Diamondback Terrapin	*Malaclemys terrapin*	A, P	
Atlantic Ghost Crab	*Ocypode quadrata*	A, P	P
Balloon		A	

[1] Canada Goose stepped on PIPL nest.

[2] AMOY observed with nest camera killing a recently hatched PIPL chick.

[3] Two separate nests.

[4] Peregrine Falcon observed with nest camera killing a recently hatched PIPL chick.

[5] 12 instances of humans observed in nesting areas, including three cases where individuals took photos of cameras.

Table 2. Hatching success of American Oystercatcher (AMOY) and Piping Plover (PIPL) nest attempts comparing field observations and camera observations of the same nests on Metompkin Island, VA, 2019. Hatching success was defined as at least one egg within a clutch successfully hatching.

	FIELD OBSERVATIONS			CAMERA OBSERVATIONS		
	Failed	Hatched	Unknown	Failed	Hatched	Unknown
American Oystercatcher	2	18	2	2	20	0
Piping Plover	5	11	6	7	15	0
TOTAL	7	29	8	9	35	0

Field observations recorded ten cases (AMOY, n=3; PIPL, n=7) of partial clutch loss during egg incubation, but cameras failed to capture any depredation events as a cause of partial clutch losses at these nests. This may have been due to periodic lapses in photo collection on some cameras for unknown reasons, or failed triggering of the motion sensor.

Notably, two cases of partial brood loss were recorded on nest cameras. In one incident a Peregrine Falcon was observed depredating what appeared to be a Piping Plover chick, and in another an AMOY was observed depredating a newly hatched Piping Plover chick.

Brood Cameras

We deployed 11 brood cameras at 11 separate AMOY brood locations. No chick depredation events were recorded with brood cameras despite the fact that eight of the 11 nesting attempts lost at least one young at some point during the brood rearing phase. It is possible that some young were lost prior to brood camera deployment, However, the frequency of site visits and detail of monitoring data were not sufficient to quantify this.

Transect Cameras

Photos from the seven transect cameras that we deployed were still being processed at the time of this report, and results were not available. However, based on a preliminary review of the time-lapsed images on these cameras, we do not believe that they documented any AMOY chick depredation events.

Predator Community

Combined observations from the nest and brood cameras provided a general characterization of the potential predator community on Metompkin Island during the 2019 nesting season. When summarizing the data, we included known shorebird predators or sources of shorebird disturbance at the site from prior years, potential predators based on information in the literature, and other potential predators based on anecdotal evidence within the season. We identified up to 22 species of birds (accounting for difficulty identifying crow and grackle species), 6 mammal species (including domestic dogs and humans), one reptile species and one invertebrate species (Appendix 2).

LESSONS LEARNED, AND RECOMMENDATIONS FOR FURTHER IMPLEMENTATION

Through this demonstration project, we successfully deployed trail cameras at an important shorebird nesting site in Virginia in order to collect additional information about predators impacting reproductive success of AMOY and PIPL. Overall, 80% percent of AMOY and PIPL nests with cameras successfully hatched, thereby limiting our opportunities to document nest predators. However, we documented several causes of both partial and full clutch loss, and chick loss that have not been reported or confirmed at the site in the past. This important information will inform future studies and management when considering factors limiting reproductive success of these shorebird species. Some of the causes of clutch/chick failure were unexpected at this site (e.g. Canada Goose, Peregrine Falcon) and highlight the need for managers to consider all possible scenarios when developing and implementing predator management programs (BP 1). Our results also highlighted the utility of nest cameras for decreasing the number of unknown records for hatching success, particularly when monitoring frequency is low such as at a remote site like Metompkin Island. If management decisions (i.e. to trap or not trap) are based on hatching success thresholds, nest cameras can help managers improve the accuracy of the information informing their actions.

We tested a novel deployment of cameras (i.e., 'brood cameras') with the objective of capturing chick depredation events at known AMOY brood-rearing areas. Even though camera placement enabled generally consistent observations of the broods, brood cameras did not document any depredation events. This may have been due to the fact that events took place outside of the range of the camera (visual or motion detection range) or that chicks were lost prior to camera deployment. We anticipated that broods would move in and out of camera range but were hopeful that at least some events caught on camera would identify a 'problem' predator. This method may have value for managers interested in characterizing the predator community in the vicinity of broods, but may not be an efficient method for confirming causes of chick mortality unless the brood rearing area is very confined. Note that the transect cameras were deployed in such a way so that the entire marsh edge was being captured (not confined to specific brood rearing area) and were set on 1s time-lapse intervals (coverage similar to video but less intensive for review). This methodology may have offered an increased chance of capturing an event but resulted in such a large amount of data that we were not able to process it all within the time period of this project.

An unexpected outcome of this project was the insight we gained into visitor use on the island. Photos from all cameras combined provided valuable information on visitor access points, general frequency of visitors at more remote areas of the site and types of activities (e.g. shell collecting, surf fishing). In three cases, nest cameras recorded visitors taking pictures of the cameras themselves. We are not able to confirm whether the cameras initially attracted the visitors to those exact areas, but regardless the interest in the cameras certainly resulted in visitor activity in very close proximity to the nest locations. Future management efforts will be adapted accordingly to decrease and prevent visitor trespass through nesting areas. We also recommend that the concept of using cameras as a way to monitor and mitigate the impacts of human disturbance on migrating (or nesting and non-breeding) shorebirds should be considered in future iterations of NFWF's recently released Guidance and best practices for evaluating and managing human disturbances to migrating shorebirds on coastal lands in the northeastern United States (Mengak et al. 2019).

Our efforts to protect and manage for nesting AMOY and PIPL on Metompkin Island will benefit from important lessons learned over the course of this demonstration project:

- Cameras offer great potential for identifying nest predators and confirming hatch success when frequency of monitoring visits is limited;
- As with field observations, camera observations must be evaluated with several considerations in mind:
    - Despite apparently uninterrupted coverage by nest cameras, it is possible to miss predation events, possibly due to the motion trigger not being activated;
    - Our nest cameras were not always able to document the exact number of eggs that hatched for each successful attempt, so our methodology is not necessarily appropriate for calculating hatch success defined as the total number of eggs hatched;
    - Photos of predation events did not always document full or partial loss of a clutch;
    - Cameras may attract visitors, even in remote areas, and inadvertently increase the risk of nests being trampled by foot;
- Methodology for future work with cameras could be modified to allow for better documentation of hatch success and full vs. partial clutch losses;
- Future work may require other techniques to track chick fate, such as radio telemetry;
- Cameras can play an important role in monitoring and assessing visitor use at remote sites and can inform visitor management and stewardship.

Overall, this project has identified important factors to consider as we evaluate and adapt predator management strategies for Metompkin Island and other Virginia barrier islands. Our results have set the stage for future work to further uncover and identify factors limiting shorebird reproductive success so that we can efficiently focus limited resources for the highest return on investment. Furthermore, we anticipate that our lessons learned about using trail cameras in this context will support future work to develop a "Supplemental Guidance for Using Cameras to Improve Predation Management at Shorebird Nesting Sites" document, which we have begun to plan in tandem with other demonstration projects. Managers throughout the Atlantic Flyway that are interested in using cameras for these purposes would greatly benefit from development of this document.

LITERATURE CITED

Mengak, L., A.A. Dayer, R. Longenecker, and C.S. Spiegel. 2019. Guidance and Best Practices for Evaluating and Managing Human Disturbances to Migrating Shorebirds on Coastal Lands in the Northeastern United States. U.S. Fish and Wildlife Service.

APPENDICES

Appendix 1. Examples of photos documenting disturbance and predation events at American Oystercatcher and Piping Plover nests on Metompkin Island, VA, 2019.

Island visitor photographing nest camera

Herring Gull depredating AMOY nest

Hatched AMOY brood

CAGO stepping on PIPL nest

PEFA depredating PIPL chick

Ghost Crab harassing incubating PIPL

Deer passing through nesting territory

BAEA flight over AMOY nest

Appendix 2. Summary of known or potential shorebird predator species observed on nest and brood cameras deployed within nesting American Oystercatcher and Piping Plover territories on Metompkin Island, Virginia 2019. "N" indicates observation from a nest camera; "B" indicates observation from a brood camera.

SPECIES (COMMON NAME)	SPECIES (SCIENTIFIC NAME)	OBSERVATION
AVIAN		
Black-crowned Night-heron	*Nyctanassa violacea*	B
Yellow-crowned Night-heron	*N. nycticorax*	B
Tricolored Heron	*Egretta tricolor*	B
Snowy Egret	*E. thula*	B
Great Egret	*Ardea alba*	B
Great Blue Heron	*A. herodias*	B
Canada Goose	*Branta canadensis*	N
American Oystercatcher	*Haematopus palliatus*	N, B
Black-bellied Plover	*Pluvialis squatarola*	N
Willet	*Tringa semipalmata*	N, B
Laughing Gull	*Leucophaeus atricilla*	N, B
Herring Gull	*Larus argentatus*	N, B
Great Black-backed Gull	*L. marinus*	B
Least Tern	*Sternula antillarum*	N
Bald Eagle	*Haliaeetus leucocephalus*	N, B
Great Horned Owl	*Bubo virginianus*	N, B
Peregrine Falcon	*Falco peregrinus*	N, B
Crow sp. (Fish/American)	*Corvus ossifragus/C. brachyrhynchos*	B
Red-winged Blackbird	*Agelaius phoeniceus*	N, B
Grackle sp. (Boat-tailed/Common)	*Quiscalus major/Q. quiscula*	N, B
MAMMALIAN		
Muskrat	*Ondatra zibethicus*	N, B
Red Fox	*Vulpes vulpes*	N
Raccoon	*Procyon lotor*	N, B
White-tailed Deer	*Odocoileus virginianus*	N
Domestic Dog	*Canis lupus familiaris*	N, B
Human	*Homo sapiens*	N, B
OTHER		
Diamondback Terrapin	*Malaclemys terrapin*	N
Atlantic Ghost Crab	*Ocypode quadrata*	N, B
Balloon		N

2019 Demonstration Project, Massachusetts

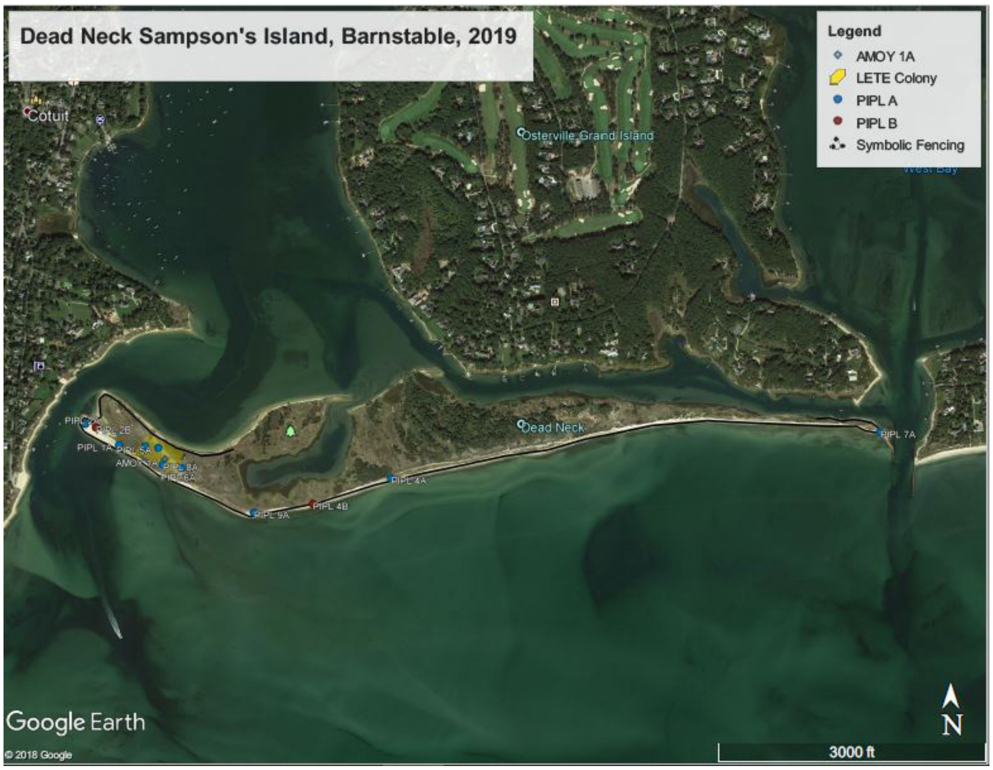
PROJECT TITLE: Managing shorebird predators amidst the beach-going public: evaluating camera use and other best practices

PROJECT LEAD: Katharine Parsons, Mass Audubon (kparsons@massaudubon.org)

SITE AND SPECIES DESCRIPTION

Site Information

Dead Neck Sampson's Island, Barnstable County, Massachusetts:



Dead Neck/Sampson's Island is a 47.3 ha dynamic barrier island subject to significant erosion due to regional shoreline engineering. It is managed as a bird sanctuary by Mass Audubon and the Barnstable Coalition for Clean Water (a local conservation NGO; formerly Three Bays Preservation, Inc.) and has been one of the most important sites for breeding Piping Plover (*Charadrius melodus*) and Least Tern (*Sternula antillarum*) in southern Massachusetts for two decades. Productivity of these species on the island has dramatically declined since the last major re-nourishment in 1999-2000 (Figures 1, 3). The productivity decline in both species is largely attributed to the enhanced avian and mammalian predation that occurs on the now narrow, eroded beaches. American Oystercatcher (*Haematopus palliatus*) and Roseate Tern (*Sterna dougallii*), which nested here in the past (most recently in 2008), no longer nest on the island. Predation management has taken place on the island for at least three decades although limited to non-lethal management until 2014. Selective removal of individual predators documented to be adversely impacting nesting plovers and terns was undertaken during 2014, 2015, 2016, and 2017, but not in 2018. Dead Neck Sampson's Island was one of several demonstration sites included in the 2017 NFWF-USFWS project 'Coordinated Predation Management for Focal, Temperate-Breeding Shorebirds in the Atlantic Flyway' (as reported in Guidance and Best Practices for Coordinated Predation Management to Benefit Temperate Breeding Shorebirds in the Atlantic Flyway, pp. 115-116). In 2018, a 3-year habitat restoration project commenced on Dead Neck Sampson's Island. In 2019, the newly created re-nourishment areas (Figures 2, 4) provided habitat for several species of coastal waterbirds and predation management on the island again included predator removal.

Figure 1. Dead Neck Sampson's Island east end pre and post 2000 re-nourishment (left 1999; right 2001)

Figure 2. Dead Neck Sampson's Island east end pre and post 2018 re-nourishment (left 2018; right 2019)

Figure 3. Dead Neck Sampson's Island west end 2001 (post 2000 re-nourishment)

Figure 4. Dead Neck Sampson's Island west end pre and post 2018 re-nourishment (left 2018; right 2019)

Little Beach/Barney's Joy, Bristol County, Massachusetts:

Little Beach/Barney's Joy of Dartmouth, Massachusetts is an important nesting site for breeding Piping Plover, Least Tern and American Oystercatcher. Little Beach is largely located within the Allens Pond Wildlife Sanctuary (APWS), a Mass Audubon-owned and managed coastal property (Figure 5). With roughly 2.5 miles of coastline, the habitat at Little Beach ranges from extremely rocky on the west side to sandy beachfront habitat in front of privately-owned cottages. The private inholdings are accessed by a dirt road flanked by coastal heathlands and marshlands. A large, tidal inlet bisects the spit, and mixes the brackish water of Allens Pond with the salt water of Buzzards Bay. The seasonally-dynamic inlet is bounded by sandy overwash habitat on both sides and closes about every 3-5 years. The landowner at Barney's Joy maintains permits to re-open the channel at a designated location to the east by Barney's Joy from where it then migrates westward over time. The Barney's Joy's side of the spit extends about another 0.5 mile (depending on the year one side can be much larger than the other) and a dune-fronted beach continues further east, bounded by an extensive heathland upland to the north.

Predation management has taken place at Little Beach/Barney's Joy for at least three decades although limited to non-lethal management until 2014. Selective removal of individual predators documented to be adversely impacting nesting plovers and terns was undertaken on the Little Beach portion (west end) of the beach complex during 2014-2019. Little Beach/Barney's Joy was one of several demonstration sites included in the 2017 NFWF-USFWS project 'Coordinated Predation Management for Focal, Temperate-Breeding Shorebirds in the Atlantic Flyway' (as reported in Guidance and Best Practices for Coordinated Predation Management to Benefit Temperate Breeding Shorebirds in the Atlantic Flyway, pp. 113-115).

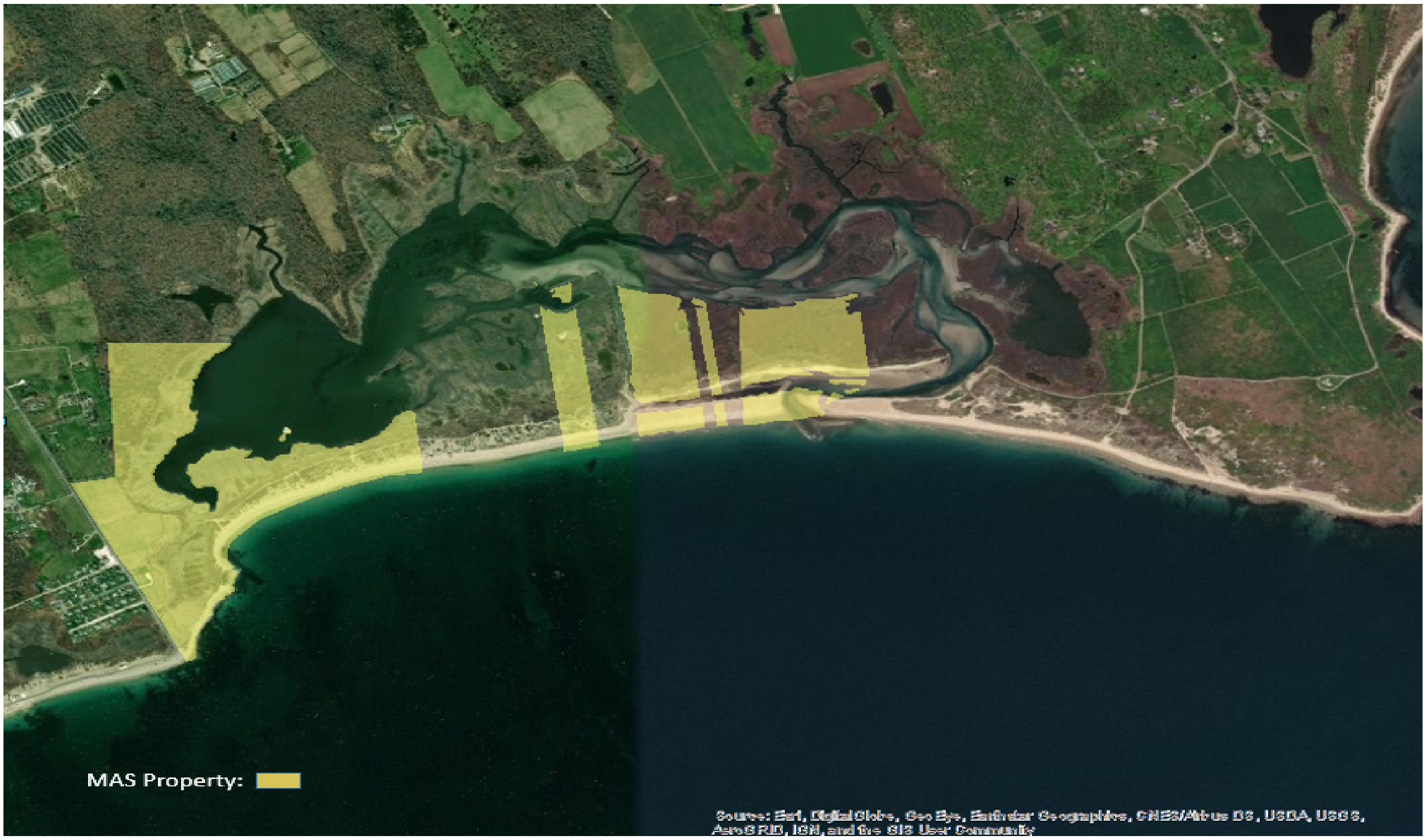


Figure 5. Property ownership at Little Beach Barney's Joy. Yellow-highlighted parcels are owned by Mass Audubon; other parcels are in private ownership including extensive beach to the east which is owned by the Barney and Joy families.

BACKGROUND INFORMATION ON BENEFICIARY AND PREDATOR SPECIES

We used the document, Guidance and Best Practices for Coordinated Predation Management to Benefit Temperate Breeding Shorebirds in the Atlantic Flyway ('Guidance and BPs') to assist in identifying beneficiary wildlife species (Best Practice [BP] 1) at both Massachusetts demonstration sites. Although our focus was on special status shorebird and seabird species known to historically nest at these sites (American Oystercatcher, Piping Plover, Least Tern, Common Tern [*Sterna hirundo*], Roseate Tern), we recorded all coastal waterbirds observed during site visits (2-7 days/week). In addition, we recorded species abundance and assessed productivity of shorebirds and terns.

Predator species known to impact beneficiary species at Dead Neck Sampson's Island include: Great-horned Owl (*Bubo virginianus*), American Crow (*Corvus brachyrhynchos*), Herring Gull (*Larus argentatus*), Great Black-backed Gull (*Larus marinus*), eastern coyote (*Canis latrans*), raccoon (*Procyon lotor*), and Virginia opossum (*Didelphis virginiana*). Predator species known to impact beneficiary species at Little Beach/Barney's Joy include: Great-horned Owl, American Crow, Herring Gull, Great Black-backed Gull, eastern coyote, red fox (*Vulpes vulpes*), gray fox (*Urocyon cinereoargenteus*), long-tailed weasel (*Mustela frenata*), striped skunk (*Mephitis mephitis*), American mink (*Neovison vison*), and feral cat (*Felis catus*).

Identification of predator species involved all methods recommended in the Guidance and BPs except telemetry. Methods included tracking, camera traps, and direct observation of predation events, described in detail below. BP1 also recommended systematic surveys of predators and predator sign, which we implemented in 2019 as a new practice. In particular, all of these methods assisted us in characterizing and managing the predator threat to oystercatchers, terns and plovers nesting at both sites. Our findings regarding the on-site predator community are detailed below in 'results.'

GOALS AND EXPECTED OUTCOMES

Our goals were to implement recommendations in the Guidance and BPs at demonstration project sites during 2019, utilize standardized methods for assessing effectiveness of predation management developed during the related 2017 demonstration project (see Site Information above), and field-test standardized guidelines for site selection, metrics for monitoring success, criteria for evaluating and reporting results.

Expected Outcomes:

a) All Piping Plover, American Oystercatcher and tern nests/broods at demonstration sites would benefit from using non-lethal protection measures (e.g., exclosures, garbage control, electric fencing) and lethal predator management.

b) Increased productivity and decreased nest failure rates at demonstration sites compared to previous years when predator management was not implemented (excluding broods/nests lost to severe weather, e.g. storm overwash).

c) Work would serve as a case study for implementation of the Guidance and BPs document for on-the-ground management, informing users who are considering implementing it at their sites, and providing information on effectiveness, suggestions for improvement and future work needed to continue to advance usefulness of the guidance tools.

METHODS: IMPLEMENTING GUIDANCE AND BEST PRACTICES INTO DEMONSTRATION PROJECT WORK

a) General Description

A variety of non-lethal and lethal predator control measures were instituted at both sites in 2019, with the goal of reducing predator impacts on nesting shorebirds. From 2014-2019, an expanded predator management plan was implemented according to Mass Audubon's institutional "Predation Management Policy for Waterbird Protection." Mass Audubon's Coastal Waterbird Program (CWP) contracted with USDA APHIS Wildlife Services to remove predators as appropriate and according to the approved plan. In addition, CWP staff conducted routine shorebird monitoring and predator monitoring (including tracking, point count surveys, and trap cameras) to evaluate the impact enhanced predator management had on the reproductive success of the island's nesting birds.

Beginning in Jan 2019, CWP shorebird monitors collected data on predator activity on Dead Neck Sampson's Island and at Little Beach. Monitors determined predator presence and activity through tracking and direct observation.

At Dead Neck Sampson's Island, predator point counts were conducted along the entire ocean side of the coastline, approximately once a month beginning in January 2019 (4 Jan; 22 Feb; 24 Apr; 10 May; 4 Jun; 1 Jul; 3 Aug; 13 Nov). Point counts were developed by establishing a survey point every 100 meters, resulting in 16 points on the Nantucket sound side and one point on the bayside near the restoration area (Figure 6). Sampling took place above the high tide line. At each point, the monitor remained for 5 minutes and recorded direct observations within 50 meters of any known and possible avian and mammalian predator species based on prior field documentation and published information. Additionally, the monitor recorded any evidence (such as tracks, scat) of predator species within 10 m of the point. Monitors also recorded environmental data and noted predator sign (e.g., tracks) between points when observed.

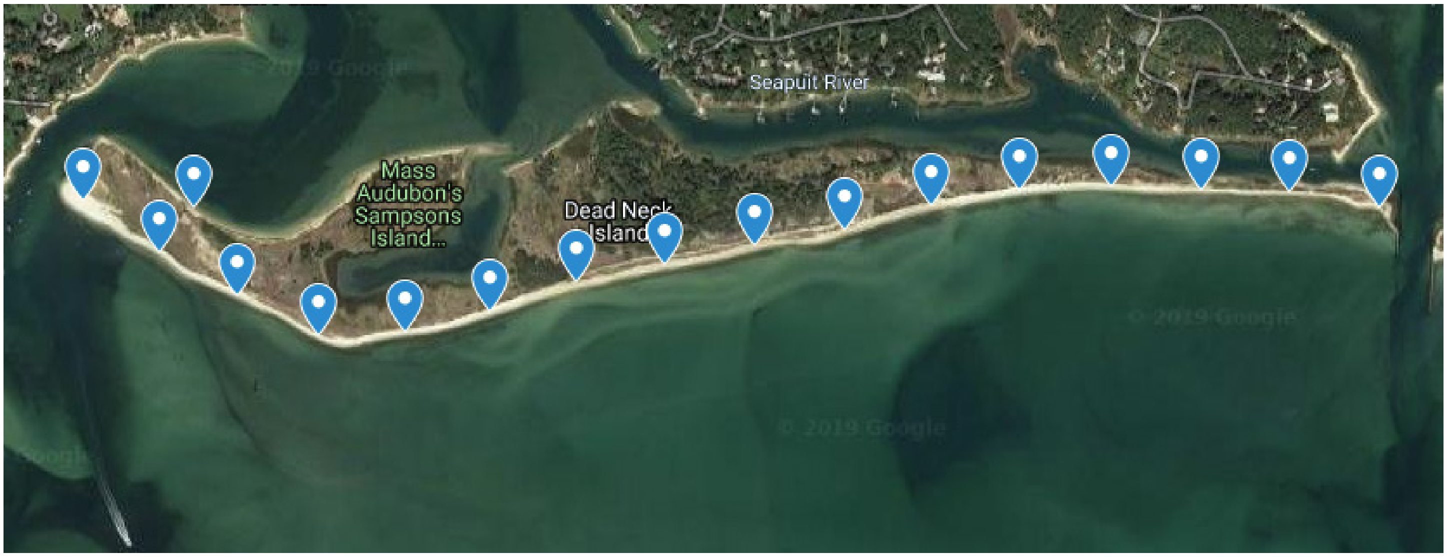


Figure 6. Permanent points established for monthly predator surveys on Dead Neck Sampson's Island 2019. During regular monitoring of nesting coastal birds, observations recorded at nest sites where eggs failed to hatch allowed probable attribution of predator species as observed. Observations of predator activity in plover brood ranges and direct observation of harassment of unfledged young by predators also allowed reasonable conclusions on predator impact.

Browning Recon Force Extreme trail cameras were placed on Sampson's Island and Little Beach in 2019 (Figures 7, 8) to improve predation management at shorebird nesting sites.

Figure 7. Location of game cameras deployed on Dead Neck Sampson's Island in 2019.

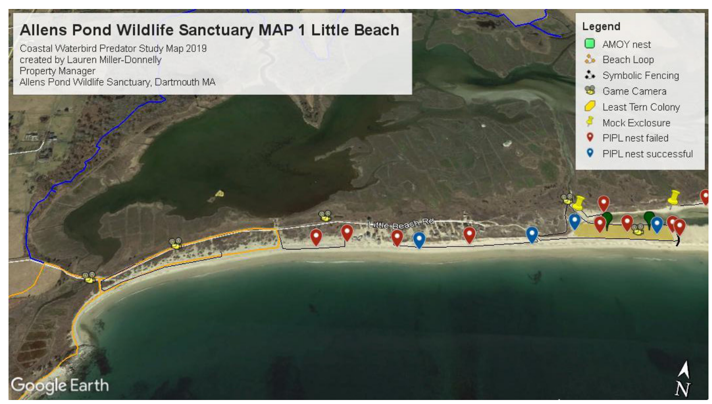


Figure 8. Camera deployment, mock exclosure placement, and nest outcomes on Little Beach 2019.

On Sampson's Island, one camera was placed at the west tip where there was nesting shorebird activity. A second was placed in the largest of the two restoration areas where there were multiple shorebird species nesting. The cameras were in place from 7 Jul until 5 Aug and were not moved from their original location. The cameras were checked by CWP shorebird monitors on a weekly basis. Five cameras were deployed at Little Beach (Figure 8).

b) Use of Guidance and BPs to Inform Work

- *Strategies and priorities for lethal and non-lethal management (BP2)*: We adopted an integrative predation management strategy at both sites including predator removal and a relatively exhaustive approach to non-lethal management. We found that we had slightly different perspectives on where our strategy should be on the spectrum of integrative to intensive management than USDA (our contractor for predator removal), and followed the BP guidance which stresses the need for all entities to be aligned in basic approach and objectives for predation management using both lethal and non-lethal methods.

- *Methodological considerations for lethal management (BP3)*: This BP helped us assess our options for lethal management. Prior years' monitoring showed that American Crow and eastern coyote were the most impactful predator species at both sites. To lethally remove egg-eating crows from shorebird nesting habitat, USDA deployed mock exclosures which were pre-baited with non-toxic brown chicken eggs in a mock nest bowl, and equipped with a trail camera. Once it was determined, through photographs or other sign, that crows were consuming eggs from the exclosures, USDA substituted toxic eggs (DRC-1339) for non-toxic eggs in the mock nest bowl. The bottoms of the mock exclosures were buried into the sand, and the tops left open to ensure only avian predators would uptake the bait. Positions for each mock exclosure were based on the frequent use of the area by crows, which was observed and inferred by CWP monitors based on tracks and observations of crows. Each exclosure was labeled with "USDA Property" and "Danger: Poison" signs to ensure they would not be tampered with by the public. In addition, USDA personnel used suppressed firearms to remove individual coyotes, skunks and foxes at Little Beach. Efforts to schedule additional night-time shooting of mammalian predators at both sites were hampered by weather, availability of USDA personnel and permit complications.

- *Methodological considerations for non-lethal management (BP4)*: This BP helped us assess our options for non-lethal management. Mass Audubon's practice according to approved institutional policy allowing predator removal as appropriate, is to implement a full range of non-lethal methods for predation management. Coastal Waterbird Program staff implemented a number of non-lethal techniques to reduce predator activity. While electric fencing was utilized in 2014 on top of Dead Neck Dredge, it was not employed this year due to concern about potential effects on American Oystercatchers and disturbance to Least Terns that could have caused late in the season. To reduce avian predation by non-lethal means, we erected symbolic fencing across the island using ½" fiberglass posts, which deterred perching by avian predators. Triangular signs were also affixed to fiberglass posts in such a way that perching was not possible (Figure 9). By eliminating perches in nesting habitat, avian predators were allowed very few vantage points from which to view shorebird nesting territories.

Figure 9. Perch-deterrent posts used during the field season.

  Additionally, in order to discourage both avian and mammalian predators, trash was regularly collected off the beaches during site checks. Monitors avoided walking within the fencing whenever possible and never closely approached shorebird nests once discovered. Once the plover chicks hatched, monitors similarly gave the birds a large buffer to minimize disturbance and human scent near hatchlings. Every effort was made to minimize disturbance to these broods and to reduce the chance of the monitors' presence attracting predators into the area.

- *Timing of predation management and unintended secondary impact (BP5)*: As recommended in the guidance document, we undertook systematic year-long surveys of beach habitats to document predator presence, abundance and activity in order to better understand the predator community phenology on Dead Neck Sampson's Island. We employed predation management methods from March through August, though lethal predator control took place April-June. Timing was determined by the presence and activity of predators in nesting areas, and by the level of recreational use on the beaches. We also documented mammal incursions into the mock exclosures baited with toxic eggs to control crows, and developed recommendations for limiting this in the future.

- *Community engagement, outreach and communications (BP6)*: This BP was used to enhance our existing policy for community engagement and outreach. According to institutional policy, both demonstration sites had updated communications plans pertaining to lethal predator management on Mass Audubon sanctuary lands. Communications plans included protocol (timing, personnel) for dealing with questions and negative press, FAQs for staff, and news media contacts. Since 2014 when Mass Audubon first undertook lethal predator management at these sites, we deemed it inadvisable to announce the use of this management tool at specific locations. Alternatively, we have advocated publicly for lethal control that is targeted, evidence-based, last resort, and humane in support of partner organizations including state and federal agencies and state-wide policy.

- *Monitoring, measuring and reporting effectiveness (BP8): We followed nearly all of the* recommendations contained in this Best Practice in our monitoring of nesting coastal birds at both sites. In addition, new in 2019, we adopted use of the web-based app NestStory which allowed us to digitize daily observational data, and make a relatively seamless transmission of summarized data to the state online system (PIPLODES and ternODES). In addition, we conducted several ancillary studies (vegetation monitoring, invertebrate prey sampling) to better understand the impact of a large, three-year re-nourishment and habitat restoration project on Dead Neck Sampson's Island. Such a significant change to available habitat and our ability to manage predation is prominent in our results and interpretation of the season.

- *Coordination across agencies (BP9)*: As recommended in BP 9, we took steps to coordinate our activities with other practitioners engaged in management benefitting shorebirds. We participated in the season-end Massachusetts Shorebird Cooperators' meeting where information on monitoring, predation management and other wildlife management methodologies were shared and discussed. Using the current NFWF-USFWS grant award for the demonstration project, we also sought to continue to support analysis of camera image data from the 2017 demonstration project with state partners.

RESULTS

a) Predation Management—Dead Neck Sampson's Island. Predator activity was documented by observers during each site visit from April through August (Table 1). In addition, two game cameras were set up on island to document predator activity, one in West Restoration Area and the other at the West tip tidal pool.

Table 1: Number of site visits (and percentage of visits) during which predator activity was observed by field technicians Apr-Aug 2019 on Dead Neck Sampson's Island.

Type of observation	April (5 site visits)	May (15 site visits)	June (19 site visits)	July (23 site visits)	August (7 site visits) as of August 10
Crow sightings	5 (100%)	7 (46%)	14 (74%)	7 (30%)	5 (71%)
Crow tracks	5 (100%)	10 (67%)	9 (47%)	12 (52%)	5 (71%)
Coyote sightings	0 (0%)	1 (7%)	0 (0%)	0 (0%)	0 (0%)
Coyote tracks	5 (100%)	12 (80%)	16 (85%)	20 (87%)	6 (86%)
Great Black-backed Gull sightings	5 (100%)	12 (80%)	17 (90%)	20 (87%)	7 (100%)
Herring Gull sightings	5 (100%)	12(80%)	17 (90%)	20 (87%)	7 (100%)

Nest And Chick Loss

In 2019 monitors recorded 11 Piping Plover nest attempts (Table 2). Seven out of all nest attempts failed, six attributed to predation, and one lost to an unknown cause (Tables 3, 4). We did not document any clutches lost to overwash in 2019, though overwash caused clutch loss in 2018. Two plover pairs re-nested after nest loss, with only one producing chicks (n=4). Of the six suspected predation events, 67% of Piping Plover nest loss was due to eastern coyote, while about 17% were likely lost to American Crow. Coyote was also responsible for the failure of a Least Tern colony on two separate occasions, as well as for the loss of an American Oystercatcher nest. In 2018, no lethal predator management of any kind took place at the site, and 46% of plover clutches were lost to probable crow predation. In 2019, twenty-four crows were removed through toxic egg uptake, likely leading to the decrease in crow depredation. However, no coyotes were removed from the island in 2019.

Ninety-four percent of plover chicks that hatched on Dead Neck Sampson's Island in 2019 fledged, a higher rate than 2018. Piping plover chick depredation was only documented for a single chick (Table 4).

Table 2. Nesting on Dead Neck Sampson's Island (DNSI) and Little Beach Barney's Joy (LBBJ) 2019

Site	Species	N pairs	N clutches	N eggs laid	N eggs hatched	N chicks fledged
DNSI	Piping Plover	9	11	42	16	15
	Least Tern	100	Unknown	Unknown	Unknown	10
	American Oystercatcher	1	1	2	0	0
LBBJ	Piping Plover	20	26	98	36	8
	Least tern	40	Unknown	Unknown	Unknown	5
	American Oystercatcher	2	3	6	0	0

Table 3. Piping Plover nest loss on Dead Neck/Sampson's Island 2019

Pair/Nest#	Attributed Cause of Egg Loss	Supporting Evidence of Loss
2a	Predation	4 eggs lost due to a predation event on 5/15. Very fresh Greater Black-back Gull tracks were observed around and right up to nest bowl. Fresh egg yolk and shells present in nest bowl with tracks surrounding area.
4a	Predation	4 eggs lost due to American Crow on 6/02-6/04. Crow tracks surrounded the nest bowl. A piece of cracked egg shell was found 5m from nest bowl with surrounding crow tracks.
4b	Predation	3 eggs were lost due to Eastern Coyote predation on 6/29. Tracks observed along the toe of dune and eventually leading right up to nest bowl.
5a	Predation	4 eggs lost on 6/08. Eastern Coyote tracks observed right up former nest bowl. Egg yolk found in nest bowl and shell found about 1m away with coyote tracks surrounding area.
7a	Predation	4 eggs lost 6/09-6/14 due to predation. Both American Crow and Eastern Coyote tracks observed less than 1 meter from nest bowl. Unknown which predator was responsible for nest loss. Important to note predicted hatch date was 6/12, could have been predated during or after hatching.
8a	Predation	4 eggs lost to coyote on 6/07. Eastern Coyote tracks observed throughout area and eventually leading right up to former nest bowl. Nest located in Least Tern Colony and was depredated same day as colony due to coyote.
9a	Suspected Predation/Unknown	3 eggs were lost on 6/10-6/14 by unknown cause. Over wash can be ruled out due to placement of nest in vegetation, safe from high tide line. We suspect nest was predated, but due to heavy rain from night before no tracks were found near nest site.

Table 4. Piping Plover chick loss on Dead Neck/Sampson's Island 2019

Pair/Nest #	Attributed Cause of Chick Loss	Supporting Evidence of Loss
6a	Unknown Cause	One 2-week old chick lost 6/17-6/22. Eastern Coyote tracks observed in usual foraging area at almost every visit, but overall cause is unknown

American Crows And Other Avian Predators

American Crows were often observed foraging and roosting on, or flying over the island; we observed crows, or crow tracks in shorebird nesting habitat on 70% of visits (Table 1). Crows were observed mostly at the east end of the island, where they flew from the nearby mainland of Osterville Great Island to Dead Neck. Two Piping Plover clutches were suspected to have been depredated by American Crow based on sign around the nests. A Great Black-backed Gull was also believed to have depredated a clutch, based on sign around the nest. Fish Crow (Corvus ossifragus) and Common Raven (Corvus corax) were not detected on the island.

Crows were seen during 95-100% of the visits to the island throughout April, but decreased to 46% of visits after mock exclosures were placed. Crow tracks were seen 95-100% of the visits to the island throughout April, but decreased to 67% of visits after the mock exclosures were placed. Live crows were seen 74% of site visits in June and 30% in July, while tracks persisted for 47% of visits in June and 52% of visits in July. These observations support a marked decrease in crow activity (Figure 10). The successful hatching and survival of four Piping Plover broods (hatch dates: 27 May, 27 May, 2 Jun and 24 Jun) is likely due to the predator control successfully suppressing crow predation.

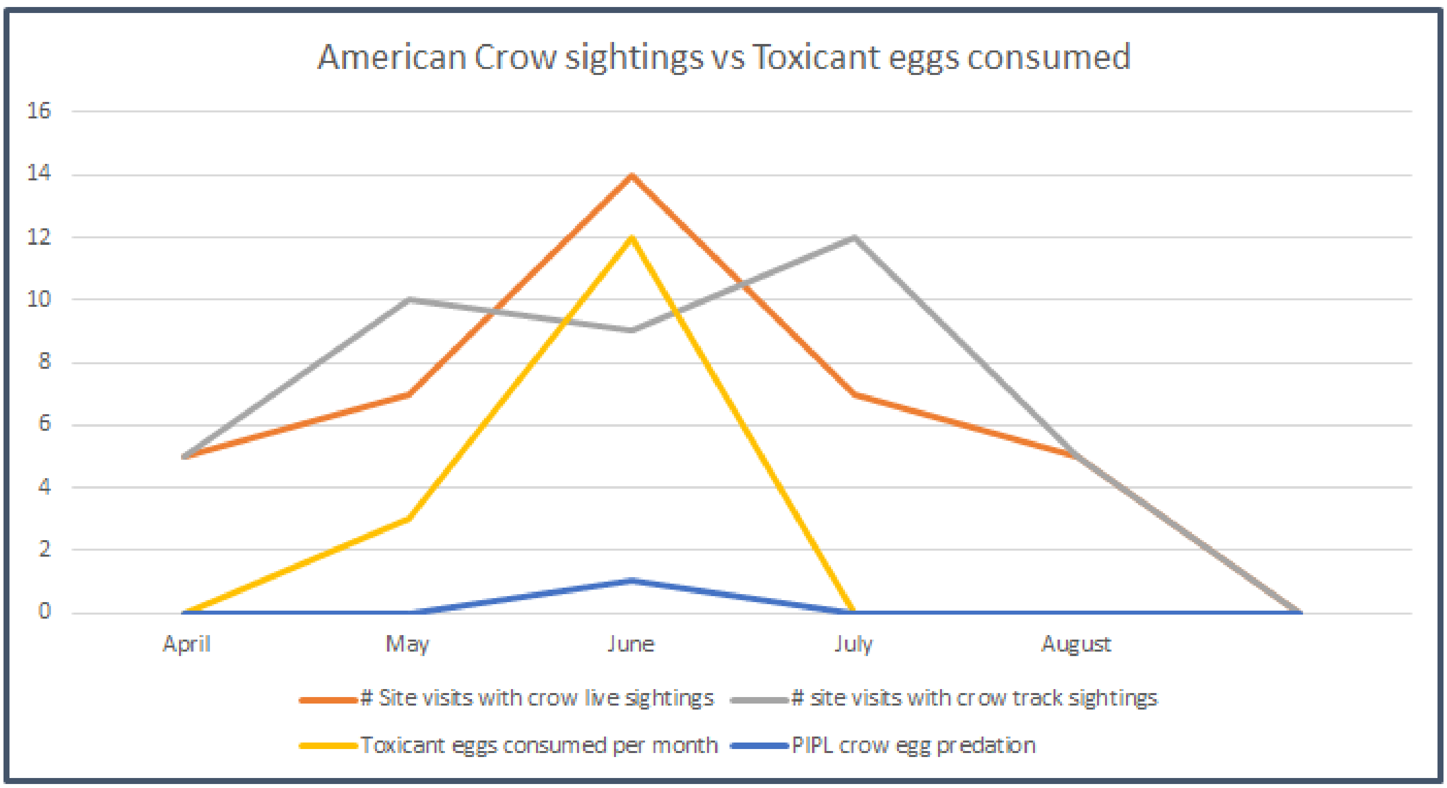


Figure 10. Number of site visits during which American Crow tracks and live sightings were observed each month during 2019 nesting season compared to toxicant egg consumption. No toxicant eggs were placed after 6/15/19; only pre-bait eggs were used after that date.

Eastern Coyotes

Eastern coyote tracks were observed during about 90% of visits (Table 1). Tracks were most commonly observed on the oceanside of island along the toe of the dune, and at both east and west tips inside of newly restored areas. An adult coyote was observed by a CWP monitor on 17 May around 7:00 am on the bayside of the island just west of the eastern tip of the island. Eastern coyotes were also observed on both trail cameras on multiple occasions usually from about 8:00pm to about 5:00am.

Coyote tracks were observed primarily along the oceanside (tidal pool to Jetty Tip) as well on the Sampson Bayside and Sampson Tip. Based on this evidence, a coyote entered and exited the island along Dead Neck Riverside on several occasions, as tracks were observed coming out of the water at the east tip on the bayside. Although a coyote had been observed accessing the island from Cotuit across the Cotuit channel in past seasons, we did not observe a coyote swimming to the island at this location in 2019. In the past, USDA has not located any fresh water on the island, showing that the habitat is not ideal for denning.

Based on sign around the nest and images captured on camera, Piping Plover egg losses were attributed to coyote predation on 7 Jun, 8 Jun, and 29 Jun. One additional nest was also suspected to have been predated by coyote, based on tracks near the nest bowl on 14 Jun. Depredation of an American Oystercatcher nest was documented and based on presence in camera images and sign around the nest, attributed to Eastern coyote on 7 Jun. Eastern coyote also likely caused the loss of a Least Tern colony. On 7 Jun monitors observed a more than 95% colony loss (at least 50 nests), which we suspected was caused by coyote, based on tracks and digging of holes where nests were present. Least Terns later recolonized this same area until the colony was lost again likely due to depredation from Eastern coyote from 21 Jul - 25 Jul. One coyote was observed on a trail camera set up in colony area on multiple nights within this time frame.

While avian predation was documented, at Dead Neck Sampson's Island, we have high confidence that coyote predation was the major factor affecting reproductive success (Table 3), based on sign around the nest and presence of coyotes in camera images. Coyote tracks were observed 100% of site visits in April, 80% of visits in May, 85% in June and 87% of visits in July. Coyote activity was not impacted significantly by predator control activities. Although not all camera images were reviewed and compiled as of the date of this summary report, we will use these images and cameras in the future to assist in verifying/documenting predation events.

b) Predation Management—Little Beach/Barney's Joy

Background

In prior years of monitoring, predation has been documented as a key factor contributing to low nest success at Little Beach. In 2018, field observations and camera surveillance indicated that red fox, eastern coyote, striped skunk and long-tailed weasel posed the greatest threat to shorebird nest, and therefore were the highest priority for mammalian predator control for 2019. Great Black-backed Gulls, a documented nest predator in 2018, and American Crows were also identified as a priority for control in 2019, should threats arise. Other potential nest and chick predators observed through daily observations, track, scat and game camera surveys at Allens Pond (2014-2019) included Virginia opossum, short-tailed weasel, American mink, fisher (*Pekania pennanti*), raccoon, gray fox, red fox, feral cat, domestic dog (*Canis lupus familiaris*), Common Grackle (*Quiscalus quiscula*), Northern Harrier (*Circus cyaneus*), Great-horned Owl, Red-tailed Hawk (*Buteo jamaicensis*), Short-eared Owl (*Asio flammeus*), Peregrine Falcon (*Falco peregrinus*), Black-crowned Night Heron (*Nycticorax nycticorax*), and Common Raven.

Game Camera Installation - Pre-nesting Season

Game cameras were set up in February 2019 in order to identify the current predator community at the site. Three game cameras were set up along the Little Beach road in order to capture animals using the road. During this time period coyote, raccoon, and skunk dominated the observations but cameras also captured red fox, gray fox, opossum, cat and gulls.

Piping Plover Nest Fate - 2019 Season
A total of 11 pairs of Piping Plovers nested at Little Beach with 17 nest attempts. Six of the nests were lost to predation; Evidence from observers, sign, and cameras suggested that 1 nest was lost to coyote, 1 to skunk, and 4 to mink. Three nests were lost to overwash and one nest was lost to unknown causes. The latter nest was lost around Memorial Day weekend among the cottage properties, coincident with intensive human use near that nest location. Of the 6 pairs that successfully hatched their nests, 2 pairs lost their entire broods. In total, 4 pairs produced a total of 8 chicks (Tables 2, 5). The final productivity was 0.73 chick per pair for Little Beach.

2019 Field Summary - Predators and Piping Plovers
May 2019: Once nesting started, two game cameras were moved to the overwash beach habitat and one camera was left on the Beach Loop. During that month, eastern coyote, red fox, gray fox and raccoon were observed on game cameras. Track surveys revealed heavy coyote presence as well as fox, raccoon, skunk, and gulls. On 7 May the first plover nest was lost due to probable coyote depredation. On 9 May, one coyote was successfully removed. The number of coyote tracks decreased after the removal, but continued to be seen. On 16 May, one plover pair lost their nest in the middle of Little Beach spit to striped skunk.

June 2019: USDA staff stationed themselves between two exclosed nests on 5 Jun and removed a striped skunk after seeing it walk on the north side of the beach towards the Least Tern colony. In the second week of June, after the removal, skunk tracks were observed as well as small mammal digs at the exclosure. Coyote scat and tracks also were observed especially on the north side of the channel. Raccoon and gull tracks were observed as well. Sign suggested that mink depredated two plover nests in June. The first mink predation of a Piping Plover nest occurred on 7 Jun (Pair #1's renest, Table 5) located along the cottage beach-fronts. Pair 12 (on the spit) also lost a nest to mink between 10-11 Jun. USDA visited the beach overnight on 11-12 Jun and removed one skunk and one gray fox. Skunk continued to visit the beach based on tracks seen after the second striped skunk removal.

On 19 Jun, monitors discovered an abundance of mink tracks and several excavated diamondback terrapin nests. Later that day we discovered that a mink had very likely depredated two Piping Plover nests (Table 5) and an American Oystercatcher nest (see section below). In the final third of June, gulls resting on the Barney's Joy end of the spit began to increase and a skunk was observed by Game Camera within the plover nests and tern colony (see section below) on 20 Jun.

Pair 10 lost their third nesting attempt, with depredation attributed to a mink on 19 Jun, and Pair 19 (along the cottages) lost their nest attributed to mink on the same date (Table 5). The last week of June we observed heavy skunk evidence on the north side of the channel, gulls lurking at the ends of the spit, skunk tracks, fox tracks, coyote tracks and many mink tracks showing evidence that they continued to dig up terrapin nests.

July 2019: In the first week of July, monitors observed abundant skunk tracks, especially on 7 Jul and 8 Jul, as well as mink tracks with frequent digging, coyote tracks and dog tracks. A skunk dug under mock exclosure #3 on 5 Jul. Throughout the end of July, fox and skunk tracks were frequently observed and there were many resting gulls.

2019 Field Summary - Predators and American Oystercatchers
American Oystercatchers did not successfully hatch young at Little Beach Barney's Joy in 2019 (Table 2). Two pairs settled on the site with the first nest discovered on Barney's Joy and lasting about a month until 25 May, just prior to hatch date. On 19 Jun the American Oystercatcher nest on Little Beach was found depredated, very likely due to mink. On 23 Jun the Barney's Joy pair's renest on Little Beach was lost with coyote tracks observed nearby.

2019 Field Summary - Predators and Least Terns

Least Terns moved between the Little Beach side and the Barney's Joy side of the AP inlet. The maximum number of terns on the 18 Jun census date was 98. Tern nests at Little Beach began noticeably disappearing between 16-20 Jun when both mink and skunk were observed visiting this section of beach. Between 20-25 Jun the tern colony further dwindled from 40 to 10 pairs on the Little Beach side with another 70 adults (35 pairs) counted on Barney's. The remaining Least Tern nests on Little Beach began to disappear until, by 12 Jul, we believed they were only nesting on the Barney's Joy side. On 16 Jun there were at least 35 Least Tern nests on the Barney's Joy side and on 20 Jun there were only six. Birds on the Barney's Joy side produced only five chicks (Table 2).

Table 5. Piping Plover nest fate data; Little Beach 2019

Pair No.	Nest Attempt	# Eggs	Hatch/ Failed	Failed Reason	Supporting Evidence of Loss	Chicks Fledged
1	A	4	Failed	Unknown disturbance-likely human	Human take—nest destroyed	0
1	B	4	Failed	Eggs lost due to mink preda- tion	Predation likely--tracks at nest	0
3	A	4	Hatched	Nest hatched. 1 chick fledged	Predation suspected—tracks in vicinity of nest	1
4	A	4	Failed	Eggs lost due to end of spit erosion	Substrate collapse	0
4	B	1	Failed	Nest abandoned	Predation likely—tracks at nest	0
6	A	4	Hatched	Successful 4 chicks fledged, adopted 1 pair 3 chick	No loss	4
7	A	1	Failed	Egg lost to over wash	High tide line past nest location	0
7	B	3	Hatched	Nest hatched. No chicks fledged	Unknown—weather hampered tracking and site visit schedule	0
8	A	4	Hatched	Nest hatched. 1 chick fledged	Predation suspected—tracks seen in vicinity of nest	1
9	A	4	Hatched	Nest hatched 2 chicks fledged	Predation suspected—predator seen in vicinity of nest	2
10	A	2	Failed	Nest lost due to end of spit erosion	Substrate collapse	0
10	B	4	Failed	Nest lost due to skunk preda- tion	Predation likely—tracks seen at the nest	0
10	C	3	Failed	Nest lost due to mink preda- tion	Predation likely—tracks seen at nest	0
11	A	4	Hatched	Nest hatched. No chicks fledged	Unknown—weather hampered tracking and site visit schedule	0
12	A	4	Failed	Nest lost due to coyote preda- tion	Predation suspected—tracks seen in vicinity of nest	0
12	B	4	Failed	Nest lost due to mink preda- tion	Predation suspected—tracks seen in vicinity of nest	0
19	A	3	Failed	Nest lost due to mink	Unknown—weather hampered tracking and site visit schedule	0
Total Fledged						8

LESSONS LEARNED, AND RECOMMENDATIONS FOR FURTHER IMPLEMENTATION

a) Were Intended Project Goals And Expected Outcomes Met?

We met our intended goal to implement recommendations in the Guidance and BPs at demonstration project sites during 2019; utilizing standardized methods for assessing effectiveness developed during the 2017 demonstration project and field-testing standardized guidelines for site selection, metrics for monitoring success, criteria for evaluating and reporting results.

We managed predators at all Piping Plover, American Oystercatcher and Least Tern nests/broods at demonstration sites using many non-lethal protection measures and lethal predator management. Due to concerns about disturbance and possible impacts to oystercatchers, we were not able to deploy electric fencing in an important nesting area. Also, due to unfavorable weather and other constraints, we were not able to target all individual predators that were suspected to be impacting the nesting birds.

Although Piping Plover hatching success increased in 2019 at Little Beach compared to 2018, fledging success was lower due to a rotating suite of mammalian predators (Table 2). American Oystercatcher and Least Tern productivity was also limited by predators, despite extensive efforts to control crows and remove coyotes, skunks, and foxes.

Fledging success for Piping Plovers was markedly higher on Dead Neck Sampson's Island in 2019 compared to 2018 (400% increase). However, this was a result of the reproductive performance of four pairs (out of nine). American Oystercatchers nested for the first time in seven years on DNSI, probably as a result of major habitat restoration that took place in winter 2019. However, the pair was unsuccessful probably due to coyote predation. A large Least Tern colony was also likely impacted by coyote predation at the site. Crow predation of eggs decreased in 2019 as a result of predation management efforts; egg losses attributed to crows were half of losses in 2018 when crows were not controlled. Coyote removal from the island in 2019 was not successful and t greatly reduced the nesting success of all monitored coastal birds.

Our work has served as a case study for implementation of the Guidance and BPs for on-the-ground management. Through our reporting, and in coordination with partners, we are informing users who are considering implementing it at their sites, providing information on effectiveness, and suggestions for improvement and future work needed to continue to advance usefulness of the guidance tools.

b) Most Important Management Implications Of The Project

Future predator management, including predator removal, is strongly recommended for Dead Neck Sampson's Island as 7 of 11 plover nest failures were attributed to predation. It is recommended that similar practices to those used in 2014-2017, and 2019 be utilized. Monitors should continue to practice a "hands-off" approach to nest and brood checks, keeping clear of the birds and leaving as little trace of presence as possible (such as walking below the tide line whenever possible) so as not to attract predators drawn to human activity into the area. Trash should also be collected whenever possible and visitor encroachment into nesting areas should be prevented through patrolling and outreach from walking through or near nesting birds.

An American mink (Neovison vison) in a predator exclosure. Chelsea Weithman

Mock exclosures should be constructed and continually utilized in future seasons to reduce crow impact on Piping Plovers, Least Terns and American Oystercatchers. In addition to monitoring crow and coyote presence on the island, the presence and distribution of all possible predators (including species not previously known to have impacted shorebirds at the site) should continue to be quantified. Our 2019 work found that the use of trail cameras can aid in this process. The image data from cameras will allow another level of analysis on the island for both predators and human disturbances. Camera images can assist in verifying specific predator species as well as identifying humans in fencing or other prohibited activities. It is recommended that use of cameras be continued in the coming years.

Electric fencing should be erected in coming years as Least Tern nesting continues to grow due to newly restored areas from re-nourishment/dredging project that will continue to be taking place during the next two years. This fencing will aid in the prevention of coyote depredation that we saw in the 2019 season. Fencing should be erected early in season (early-mid April) to minimize disturbance to nesting birds.

At Little Beach/Barney's Joy, we faced some minor challenges with the operation of the game cameras. Prior to future field deployment, we will establish a clear protocol with trouble-shooting solutions to follow so that every technician is able to restart the different cameras after changing out SD cards. The shifting nature of the predator community posed another challenge. In particular for 2019, mink arrived in force at the end of the nesting season. We will update the list of predators approved for removal based on this season's evidence. We will also speed up communication channels to expedite the decision-making process.

c) How Did The Guidance And BPS Benefit the Work?

The Guidance and BPs benefited our work in significant ways during the 2019 nesting season. In particular, we:

- Undertook year-round, systematic surveys (point counts) to quantify predator presence on Dead Neck Sampson's Island. This practice allowed us to better time predation management activities and complemented the other predator identification methods we are used (such as tracking) as outlined in the Guidance and BPs.
- Deployed game cameras in strategic locations to answer specific questions at both demonstration sites.
- Engaged in a collaborative project with other demonstration project partners to document camera methodology to assist in expanding the guidance document
- Adopted a new data collection tool to computerize daily productivity data and streamline submission of data to state agencies and partners. Having daily survival rates assists in estimating actual productivity measures.

d) Summary Of Lessons Learned &/Or Things To Change In Future Field Work

In future field work, we will take advantage of new information on camera methodology to develop a standardized protocol for use at all Mass Audubon-protected nesting sites where cameras are indicated. In addition, we will work to have our decision-making response to predation events be flexible and based on a clear, agreed-upon strategy. Finally, we will develop an approach to electric fence use that is field-tested and agile in order to protect newly available nesting habitat for oystercatchers, terns and plovers; this will be an important methodological focus in 2020 at both Dead Neck Sampson's Island and Little Beach Barney's Joy.

e) Suggestions About How The Guidance And Best Practices Might Be Improved Or Altered

- We recommend that information on the possible outcomes of using exclosures be elaborated. The Roche et al. citation (p. 80) is not referenced (Methods of nonlethal control DB4.2; p 40) in regard to probability of adults being predated at exclosures; this is a key area of concern. Similarly, experiences managers have had on Martha's Vineyard with chicks lost immediately after hatching and emerging from exclosures is reported on page 51, but not included with the main exclosure discussion. The risk of chick loss is not included in the PiperEx decision-making tool, but the documented loss of 1-2 day old chicks at exclosures at many sites in Massachusetts is a strong disincentive to using exclosures under certain circumstances. PiperEx does not comprehensively accommodate the disproportionate impacts of adult mortality and chick loss (i.e., total nesting season failure with little expectation of re-nesting if chicks are lost) on the decision to use exclosures. Finally, information on the recommended practice to check adult activity at exclosures daily is not provided, nor is this time commitment discussed as part of the decision-making process when considering use of an exclosure in any given situation.

- The use of effigies to deter crow activity in nesting habitat is mentioned, but no references are provided.
- The effect of using lasers to repel predatory species is mentioned, but possible impacts to beneficiary species is not discussed.

Implementing predator control programs will help Piping Plover chicks flourish. ©Ray Hennessey, www.rayhennessy.com

Guidance for Using Cameras to Improve Predation Management at Shorebird Nesting Sites

Developed by Katharine Parsons, Hope Sutton, Alex Wilke, Sarah Karpanty, and Caleb Spiegel
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PROJECT BACKGROUND

In Summer 2019, the National Fish and Wildlife Foundation-funded Guidance and Best Practices for Coordinated Predation Management to Benefit Temperate Breeding Shorebirds in the Atlantic Flyway (Guidance and BPs) was published on the Atlantic Flyway Shorebird Initiative website (https://atlanticflywayshorebirds.org/). The Guidance and BPs synthesized interviews with managers and scientists along with published and gray literature on all aspects of predation management. The use of camera technology was reviewed and recommended for use within Best Practice 1: Identifying Beneficiary Species and Predators for Management and Best Practice 2: Identifying Strategies, Triggers and Priorities for Lethal and Nonlethal Management. Cameras also can be a critical tool to inform guidance in Best Practice 8: Monitoring, Measuring and Reporting Effectiveness to ensure that implemented management practices are adaptive.

The use of cameras is supported by information from literature review and expert knowledge in the Guidance and BPs, and broad guidance is provided in the document on their use in the field. However, no comprehensive and synoptic resource currently exists that provides specific methodological details on how to design, implement and analyze a camera-based project to benefit shorebird predation management programs. Such a resource has been identified by several Atlantic Flyway shorebird managers as a priority. In spring and summer 2019, three additional demonstration projects were conducted in North Carolina, Virginia, and Massachusetts as an outgrowth and testing of the concepts in the Guidance and BPs. All three of the projects used cameras as a tool for assessing and improving their predation management practices. As part of this work, demonstration project leads, in partnership with Virginia Tech and the US Fish and Wildlife Service worked together to outline and begin to compile information for a "Supplemental Guidance" document, which if completed can serve as a complement to the Guidance and BPs.

Project Outcomes

Here we present an initial outline, developed collaboratively by demonstration project partners, for a comprehensive guidance document that could be developed with additional resources. We have also compiled and presented experiences, lessons learned and recommendations regarding the design and implementation of camera projects to benefit predation management. We stress that the work is not, in and of itself, a synthesis document, but rather an outline and summary of project-based information that could guide and provide information for a future effort.

Next Steps

Project partners generated a comprehensive outline of information needs that should be considered when developing a field project using cameras in shorebird nesting habitat for management and/or research (Section A). This outline can serve to structure content for a future guidance document that synthesizes available published and unpublished information for managers that want to use cameras to improve management. In addition, the three demonstration projects provided extensive information on details and logistics in collecting image data and data management at their sites, that may aid other managers in camera study design (Section

B). Insights provided by demonstration projects on study design and analyses are site specific, and should not be considered exhaustive or prescriptive. Effective step by step guidance on these topics will require extensive additional work, especially considering the array of often diverse monitoring and management objectives across sites and seasons.

This outline and associated project-based insights provide an important initial contribution towards a comprehensive supplemental guidance document for improved camera use in shorebird management and conservation. We suggest that the material could serve as the basis for a future multi-AFSI partner funding proposal that aims to continue collaborative work toward development of a supplemental camera guidance document. Demonstration project partners that worked on this document (see names and e-mail addresses below) have expressed interest in assuming an organizational role in future work, including co-developing funding proposals, and encourage partner collaboration in these areas in the near future.

American Oystercatcher adult feeding chick. ©Ray Hennessey, www.rayhennessy.com

SECTION A - OUTLINE OF INFORMATION NEEDS FOR CAMERA USE IN PREDATION MANAGEMENT

1. Setting objectives: hypothesis testing (e.g., characterizing predator communities, assessing causes of nest failure, assessing causes of chick loss)

2. Study design: camera spacing/density, field of view, numbers of cameras and period of operation, still versus video data collection, time lapse versus motion-triggered, white-flash versus infrared, remote download versus physical check

a. Camera equipment
- Brand/expense guidelines
- Minimum specifications (field of view, photo/video quality, trigger speed)
- Batteries (rechargeable vs. non)
- SD cards

b. Data collection protocols
- Still (single vs. multi-shot) versus video
- Time lapse versus motion-triggered
- Flash considerations (e.g. white-flash versus infrared)
- Night vision
- Download options (i.e. manual/physical versus remote options)

c. Field installation
- Field logs
- Number of cameras and spacing
- Height and proximity to target (including avoiding unintended targets)
- Perching deterrents
- Locks and security

d. Checks and maintenance
- Field logs
- Battery life and camera fail checks
- Memory card replacement
- Supplemental field materials (keys etc.)

e. Adaptive management (including trouble-shooting)

f. Data processing and management
- Image review methods
- Data interpretation
- Database configuration and entry
- Data sharing
- Time considerations

3. Analytical approaches

a. Determining return on investment

b. Assessing predator management effectiveness vs. other management actions

4. Reporting

5. Additional resources

SECTION B - INSIGHTS, LESSONS LEARNED, AND RECOMMENDATIONS ON CAMERA USE FROM THREE 2019 DEMONSTRATION PROJECTS

(III) NORTH CAROLINA DEMONSTRATION PROJECT

Project Title: Using guidance and best practices to inform and assess predator removal efforts to support nesting success of American Oystercatchers on Masonboro Island, North Carolina

Organization: North Carolina National Estuarine Research Reserve; Hope Sutton suttonh@uncw.edu

1. Setting Objectives

Project Objectives and Approach: Coordinated breeding season surveys since 2013 have consistently shown that Masonboro Island hosts approximately 10% of North Carolina's oystercatcher nesting population, ranging from 33 – 40 nesting pairs each year. Low average annual reproductive rate was used as a trigger to determine that predator management should be implemented to support conservation goals. Selective use of wildlife cameras on American oystercatcher nests during the 2017 project improved understanding of causes of nest failure and resulted in more accurate identification of predator species. 2019 project goals and expected outcomes included: 1) improve identification of causes of nest failure due to predation; 2) increase effectiveness of predator management and protection of nesting shorebirds; 3) develop site-specific approach to assessing causes of nest failure informed by comparisons of camera results with field observations and comparison of camera types and settings; 4) contribute to development of a supplemental camera guidance document; 5) support conservation goals for shorebirds within the Atlantic Flyway; and 6) prepare for data analysis to support assessment of predator management efforts. Wildlife cameras were deployed on 17 nests to support assessment of causes of nest failure and document predator presence and activity levels between May 1, 2019 and July 31, 2019. Two-camera arrays were deployed 2 feet above ground level 3 meters from each nest.

2. Study Design

a) Camera Equipment:

- Recoynx – Hyperfire Semi-Covert IR cameras were used for still pictures during the 2019 season on Masonboro Island, NC. This model has a motion detection range up to 30m but the temperature of the triggering source in relation to ambient air temperature can affect triggering, so smaller targets farther away from the camera location may not effectively trigger the camera.
- Bushnell – Trophy Cam HD Aggressor cameras were used to collect continuous video during the 2019 season on Masonboro Island. Detection distance is up to about 30m.
- Both cameras use AA batteries - Recoynx takes a maximum of 12 batteries and Bushnell uses a maximum of 8. It is not necessary for all the batteries to be installed for the camera to operate properly, but to ensure a longer deployment without missing data, the maximum number of batteries was installed. Rechargeable batteries were not preferred due to reliability issues, especially in extreme temperatures.
- Most cameras are set up to include a date/time stamp on the captured image. Cameras should be formatted with correct time and date to support image processing and cataloguing. Blank 32 GB SD cards were used and allowed for adequate data storage space between maintenance opportunities. SD card size needs to be appropriate to study design and maintenance schedule to ensure images are not lost. Labeling SD cards and utilizing several storage containers to keep cards organized when moving between field and lab supports good image management.
- Based on the budget available, image quality needs to be balanced with the number of cameras needed to complete the study. For some studies, a greater number of lower priced cameras may end up being more useful than a smaller number of higher priced cameras.

b) Data Collection Protocols:

- Study design will be dependent on objectives. To assess predator presence and activity levels, cameras may be installed across areas of use based on visible predator sign and spaced evenly to provide as much coverage as possible based on the number of cameras available. At the NC site, we evenly spaced 40 cameras across the 8-mile length of a narrow, linear habitat, alternating camera orientation east or west, creating a grid layout. When utilizing cameras to assess causes of nest failure, we installed cameras 3 m away from and pointed directly at nests.
- Due to the remoteness of the NC site and difficulty getting to cameras to switch out memory cards, motion activated settings were utilized. In most cases, using time-lapse setting will result in a far greater number of images than using a motion trigger setting. Depending on the study goals, it may be appropriate to use time-lapse, but retrieval of data storage cards needs to be planned accordingly to ensure data is not lost due to cards becoming full.
- Although it is a camera intensive approach, a two-camera array consisting of one camera set to capture still images and one camera set to collect video resulted in the most reliable capture of activity resulting in nest failure.
- Motion activated cameras with night mode set for infrared flash rather than white-flash were used in NC with good results at nests. IR appears to result in little to no disturbance of mammalian predators at night, although images are of generally lower quality with some blurriness and color distortion; white flash may be more appropriate if higher quality images are preferred.
- Although it can result in higher numbers of images of non-targets (i.e. wind-blown vegetation) being captured, sensitivity was set to “high” for both cameras to reduce the likelihood of failing to capture a target organism. Video was set to 1280 x720 HD video size at a 5 sec interval, which resulted in high quality videos but small enough files to manage. Still picture cameras were set to “3” pictures per trigger with a 1 second wait time between pictures. Cameras were set to 1080P resolution with no delay between triggers and “balanced” night mode, resulting in good quality images and reliable capture of predation events.

c) Field Installation:

- For nest monitoring, cameras were installed by one or two field staff, typically the day after a nest was located. When possible, cameras were installed during the coolest part of the day to avoid disturbance related impacts to eggs being left unattended.
- For nest monitoring, we installed cameras 3 m from the nest at 0.5 m off the ground. Due to the lack of trees in our barrier island habitats, metal cable locks were used to secure cameras to 4’ steel U-channel posts. Posts were buried approximately 0.75 m into the sand and included a small metal bar anchor near the base of the post to deter theft. Bungees cords were also used to secure the camera and ensure camera angle stability. The NC site has a fairly low level of human activity in nesting areas, so theft of cameras was not a major consideration. In areas where theft is more likely, additional deterrent measures may be needed, including camera lock boxes or more significant anchoring devices.
- In NC, signage is attached to cameras to deter theft. Signage reads: property of the state, camera is equipped with GPS tracking device, wildlife camera research project - do not disturb. Because the site is a research reserve, most visitors are aware of the research studies that occur and we rarely have theft or vandalism of research equipment.
- Cameras should be labeled with a unique identifier (letter/number code) and used for records per camera detailing deployments. Other data that should be recorded for camera deployments includes: dates, locations, orientations, any variance in height and distance from target, settings, and operational malfunctions or issues.
- Ensure consistent angle and distance from target to support image comparison. Take orientation into account when installing cameras to ensure images are not overexposed (direct and seasonally declinated east and west not recommended).
- Ensure area between camera and target is free of accidental targets that could trigger the camera (waving plants can result in quick consumption of storage card and battery power).

d) Checks and Maintenance:

- Development of a field checklist is recommended to ensure that all needed supplies and equipment are packed prior to leaving for the field. Our field checklist for camera installation and maintenance includes new batteries, spent battery container, lens cloth, bungees, SD cards, GPS unit, padlock key, padlocks, lubricant spray, folding shovel, cables, cameras, camera signs, field notebook, pencils, u-posts, measuring tape, multitool, sandpaper. The technician can quickly scan down the list and double check that the needed supplies are packed, based on the plans for the day.
- New cameras should be tested prior to field deployment to ensure proper operation.
- Most cameras have an indicator of battery power (% charge remaining) on the display. Although we found that these readings were not always reliable, we changed out batteries during maintenance checks if battery power was below 60%. Technicians kept a stock of new batteries and a container for separately storing spent batteries in their packs at all times.
- All issues or instances of faulty operation should be recorded in the field log immediately to avoid lost information regarding failure of cameras to capture desired information. Particularly if a large number of cameras are deployed across a large area, all details of every deployment should be recorded in writing to inform later data analysis.
- For cameras deployed at nests, camera operation and battery levels should be checked following observation of nest/chick status. All batteries should be replaced if battery status is below 60% to ensure that predation events are not missed due to battery failure. Camera checks should be done as rapidly as possible to avoid temperature and disturbance related impacts to eggs and chicks.

e) Adaptive Management (including troubleshooting): No information provided

f) Data Processing and Management:

- Image review methods:
    - If large numbers of cameras are used, manual processing of images may be prohibitively time intensive. However, for studies using smaller numbers of cameras or for studies where termination of camera use is staggered, such as in nest fate studies, manual review of images and short videos is manageable.
    - If video is used, setting to short (5 sec) video segments results in manageable review.
    - Each image should be reviewed and cataloged, noting all images that contain predators and predation activity or unusual behavior.
    - In NC, images containing human activity are noted in the image catalog but image data is not retained due to concerns about privacy.

- Data interpretation:
    - Occasionally, images are challenging to interpret. Animal images can be incomplete or obscured by darkness or other environmental factors. Weather conditions can further complicate identification. Data cataloging should allow for images to be noted to the finest taxonomic level possible, without speculation, assumptions, or best guesses (i.e. 'mammal, unknown').

- Database configuration and entry:
    - A consistent naming convention should be used for all images. This convention should include nest number, camera number, and date. Defining consistent coding in advance for cataloging content of images to include factors that will be analyzed will save time when analyses are undertaken at the conclusion of the field studies.

3, 4, 5. Analytical Approaches, Reporting, Other Resources: Not yet developed

(II) VIRGINIA DEMONSTRATION PROJECT

Project Title: Using cameras as essential tools for managing American Oystercatchers and Piping Plovers on Metompkin Island, Virginia

Organization: The Nature Conservancy Virginia Coast Reserve; Alexandra Wilke awilke@tnc.org

1. Setting Objectives

Project Objectives and Approach: Managers have recently recognized the need for a re-evaluation of the predator communities and the extent to which they are limiting the reproductive success of shorebirds relative to other factors (i.e., flooding and habitat loss related to island change, sea-level rise, storms) at some sites in coastal Virginia. This information is essential for managers to effectively implement adaptive predator management in a highly dynamic and complex coastal system where the conditions and variables that impact nesting shorebirds change over time. Metompkin Island, located within the Virginia barrier island chain, presents a current scenario where this adaptive management approach is needed to guide current and future management activities. Metompkin is remote and difficult to access, and consequently, shorebird monitoring is typically conducted on a weekly basis which does not allow for precise documentation of all the factors limiting reproductive success. With this demonstration project, we addressed the need for a current assessment of other potential predators at the site to benefit nesting shorebirds, as well as colonial waterbirds and other wildlife such as diamondback terrapins. Our primary objectives for this demonstration project were to: 1) characterize the predator community impacting nest success of American Oystercatchers (AMOY) and Piping Plovers (PIPL), 2) calculate hatching success using field observations and camera observations and evaluate the differences, 3) document causes of nest failure, and 4) test two novel techniques for using cameras to identify causes of chick loss for AMOY. Our approach included: 1) deployment of cameras at 27 active AMOY nests, 2) cameras at 28 active PIPL nests ('nest cameras'), 3) 11 cameras focused on specific AMOY brood-rearing areas ('brood cameras'), and 4) 7 cameras in a transect fashion allowing for wide-angle visual monitoring of known oystercatcher brood-rearing areas ('transect cameras').

2. Study Design

a) Camera Equipment:

- Brand/expense guidelines:
  - In 2019, TNC deployed two brands of cameras on Metompkin Island to characterize the predator community at the site and document causes of nest lost for Piping Plovers and American Oystercatchers and chick loss for American Oystercatchers. Cameras were deployed as 'nest', 'brood' or 'transect' cameras.

    i) Nest and Brood Cameras: Blaze Video cameras, 16-megapixel. We opted for less expensive cameras due to the quantity needed vs. available budget and decided that the specifications of these cameras would meet our needs. We recommend carefully considering project needs and matching that with an appropriate camera versus buying equipment that is more expensive/ sophisticated than what is required.

    ii) Transect Cameras: PlotWatcher 6 Pro time-lapse cameras, plus one Brinno MAC200DN. These cameras were chosen because they were true to 1s intervals (which we did not find in other brands). We wanted these cameras set on time-lapse at 1s intervals to best capture predation events while not using as much battery and storage as video.
  - Caution that many components of different camera brands are the same components packaged differently with different software.

- Minimum specifications (field of view, photo/video quality, etc.):

Setting up camera equipment on a Virginia beach. TNC

  - Remember that field of view specs are based on a certain distance from the camera, which is not always specified by the manufacturer. We recommend field tests prior to deployment to make sure project needs will be met.
  - Caution that when considering time-lapse capability of a camera (time-lapse interval, reset interval, night time capability) product descriptions are not always accurate, i.e. actual capabilities fall short of advertised capabilities. For example, an advertised time- lapse interval of 1s may in fact not be possible.
  - Caution against assuming that higher megapixel ratings on cameras means higher quality photos. Most ratings are interpolated (enhanced via software) versus native resolution. Higher ratings do not necessarily mean more detail when zoomed in. Recommendations are to test images/video from different cameras and not rely solely on advertised megapixel ratings. https://www.trailcampro.com/pages/5-most-common-trail-camera-myths
- Batteries:
  - Environmental variables WILL impact battery function and must be considered when planning a project.
  - We attempted using a pre-fabricated solar kit (battery box with solar panel) with 6V, rechargeable acid sealed batteries sold separately (voltage varies depending on camera specs) to minimize battery waste and reduce required battery changes and disturbance at the site. We determined that the solar panels were generating 9V in direct sunlight which fried some cameras. We recommend trying to use solar panels if possible to reduce battery waste but field testing set up prior to deployment. Note that a solution could have been to cover the panel partially to reduce the amount of voltage generated.
  - We adapted and used the 6V batteries alone and/or AA alkaline batteries. We did not attempt rechargeable AA batteries because of prior experience with poor performance.
  - Caution about proper and safe storage of all batteries, especially acid sealed batteries. Do not store in vehicles or other areas that reach extremely high temperatures; instead store in climate-controlled areas with a partial charge.

- SD cards:
  - We used PNY 128GB SD cards formatted from xFat to FAT32.
  - The majority of trail cameras only accommodate the use of 32GB SD cards because the cameras only read the FAT32 format and are unable to read the higher capacity SD cards (eg. SDHC, SDXC).
  - We opted to use a free program available online to change the format of the higher capacity SD card to FAT32. This allowed us to reduce the number of camera checks needed to change SD cards.
  - We recommend using the fastest read/write speeds available to reduce transfer time.
- Mounting:
  - We used a DIY mounting bracket solution that was a quarter of the price of buying an

accessory mounting bracket from the manufacturer. Components included:

i) Eye bolts, 0.25 " x 3" stainless steel - 2 per camera
ii) 0.5 " flat washer, 1 - 0.25 OD 0.062 thick - 2 per camera
iii) 0.5 - 13 x 1.5 hex head bolt - 1 per camera
iv) 0.5 - 13 hex finish nuts - 2 per camera
0.25 - 20 hex finish nuts - 4 per camera

- We mounted the brackets with cameras on U-channel posts with pre-drilled holes for the mounting bracket and could be easily deployed in the sandy, beach environment. Occasionally, posts were difficult to remove due to obstructions underground but were generally easy to deploy and remove.

- General tips:
  - Careful consideration of project objectives will inform required camera technology and settings (e.g., time-lapse intervals, still photo vs. video, reset time, mpx, etc.)
  - We recommend field testing a small number of cameras prior to purchasing total number needed and prior to deployment for a few days up to multiple weeks to verify camera specifications, test battery life, etc.
  - When meaningful, we recommend considering ways to reduce the frequency of camera checks by using solar power kits for rechargeable batteries and high capacity SD cards. However, we caution that infrequent camera checks will also reduce your ability to detect problems and ability to troubleshoot.
  - We recommend careful consideration of the ideal frequency of camera checks to minimize disturbance and still meet project objectives. Cellular cameras should be considered if connectivity and budget allows.
  - We decided that a simple deployment with no concealment or other material used to camouflage the cameras was best for our situation and site (see c. Field Installation below for notes on birds returning to incubate after nest cam deployment) but recognize that different conditions at different sites may warrant more effort to camouflage equipment. See also notes on installation.
  - The use of perching deterrents should be carefully considered and employed when safe and possible.
  - We recommend labeling each camera and SD card with individual ID numbers to be used for tracking during data collection.

b) Data Collection Protocols:

- Still versus video:
  - We opted to use still photos as opposed to video because of storage, battery life and review time considerations.
  - Note that some cameras (like the Plotwatcher and Brinno brands that we used) set on time-lapse photos provide an output that is the still images stitched together into video format - reducing editing time but still allowing for extracting individual frames through the software.

- Time-lapse versus motion:
  - We employed both time-lapse and motion detection settings during our project to meet different project objectives (nest vs. brood vs. transect).

    i) Nest and brood cameras were set to motion detection with three images per trigger and a reset time of 5s.

    ii) Transect cams were set to time-lapse at 1s intervals. Night vision was not an option on these cameras. We considered combining LED light with no flash on these cameras which proved prohibitive due to battery life.

- Motion detection cameras were set at high setting to reduce the chance of 'missing' events but likely resulted in many false positives (i.e., photos triggered by vegetation, slight movements of incubating birds, etc.).
- We recommend that careful consideration be given when choosing between time-lapse and motion detection for a project, acknowledging that: 1) motion detection may produce photos more directly tied to events of interest but may also result in missed events and/or many false positives, 2) time-lapse interval settings needed to document unpredictable events like predation events are very small and will result in large numbers of photos to be processed.

- Flash considerations and Night Vision:
    - We highly recommend using no-glow/black flash cameras that transmit infrared light above the 940nm spectrum to avoid potential disturbance or attractants at deployment site. White flash and low glow flashes will produce better quality images but the flashes will be visible to other animals, including birds. Be aware that manufacturers may have different definitions or names for no-glow so careful attention needs to be paid to the actual specifications.
    - Caution that the flash distance on no-glow cameras is limited (e.g., 120 ft with white flash and 80-85 ft with no-glow) so careful consideration should be given to project objectives and weighing the pros and cons of no-glow versus white flash or low-glow. We recommend field testing prior to deployment.

c) Field Installation:

- In the context of cameras being deployed in and around active nesting areas, we recommend limiting installation time as much as possible to reduce disturbance and limiting general activity in proximity to nests (e.g., number of people, physical disturbance around nest site, etc.).
- We recommend recording data on installation duration and, for nest cameras, the time until incubation resumes. We also recommend protocols that emphasize the importance of confirming that incubation resumes and setting time limits for abandoning installation if birds do not return, acknowledging that these limits will vary depending on environmental conditions, site conditions and stage of nesting attempt. For example, we had the most challenges with AMOY returning to incubate early in the laying stage.

- Field logs:
    - We used Collector for ArcGIS to record all information related to camera deployment, camera checks and associated productivity monitoring of nesting species. This mobile data collection app allows for multiple users to access and edit information in real time, enabling easier data sharing and increased efficiency of field work. Collector also allows the user to navigate to and from deployment and nest sites.
    - Users can build customized data layers within the app to meet project needs. Access for building layers requires a publisher license through ESRI (subscription required) which may be available through some organizations and/or agencies. Access for adding/editing data to existing layers only requires a user license sent via an invitation. Smaller groups without access could benefit from larger organizations that have access by being sent an invitation for a user license. Details may vary by subscription. Similar products exist (e.g. EpiCollect) that are free.

- Spacing, height and proximity to target:
    - We recommend carefully weighing the pros and cons of height and proximity to target

decisions for nest cams. Higher cameras may allow for better visuals of nest contents but may also better attract perching predators and/or attention from visitors. Cameras deployed closer to nests will provide clearer photos of the nest site but may prevent birds from returning to incubate.

- Specific protocols for the height and proximity to target for nest cameras will likely vary by site and by species. For example, birds more acclimated to human activity and disturbance may tolerate cameras deployed closer to active nests. During our project, Piping Plovers tolerated the cameras better than American Oystercatchers and returned to incubate faster. This allowed us to deploy cameras closer to nest. Our protocol included the following:

  i) Nest cams were deployed ~1ft above the ground, 3-6 meters from the nest.

  ii) Brood cams were deployed ~3ft above the ground in close proximity to observed brood location.

  iii) Transect cams were deployed ~3ft above the ground approximately 40m apart, parallel to a predetermined marsh edge.
- When deploying cameras, carefully consider the direction of the camera so as to avoid the rising and setting sun. If using solar panels, consider the direction related to the sun path while avoiding sunrise and sunset.

- Perching deterrents:
  - We did not use perching deterrents on the cameras. We decided that the low profile of the nest cameras would limit their use as perches by avian predators and we were also concerned about the potential danger to researchers and visitors (i.e. sharp objects deployed low to the ground). However, we did document frequent use of the cameras as perches and recommend that perching deterrents should always be considered when deploying cameras.

- Locks and security:
  - The remote location of our site did not warrant any locks or security measure for our project. We did document visitors looking at cameras, taking photos of cameras, etc. but did not experience any vandalism.
  - By not concealing our cameras, we potentially attracted curious visitors to the nest site to look at the camera. However, with the remote location and low visitation we did not think the additional disturbance of adding locks or other security measures was warranted.

- Other supplies:
  - We recommend maintaining a checklist of all field supplies required, to be cross-checked prior to each site visit.
  - Other supplies for our project included: beach cart, camera bag, mallet, wrenches for set up (3 needed, including adjustable wrench - could have used wing nut to decrease the number of tools needed), toolbelt to keep all tools and keep from setting down anything on ground.

d) Checks and Maintenance:

- Check and double check that you have all equipment prior to field site visits.
- On each visit, replace SD cards. The frequency of battery replacement will depend on project specifics and logistics. We recommend reducing disturbance to the site and battery waste when possible by developing a threshold for changing or not changing batteries that is based on your

project specifics (frequency of camera checks, number of photos being taken, use of flash, etc.). For example, our protocol specified that batteries were changed if they were at 50% capacity or less during the camera check.

- We recommend that when removing photos from SD cards, cards are not reformatted unless using a formatter program, despite general best practice protocols that call for reformatting between deployments to defragment the card.
- We recommend that you do not preview photos from devices other than the computer to which you intend to transfer the photos (e.g. digital camera). This can corrupt the card and prevent the ability to download photos. Adapters are available to safely preview photos or look to purchase a trail camera with an internal viewer. https://www.trailcampro.com/pages/5-most-common-trail-camera-myths
- To avoid loss or damage of cards and photos, we recommend that when possible photos from SD cards be transferred to their storage location (computer, external hard drive, cloud) the same day that they are retrieved from the field.
  - The amount of storage space needed for the anticipated number of photos from a specific project must be carefully considered. Solutions may include local servers, external hard drives or online cloud storage. Consider the ability for multiple users to access the data simultaneously.
  - We caution that downloading SD cards can be a time intensive process that will vary depending on variables such as the speed of the card, card readers, ports, number of photos, computer RAM, etc. These details should be considered when planning project logistics. Multiple SD card readers can allow for downloading multiple SD cards to the same computer simultaneously. Some single USB/multiple port readers are available but download cards separately. More expensive single USB/multiple ports with simultaneous download are also available.

e) Adaptive Management (including troubleshooting):

- We noted the impact of insects on visibility on some cameras under certain environmental conditions and dirt on camera lens. This appeared to be more of a problem closer to the marsh.

f) Data Processing and Management:

- Recommendations for programs and software available to manage and facilitate data processing are likely to change rapidly as new products are created. At the time of this report, we recommend that anyone beginning a camera trap project begin by reviewing the following paper: Young et al. 2018. A variety of options exist for software that facilitates cataloging, reviewing and processing photos and should all be considered in the context of specific project objectives and needs. In some cases, the utility of the programs may be limited due to requirements of pre-existing expertise (e.g., R statistical software), cost or limits on number of photos.
- During project development and before beginning photo processing, we recommend a thorough thought process about specific project objectives and exact metrics that need to be extracted from the photos. Only then can an appropriate and efficient process be configured. We caution that photo processing is time intensive and clear objectives need to be set.
- We used a basic photo processing software (Picasa) to review and 'star' photos of interest based on our objectives of documenting disturbance (birds leaving nest) and predation events. The ability to star photos allowed for filtering those photos and facilitated data entry.
- We opted to manually organize photos and enter observations of interest into an Excel database. Careful organization of the photos allowed for multiple users to quickly access needed information and accounted for all attributes associated with the camera.

- Data interpretation:
  - Recommend multiple observers review any photos that have questionable interpretation, e.g. difficult identification of an animal.

    - Photos should be stored and cataloged for easy access by multiple observers.

- Database configuration and entry:
    - To meet our project objectives, wecorded disturbance and predation events from images collected on nest and brood cameras.
    - We maintained an Excel database with records of noted events for each nest and also kept general notes of interest about camera deployment or nesting attempt that would not be captured under a predation or disturbance event (i.e. problems with camera, missing photos, notable hatch dates, etc.). The database included hatch success information from field observations and camera observations.
    - Starred photos were captioned with event description and then tagged as ‘entered’.
    - Transect cameras photos were not yet reviewed at the time of this report.
- Data sharing:
    - The ability to share data between multiple users should be considered when establishing a data processing and management protocol. Remote desktop connections can allow multiple users connected to the same network to access the same files, although only one at a time. Cloud based systems can allow simultaneous access by multiple users but may incur additional costs if not available within an organization or agency and/or may be restricted by the quality of internet connection. Some of the software programs available as discussed above allow for web access to databases and multiple user access at the same time (e.g. Camelot).
    - Collector for ArcGIS is a good solution for multiple user access to active databases.

- Time considerations:
    - Camera trap projects can be very time intensive. We caution project managers to fully account for the time required to review photos, extract data and meet objectives. We maintained an excel file to record the time spent reviewing photos and track progress with what photo files were reviewed. This enabled an assessment of time commitment as well as allowing for multiple people to pick up on photo review without having to double check progress to that point.
    - Note that processing time will vary depending on skill level and experience of observer.

3, 4, 5. Analytical Approaches, Reporting, Other Resources: Not yet developed

(I) MASSACHUSETTS DEMONSTRATION PROJECT

Project Title: Managing shorebird predators amidst the beach-going public: evaluating camera use and other best practices

Organization: Coastal Waterbird Program, Mass Audubon; Katharine C. Parsons kparsons@massaudubon.org

1. Setting Objectives

Project Objectives and Approach: High egg and chick predation resulting in low productivity is one of the largest threats currently facing American Oystercatcher and Piping Plover in Massachusetts. Additionally, shorebird nesting in the state occurs in a human disturbance spectrum ranging from urban sites to suburban community beaches to relatively undisturbed beaches under conservation management. Although beach recreation is thought to have a large negative impact on nesting shorebirds, the mechanisms driving this relationship are complex, and there is little guidance on effective management practices to mitigate predator impacts within the context of human recreation. We collected image data (time-lapse during daylight hours; motion-detected images at night) with trap cameras at nesting sites with varying levels of recreational use to investigate possible relationships between disturbance and predation events. We deployed cameras to record activity in habitat with active shorebird nesting (cameras were not focused on nests) to evaluate the efficacy with which cameras can document both human disturbance and predator activity, and to explore possible relationships between both.

2. Study Design

a) Camera Equipment:

- In 2017 and 2019 Browning Recon Force Extreme trail cameras were used by Mass Audubon on Dead Neck Sampson's Island. The cameras have an 80 ft detection range and produce 20-megapixel images. The trigger speed of the cameras is 0.4 seconds when using the motion activated option.
- The cameras take eight batteries. It is recommended not to mix battery brands and to not mix old and new batteries. It has been found that rechargeable batteries do not last as long as regular batteries so they should be used with caution.
- Choosing the correct SD card is a vital step for using the camera successfully. It is recommended that new SD cards are purchased for each season as internal damage that occurs over a season may not be obvious. For Browning game cameras, Browning, SanDisk or Kingston SD Cards are recommended. It is best to use a class 10 SD card as it will be able to transfer the most digital information per second. The class number can be found on the front of the SD card with a circle around it.
- All SD cards should be formatted before being used in the field. For Browning cameras this can be done by inserting the SD card into the camera locating Delete All in the Setup Menu and selecting Yes. SD cards can also be formatted on a computer.
- It is highly recommended when taking an SD card into the field that it be secured in an SD card case to prevent damage. Keeping sand from entering the cases is imperative as this can quickly damage SD cards. A variety of cases can be purchased ranging from plastic to cloth.
- A lock box will not only protect the game camera from the elements but deter theft as well. Confirm the lock box will fit your specific camera dimensions before purchase. A lock box that has a padlockable design (a small hole at the bottom of the lock box) is encouraged for extra security.

b) Data Collection Protocols:

- Both still cameras and video recorders are advantageous to conservation research. However, photos are the easiest to collect as still cameras they take up less storage space on SD cards and use less battery power. Videos that are taken at nighttime are often of poorer quality but could be beneficial to document predation events by nocturnal predators.

- Using time-lapse to document daytime activity eliminates the risk of a camera not being triggered by a motion. For example, a predator may walk by too quickly and not be in the camera's field of vision. It also allows the camera to catch wildlife that is too small or far to trigger the cameras motion sensors.
- The Browning Recon Force Extreme cameras used on Dead Neck Sampsons Island in 2017 and 2019 used an infrared flash. Although this is nearly invisible to humans it is possible some predator species may see the flash at night.

Piping Plover caught on camera. TNC

- Due to the large number of files collected during a season, storing the files in an online database may not be feasible due to storage limits. Storing the files on a network drive within the organization's server may be a better alternative. This will allow staff to access the files from any company laptop and eliminate the need to transfer files to memory devices. If the files are kept on one staff member's computer, they could easily be lost from damage or user error. If a network drive is not available for use an external hard drive is recommended to act as a backup in case of file loss.

c) Field Installation:

- The date of installation and take down should be documented in a field log.
- On Dead Neck Sampson's Island in 2019, the cameras were placed in areas where shorebird nesting was taking place. Proximity to nests and the camera's ability to view nesting activity was taken into consideration when choosing a placement. The camera in the restoration area was placed approximately 0.5-1.0 ft off the ground to accommodate for slopes in the terrain. The camera on the west end was placed approximately 0.5 ft. off the ground in case of overwash.
- In order to deter perching, trail cameras that are placed in lock boxes can be screwed into the topmost hole of the post. This will allow the lock box to extend above the top of the post.
- To deter theft a coated braided steel cable should be secured to the lock box with a padlock via the padlock hole located on the bottom of the lock box. The cable can then be run through a cinder block and buried approximately 2-4 ft.

d) Checks and Maintenance:

- All SD card changes and camera maintenance should be documented in a field log. This includes shifting of cameras and changing of camera location/direction. Notes should also be made if camera condition is found to be deteriorating, if overwash near the camera has occurred, or sand has built up on the camera lens or sensor.
- When the cameras are first installed, the SD cards should be replaced within 2-3 days to determine that the camera settings are correct and it is functioning properly. This will also help staff determine if the field of view is what is desired for the study. After this initial check, SD cards should be exchanged a minimum of once a week. This will allow staff to review the images/videos and determine if any issues have arisen in terms of the camera's function/placement.
- When removing/inserting an SD card the camera should always be turned off. Removing an SD card when the camera is not turned off can result in SD card damage and loss of image files.

- Battery power should be checked during any form of maintenance. Staff should carry enough batteries in the field to replace a full set if it is determined the battery power is low.
- Supplemental field materials to consider for camera maintenance: keys for padlocks and lock boxes, batteries, cleaning kits, extra screws/bolts.

e) Adaptive Management (including troubleshooting): none provided

f) Data Processing and Management:

- Image review methods:

  ● If a Browning trail camera is being used to collect time-lapse files, the Buck Watch Time-lapse Viewer should be used. This time-lapse viewer software can be downloaded from the Browning website. A Mac version of this software is not currently available so a PC must be used. This program allows users to view time-lapse files image by image. Time-lapse files can also be viewed as videos by converting the file type from .TLS to .AVI. To do this remove the .TLS part of the file title and replace it with .AVI. Viewing the time-lapse as videos may make reviewing image by image more difficult. Still photos and standard videos captured by trail cameras can usually be viewed without special software.

  ● Within a series of images, scan each image relatively carefully for the presence of a "disturbance source" (e.g., predators, pedestrians, dogs) and species being protected (e.g., plovers, terns, other shorebirds). For every image that contains one or more of the above, complete designated data variables on the data sheet. Info should include visibility and other weather variables and possibly more extensive notes. If the viewer is uncertain about anything they witness in the data, notes should be made to come back to the image with more reviewers. Unique behaviors should also be documented. Some examples are people running near the camera, people entering closed shorebird habitat, protected species acting defensive or tending young and predator activity that is directly impacting a protected species. Aside from recording visibility and temperature, all the other important weather variables including tide will have to be found in weather archives online and added to data sheet later. Every instance of a disturbance source or protected species appearing in a frame will entered in an .xls file for analysis.

3, 4, 5. Analytical Approaches, Reporting, Other Resources: Not yet developed


ATLANTIC FLYWAY
SHOREBIRD
INITIATIVE