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

August 2019

ATLANTIC FLYWAY SHOREBIRD INITIATIVE

CONTRIBUTORS AND ACKNOWLEDGMENTS

RECOMMENDED CITATION

Hunt, K. L, Karpanty, S. M., Davis, K. L., Wilke, A., Myers, N., Spiegel, C., Schulte, S., Catlin, D. H., Fraser, J. D. 2019. Guidance and Best Practices for Coordinated Predation Management to Benefit Temperate Breeding Shorebirds in the Atlantic Flyway. U.S. Fish and Wildlife Service and National Fish and Wildlife Foundation.

DOCUMENT DESIGN

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COVER PHOTO CREDITS

American Oystercatcher, Doris Rafaeli; Red fox, Bill Thompson; Piping Plover exclosure, Erin Eve; Raccoon tracks, Terry Ross; Snowy Plover, Mark Vance; Piping Plover chick, USFWS; Shorebird sign, Scott Kruitbosch; Wilson's Plover, Isaac Sanchez

TABLE OF CONTENTS

BACKGROUND AND RATIONALE

The Atlantic Flyway Shorebird Initiative (AFSI) highlights predation as one of four primary anthropogenic threats to shorebird populations in the Atlantic Flyway. The AFSI implementation plan for predation focuses management efforts on four temperate breeding shorebirds: American Oystercatcher (*Haematopus palliatus*), Piping Plover (*Charadrius melodus*), Wilson's Plover (*Charadrius wilsonia*), and Snowy Plover (*Charadrius nivosus*); hereafter, 'beneficiary species' or 'beneficiaries.' Throughout the breeding range of these beneficiary species, a variety of predation management programs are currently implemented by federal, state, and non-profit entities. However, funding for many of these programs is tenuous and coordination across sites and species is often lacking. At nesting sites that lack predation management programs, high predation pressure can result in poor annual shorebird reproductive success and may lead to population sinks and contribute to population declines. Furthermore, the lack of coordinated implementation of predation management efforts across the ranges of the beneficiary species likely dilutes the benefits of other types of management at a flyway scale. Increased coordination of predation management strategies and resources is needed to maximize the effectiveness and efficiency of management programs for temperate breeding shorebirds across the Atlantic Flyway of North America.

This document is the result of an extensive effort to collect, synthesize, and summarize information on predation management to benefit temperate breeding shorebirds into a best practices ("BP") format that will facilitate, encourage, and inform increased management coordination and efficiency throughout the North Atlantic Flyway. The document was developed through an iterative process that included the following:

1. the development of a comprehensive list of best practices to be considered when beginning or maintaining any predation management program;
2. the development of interview questions, based upon the list of best practices, to collect information about predation management activities along the U.S. Atlantic Coast;
3. formal interviews of 29 biologists and managers representing the U.S. Atlantic Coast flyway,
4. an extensive review of peer-reviewed and gray literature;
5. an open comment period for flyway shorebird and predation managers to edit, comment, and improve the document; and
6. the final compilation and synthesis of all information collected into the framework provided by the initial list of best practices.

The steps described above that led to this BP document were led by biologists from the U.S. Fish and Wildlife Service (USFWS) and the Virginia Tech Shorebird Program (VT), with support and consultation from additional project leads from The Nature Conservancy (TNC), Manomet Center for Conservation Sciences, and US Department of Agriculture Wildlife Services Program (hereafter referred to as "BP Leads"). The participants in each project demonstration site (see 'Contributors and Acknowledgments' on Page 2) also provided input into the design of the BPs and the questions asked of interviewees during the information collection phase of this work as described below. Finally, the draft document was reviewed by stakeholders throughout the Flyway with over 50 individuals and organizations responding. When the term 'We' is used throughout this document, it refers to the combined input of the preceding parties.

This document provides a synthesis of available guidance, tools, and resources needed to plan and implement predation management, set management goals, and evaluate success for AFSI priority beneficiary species.

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.

AFSI FOCAL SPECIES DESCRIPTIONS

The Atlantic Flyway Shorebird Initiative has identified the following four focal species to represent the conservation needs of temperate and tropical breeding shorebirds along the U.S. portion of the Atlantic Flyway: American Oystercatcher, Piping Plover, Wilson's Plover, and Snowy Plover. Additionally, the AFSI highlights coastal development, human disturbance, sea-level rise and predation as potential limiting factors for populations of these four species. This BP document specifically focuses on these species and the issue of predation, however the resources and guidance can also be applied to other avian species and other taxa such as sea turtles nesting in similar habitat types. Throughout the document, the four focal species and other taxa using similar habitats are referred together as 'beneficiary species' or 'beneficiaries.' General species descriptions are provided below.

American Oystercatcher (*Haematopus palliatus*; adapted from the American Oystercatcher Working Group 2012)

The American Oystercatcher is a large shorebird, commonly found in coastal marshes and along beaches, and is distributed throughout coastal North America. On the Atlantic Coast of North America, American Oystercatcher breed from Nova Scotia to Florida in March through August and are found year-round from New Jersey to Florida in the U.S. portion of the Atlantic flyway. American Oystercatcher forage primarily on saltwater bivalves and therefore the species is restricted to coastal marine habitats. American Oystercatcher are a long-lived species and generally do not breed until at least three years of age. Average clutch size is three eggs and pairs will renest multiple times if eggs are lost. Pairs typically raise only one brood raised per season. Numbers of chicks fledged per pair varies widely throughout the range, by site and by year. The U.S. Atlantic and Gulf coasts support approximately 12,450 individuals during the non-breeding season (S. Schulte, unpublished data, Manomet).

American Oystercatcher. Doris Raphaeli

Piping Plover (*Charadrius melodus*; adapted from Elliott-Smith and Haig 2004)

The Piping Plover is a small-bodied, federally listed shorebird that generally inhabits sparsely vegetated and un-vegetated beaches, riverine sandbars and alkali lake shorelines. On the Atlantic Coast of North America, the species breeds from April through August from Newfoundland to North Carolina and winters primarily from North Carolina through Florida. Piping Plovers typically forage on freshwater and marine invertebrates, as well as terrestrial and benthic invertebrates. They are primarily seasonally monogamous laying one four-egg clutch per year, but pairs are apt to re-nest if eggs are lost. Pairs typically raise only one brood raised per season. The Piping Plover is listed as federally threatened in the Great Plains and on the Atlantic Coast and federally endangered in the Great Lakes. Atlantic Coast populations experienced a decline prior to being listed under the Endangered Species Act in 1986 and have rebounded in many locations since then with the help of nest exclosures and management efforts to limit anthropogenic interactions. The 2017 breeding population estimate for Piping Plover of the U.S. Atlantic Coast is approximately 1,731 pairs (A. Hecht, personal communication, USFWS).

Piping Plover. USFWS

Wilson's Plover. Jean Hall

Wilson's Plover (*Charadrius wilsonia*; adapted from Zdravkovic et al. 2018)
The Wilson's Plover is a medium-bodied shorebird that nests on sparsely vegetated saline areas such as beaches, dunes, and the edge of lagoons. On the Atlantic Coast of North America, Wilson's Plovers breed from Virginia to Florida from April through August and are found year-round from South Carolina to Florida. They forage in intertidal mud flats, salt flats, and in beach dune areas on crustaceans, particularly fiddler crabs, and other invertebrates. Wilson's Plovers lay one three-egg clutch per season but will often renest after clutch failure. The population status of Wilson's Plovers is estimated as 1,000 -1,100 pairs along the U.S. Atlantic Coast and referenced as Trend 4, Apparent Decline (Zdravkovic et al. 2018).

Snowy Plover. Lynn Schmid

Snowy Plover (*Charadrius nivosus*; adapted from Page et al. 2009)
The Snowy Plover is a small-bodied shorebird that commonly breeds from April through August on unvegetated and sparsely vegetated beaches and shores of inland alkaline lakes. They have an inland and coastal breeding population. On the eastern coast of North America, the Snowy Plover breeding range is limited to the Gulf coast of Florida. Snowy Plover forage on terrestrial, freshwater, brackish, and marine invertebrates. Throughout their range, Snowy Plovers typically lay three-egg clutches and are known to exhibit a variety of breeding strategies, ranging from polygamy to monogamy, depending on location. The Pacific Coast population is listed as threatened under the Endangered Species Act. The Atlantic Flyway population is not federally listed, but is state-listed as threatened in Florida. The current population estimate for Snowy Plover on the breeding grounds of the U.S. Gulf Coast is approximately 200 to 225 pairs (Himes et al. 2006).

PREDATORS OF THE ATLANTIC FLYWAY

Predators of eggs, chicks, and adults of the four focal shorebird species considered here were identified through literature review, interviews with land managers, and comments by reviewers of drafts of this document. Predator species vary among locations, and even time at a given location, and may include the following, grouped by taxa:

Mammalian Predators: raccoon (*Procyon lotor*), red fox (*Vulpes vulpes*), gray fox (*Urocyon cinereoargenteus*), coyote (*Canis latrans)*, domestic dog (*Canis lupus familiaris*), bobcat (*Lynx rufus*), feral free-ranging cat (*Felis catus*), American mink (*Mustela vison*), long-tailed weasel (*Mustela frenata*), short-tailed weasel (*Mustela erminia*), feral hog (*Sus scrofa*), Virginia opossum (*Didelphis virginiana*), striped skunk (*Mephitis mephitis*), rat (*Rattus sp.*), chipmunk (*Tamias striatus*), nine-banded armadillo (*Dasypus novemcinctus*).

Avian Predators: Herring Gull (*Larus argentatus*), Great Black-backed Gull (*Larus marinus*), Laughing Gull (*Larus atricilla*), Gull-billed Tern (*Gelochelidon nilotica*), American Crow (*Corvus brachyrhynchos)*, Fish Crow (*Corvus ossifragus*), Common Raven (*Corvus corax*), European starling (*Sturnus vulgaris*), Boat-tailed Grackle (*Quiscalus major*), Common Grackle (*Quiscalus quiscula*), Great Horned Owl (*Bubo virginianus*), Northern Harrier (*Circus cyaneus*), American Kestrel (*Falco sparverius*), Merlin (*Falco columbarius*), Peregrine Falcon (*Falco peregrinus*), Black-crowned Night Heron (*Nycticorax nycticorax*).

Other Predators: snake ssp., iguana spp. (*Iguana spp.*), ghost crab (*Ocypode quadrata*), and fire ant spp. (*Solenopsis spp.*).

Eastern Coyote. Andrew Rettig

American Crow. Steve Haycock

Ghost crab. Audrey Albrecht

Raccoon, red fox, and coyote were identified as the most frequently targeted species for predation management by interviewees, followed by crows and two species of gulls (Fig. 1).
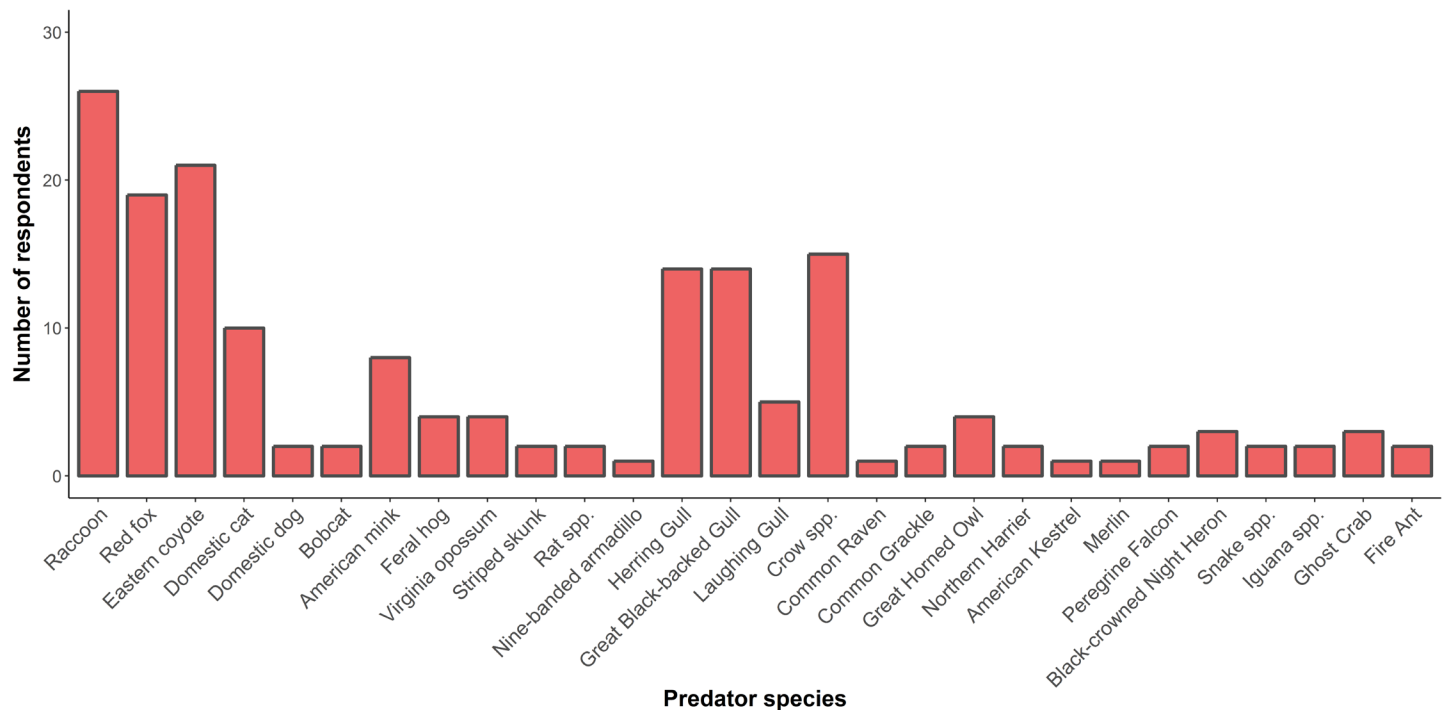
Figure 1. Predator species targeted for management along the Atlantic Flyway as indicated by 29 interview respondents. Note, the literature review revealed many additional species targeted but only interview responses are noted in this figure. See section 1.4 in the BP predator database for specific responses.

LAND MANAGER AND BIOLOGIST INTERVIEWS AND DATABASE

A critical part of the iterative process to develop this document was to solicit information and expertise through interviews with managers and biologists having direct experience with predation management along the Atlantic Flyway. To identify potential interview candidates, Virginia Tech worked with the BP leads and demonstration sites to identify and contact 74 individuals with predation management experience with a screening email request for participation (see *Supplemental Material: Interview Consent and Questions*).

We considered the following criteria when identifying potential interviewees: 1) direct job-related predation management experience along the Atlantic Flyway, 2) geographic representation across the Atlantic Flyway, and 3) representation by a diversity of organization types (e.g., non-profit, state-government, federal-government).

Based on consent via the screening email, Virginia Tech conducted 29, 1 to 2-hour interviews in February–May 2017, where respondents answered questions either over the telephone or via a web-based survey regarding past and present predation management activities. Interview questions are available in *Supplemental Material: Interview Consent and Questions*.

The interview respondents included representatives from each coastal state along the U.S. Atlantic flyway, and a variety of land managers and biologists working in varied geographic settings and for non-profit, state and federal organizations (see Table 1; Fig. 2; Columns A-E in the database for details on each interviewee's name and affiliation, *Supplemental Material: Database of Interview Responses*. Some respondents requested that their names and associated site names and locations be kept anonymous. Those responses are coded as such in the data and throughout this document, as appropriate.

All of the data from the interviews are available in *Supplemental Material: Database of Interview Responses*. Specific manager interview responses can be found in the database and are denoted throughout the

document with '**DB**'. The database contains a complete record of all manager responses and should be consulted for additional details. All activities were conducted in accordance with Virginia Tech's Institutional Review Board (Virginia Tech IRB # 17-003).

LITERATURE REVIEW

We conducted a comprehensive review of the peer-reviewed and gray literature related to predation management from both within and outside of the Atlantic Flyway to consider and include during the development of the BPs. We synthesized and used this information to supplement and/or support information gathered from the interviews and reviews of the draft document.

We started the comprehensive literature review using 'Google Scholar' as our search engine. We typed in combinations of the following: 'predation management', 'shorebirds', 'sea birds', 'sea turtles', 'Atlantic Coast', 'plovers', 'Piping Plover', 'American Oystercatcher', 'Snowy Plover', Wilson's plover', 'predators', 'predation management techniques', 'lethal predator control', 'avian species', and 'research'. We then used the resulting publications and reports to find additional information, examples and citations. We also received publications, reports, and citations from land managers provided during the interviews.

DEMONSTRATION SITES

In addition to the interviews and literature review, six demonstration site projects were also developed and implemented as part of this BP effort. The purpose of these demonstration projects was to implement novel predation management activities, test questions or assumptions about existing management actions, in concert with the development of the BPs, and to then summarize the information gained from each demonstration site into useful case studies tied to the BPs. Demonstration sites were selected by USFWS based on their geographic, organizational and methodological diversity. The following is a brief description of what is unique about each demonstration site.

Florida: The Florida demonstration site explored the effectiveness of a relatively new method of nonlethal control, conditioned electric stimulus aversion, to deter Fish Crows from depredating shorebird and waterbird nests and chicks.

Table 1. Types of organizations represented by interviewees (n = 29) along the Atlantic Flyway.

Organization Type	Number of interviewees
Non-governmental Organization	6
State Fish and Wildlife or Natural Resource Agency	11
Federal Agency (USFWS, NPS, USDA Wildlife Services, National Estuarine Center)	12
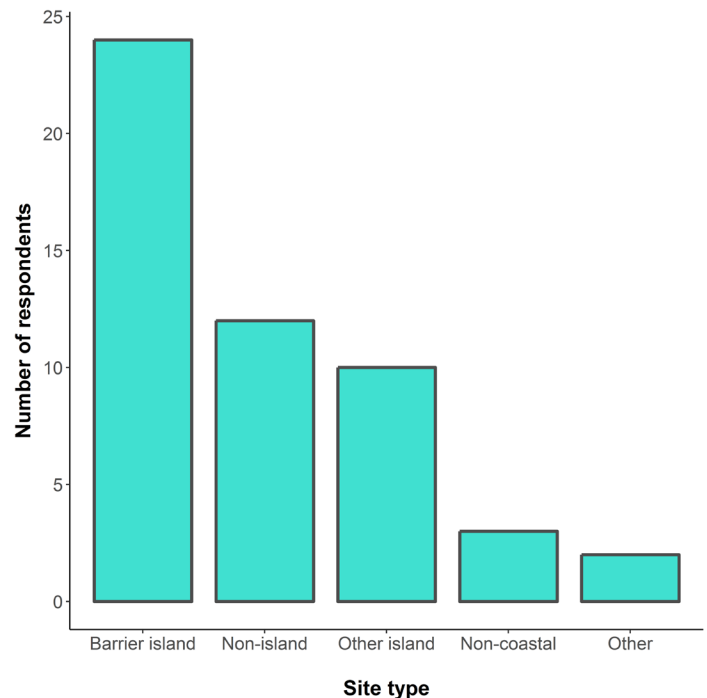
Figure 2. Geographic settings along the Atlantic flyway in which predation management was implemented as indicated by 29 interview respondents. See Question 1.1 in Supplemental Material: Database of Interview Responses for specific responses.

Georgia: The Georgia demonstration site experimentally tested the effects of nest exclosures on Wilson's Plover nest success and chick survival. Although exclosures are often used in Piping Plover management, they have not been used frequently in Wilson's Plover management.

South Carolina: The South Carolina demonstration site examined the chronology of lethal management activities to determine the ideal timing to benefit both beach nesting birds as well as sea turtles.

North Carolina: The North Carolina demonstration site increased nest and chick monitoring efforts to better quantify nesting activity and success of shorebird species in response to increased predator management efforts and used nest cameras to help

identify predation events as well as predator species.

Rhode Island: The Rhode Island demonstration site focused predator management efforts at sites where limited predator management had previously occurred and compared productivity at sites where a combination of lethal and nonlethal management was used versus sites where only nonlethal management was used.

Massachusetts: The Massachusetts demonstration sites used camera traps to evaluate the relationship between human disturbances and predation and tested the hypothesis that greater human disturbance of nesting birds contributed to increased predator impacts.

Each case study and its links to the BPs is presented in detail in ***Supplemental Material: Demonstration Sites***.

HOW TO USE THIS DOCUMENT TO IMPLEMENT ADAPTIVE PREDATION MANAGEMENT

Figure 3 provides an organizational framework for this document. We have divided the BP document into sections 1–9 based on the logical steps a manager might go through during the process of planning, implementing, reviewing, and revising a predation management program. These considerations include site evaluation, management implementation, public outreach, laws, regulations, and permits, evaluating management effectiveness, and funding considerations.

We acknowledge that managers may consider one, a few, or all of these steps, depending on what is appropriate for their site(s), but we present all steps as important components to an effective and well-planned predation management program. These steps do not need to be followed in sequence, but this may be useful for someone just beginning a program. We present a visualization of how these BP components may be viewed as a circular flow diagram that emphasizes the adaptive management nature of predation management (Fig. 3).

We also reference the database of interview responses (***Supplemental Material: Database of Interview Responses***) throughout the BP document, by including the questions that are relevant to each BP topic. These are noted in the text as 'DB' followed by the question number(s), and we encourage managers to reference this resource for detailed information about how different management strategies have worked in various locations. As the database was best maintained as an excel file, this Supplemental Material Database of Interview Responses is an external file to this document.

In addition to the nine BP topics and interview database, we also include additional resources and examples in the demonstration site case studies (***Supplemental Material: Demonstration Sites***) and in supplemental material for the individual BPs. There is a wealth of detailed information in these supplemental materials that managers may find useful if they seek more information on how this document was compiled or how different predation management BPs have worked for others.
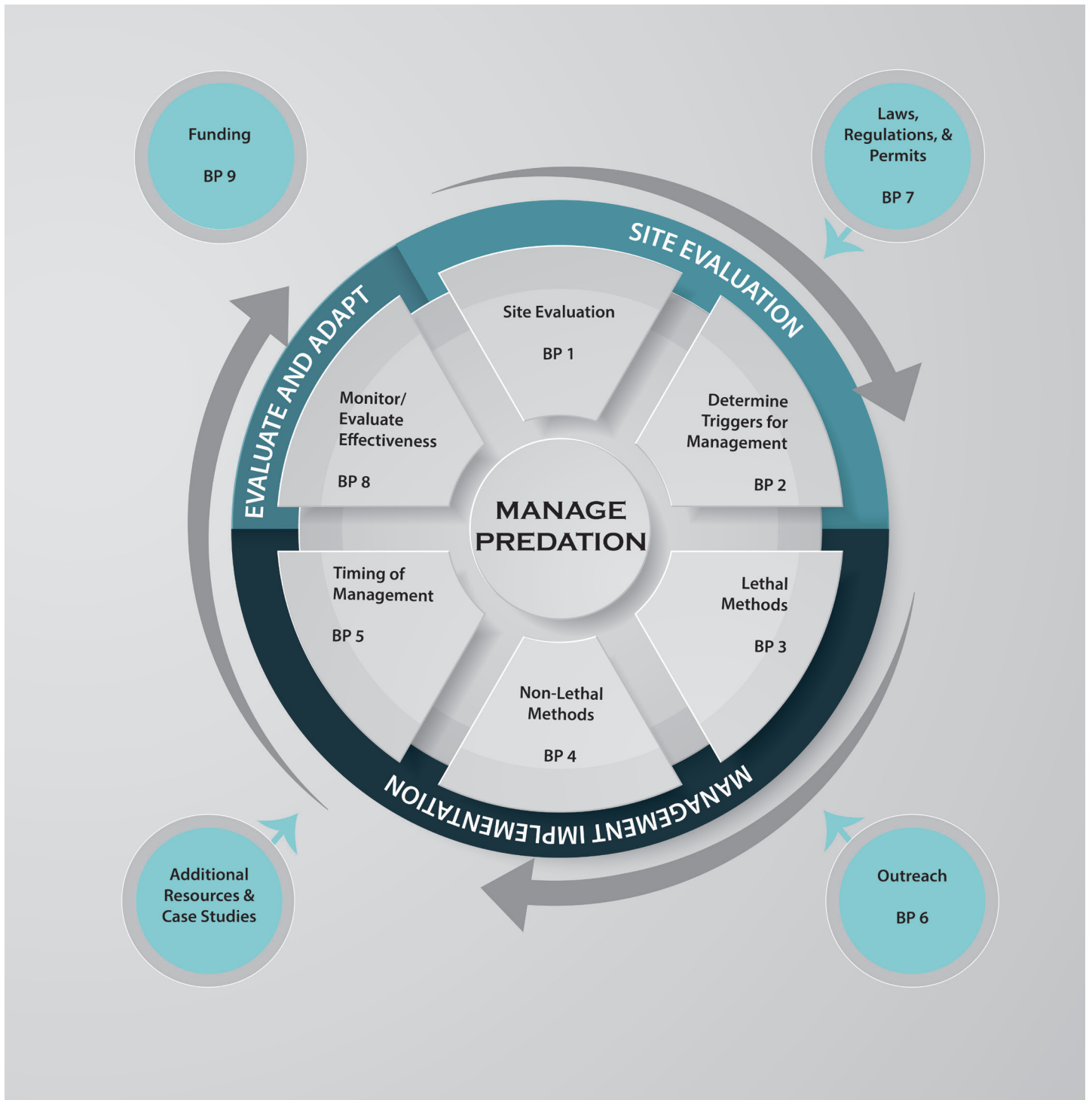
Figure 3: The predation management adaptive management flow diagram is a way to visualize how managers will approach this predation management BP. Depending on previous experience, a manager may begin predation management at any point with the goal of constantly revising and improving upon the overall program in an adaptive framework.

BEST PRACTICE 1: IDENTIFYING BENEFICIARY SPECIES AND PREDATORS FOR MANAGEMENT

WHY IS THIS IMPORTANT?

Before implementing predation management at your site(s) it is necessary to identify:

- Beneficiary species at your site, and
- Known predators and potential predators.

Although the BPs contained in this document focus primarily on avian beneficiary species (i.e., AFSI focal species and colonial nesting waterbirds, migratory shorebirds), they may also be used to guide predator management efforts for the benefit of non-avian target species such as sea turtles and diamond-backed terrapins.

The following sections provide examples of best practices for identifying beneficiary and predator species.

HOW TO IDENTIFY BENEFICIARY SPECIES (DB 1.2, 1.3)

Managers along the U.S. Atlantic Flyway are currently implementing predation management to benefit a wide variety of species representing different taxa. For example, of the 29 individuals that were interviewed, 89% (n = 26) indicated that their predation management benefited one or more AFSI focal species, in addition to other avian and turtle species, including colonial nesting waterbirds, sea turtles and migratory shorebirds (Fig. 4, DB 1.2, *Supplemental Material: Database of Interview Responses*).
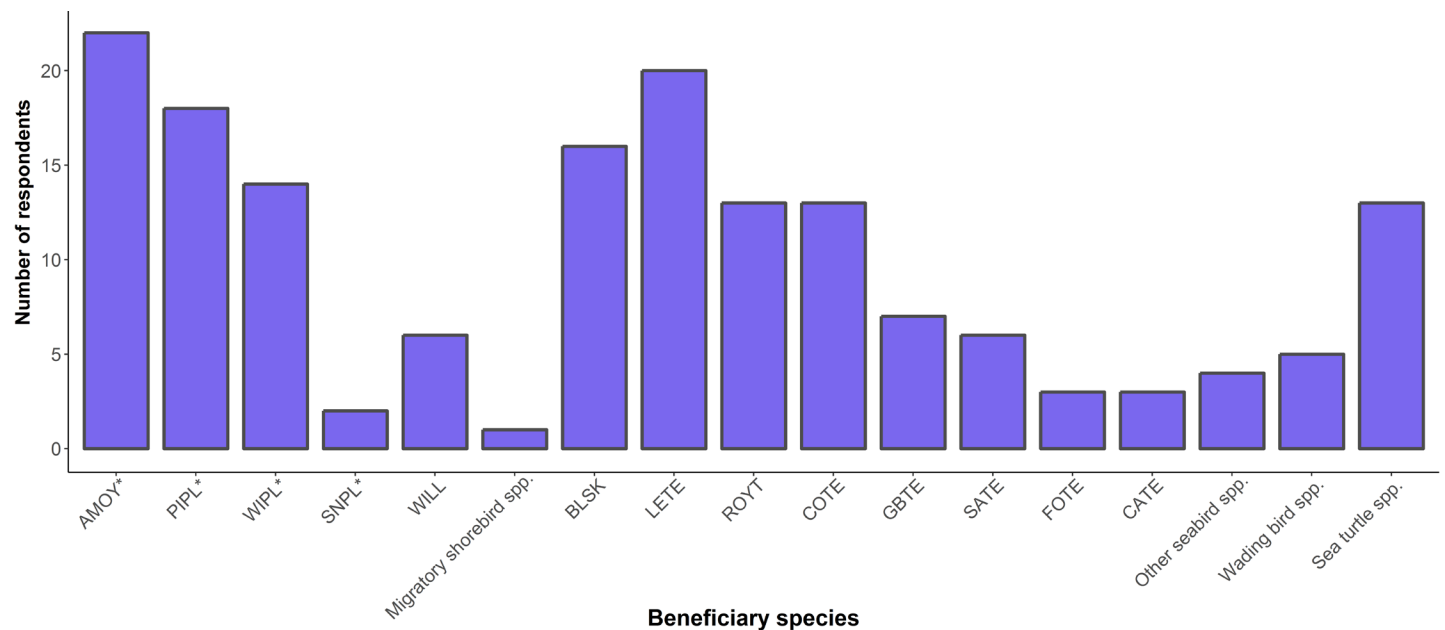
Figure 4. Beneficiary species for which predator management is/was implemented along the Atlantic Flyway as indicated by 29 interview respondents. See section 1.2 in the Supplemental Material: Database of Interview Responses for specific responses and Supplemental Material: Demonstration Sites for demonstration site details. An asterisk placed next to species names indicates an Atlantic Flyway Shorebird Initiative (AFSI) focal species. Four letter codes used are standard AOU abbreviation. Some interviewees used the terms seabird and water-bird synonymously.

At many sites, the beneficiary species may already be known. However, when developing a new or modifying an existing management program, the fundamental task of identifying and/or documenting the beneficiaries is important. We recommend a tiered approach to collecting the information necessary to determine if there is a predation management challenge to be addressed: 1) surveys/inventories, 2) abundance or density estimates, and 3) productivity estimates. We recommend managers review current literature for recent and recommended protocols to quantify these parameters with the least possible disturbance to the nesting birds.

- Species inventories and distribution: Formal presence/absence surveys or species inventories may be used to determine what species are present at your site and overall distribution patterns in an area. These surveys will involve a complete walk-through of your site during the breeding season to record the species present. Best practices would include systematic surveys in an occupancy framework which accounts for the influence of detection error in estimates of presence or absence (see McKenzie et al. 2005 for methods).

- Species counts: Managers may decide to obtain estimates of the numbers of individuals, pairs, or nests of species present at a site using transect, area, or point count methods. Depending on the goal, these can be general counts that could be used as indices for the number of species present or they could be more detailed counts where abundance and density are estimated (e.g., see Program DISTANCE, http://distancesampling.org). It is important to remember to be mindful of your disturbance when conducting surveys and counts.

- Productivity information: Monitoring nesting pairs and basic reproductive rates (hatching and fledging success) will provide managers with important information about which shorebird species are being impacted by predators and at which stage. This will involve locating nests and determining the fate of nests or chicks. Methods used include remotely-triggered camera traps (see below in section on how to identify predator species for details) and visits to nest sites by nest monitors at frequencies that enable accurate estimates. Managers should carefully consider the potential impacts of frequent nest checks including excessive disturbance or potential of attracting predators. Nest visits may occur daily to weekly

Snowy Plover nest. Audrey Albrecht

depending on the logistical resources available at a site. Visits at a frequency of daily to every 3 days are recommended as best practices for assessing productivity accurately, but when possible, checks should be done from a distance to minimize disturbance and the potential of attracting predators to the nest.

Each of these metrics (presence/absence, abundance, productivity) are recommended again as part of BP 8 for monitoring the effectiveness of a predation management program. Each demonstration site summarizes their metrics and methods used (*Supplemental Material: Demonstration Sites)* as do the interviewees in database question 1.3 (*Supplemental Material: Database of Interview Responses*). It is important to emphasize that the best practice for identifying beneficiary species for predation management involves collecting data on all three points above. Without data on beneficiary presence, distribution, abundance, and productivity, it is difficult to know whether predation is a factor potentially limiting the population and whether predation management is truly warranted.

HOW TO IDENTIFY PREDATOR SPECIES (DB 1.4, 1.5)

Managers interviewed along the Atlantic Flyway identified a variety of methods or incidental types of observations by which predators are identified at a site and potentially, or actually, determined to be impacting beneficiary species. These include, in order of the frequency of use: sign at nests (tracks and other sign), incidental track sightings in nesting areas, game cameras, observations of predators, anecdotal evidence other than categories listed here, track transects, prey carcasses, predator sign(s) at site, radio telemetry, and historic information (Fig. 5). Details on how each interviewee assessed predator species are presented in questions 1.4 and 1.5 in the database (*Supplemental Material: Database of Interview Responses*), and in each demonstration site case study under their description of BP 1 (*Supplemental Material: Demonstration Sites*).

Based on the feedback provided during the manager interviews and information from the literature, the benefits and drawbacks of each of these methods or types of incidental observation are discussed below. We present the methods or incidental observations in order of the level of detail and evidence, from most to least, which they provide on the current interactions of predators and beneficiary species at a site. We recommend that managers use as many of these techniques at the same time to best identify the present-time interactions of predator and beneficiary species.
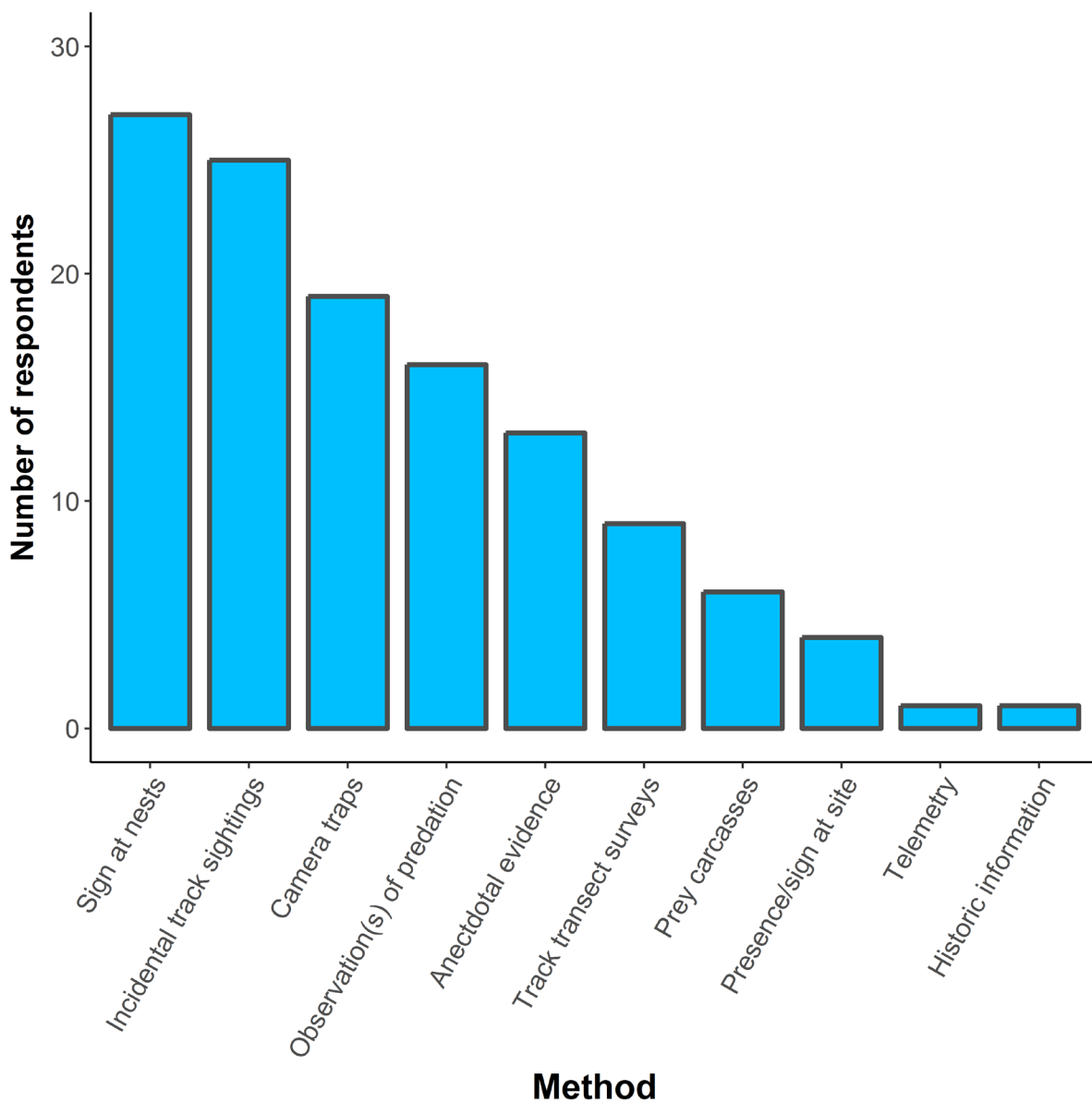
Figure 5. Methods used to determine that predator species were present at sites and potentially affecting beneficiary species along the Atlantic Flyways as indicated by 29 interview respondents. See section 1.5 in the BP predator database for specific responses.

1. Game cameras

Game cameras are weatherproof cameras that can be deployed in the field and set to take either still photos or video, and to be either motion-triggered or time-lapsed. Depending on the placement and settings of the camera(s), the resulting data can range from general to specific. For example, cameras can be deployed at the nests of beneficiary species to accurately identify predators and/or to assign nest fates and document depredation rates; these data demonstrate that a given predator is a source of predation among beneficiary species versus just present in an area. Cameras can also be set up in systematic 'grids' to provide information about predator movements, occupancy, and abundance. Or, cameras can be set up along predator trails or in areas with easy access to opportunistically document which predator species are present. The latter two types of data are valuable, but managers should be careful not to assume that because a predator is present that it is a factor either impacting or limiting the population of the beneficiary species. The ability to detect animal species will vary by location, camera brand, camera placement, ambient temperature, precipitation, and by species' size and behavior (Lyra-Jorge et al. 2008).

The detection zone used by the camera needs to be considered and could determine if the camera can be used as a broad, catch-all system for monitoring wildlife. If game cameras are deployed and users cannot conduct a detectability assessment, two cameras should be placed on opposite sides of the area of interest (Pease et al. 2016).

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

Game cameras at nest sites: For the purposes of identifying predators that are impacting beneficiary species, we recommend that game cameras at the nest are a best practice. The presence of predators in an area does not necessarily indicate a threat to the beneficiary species. Specifically, we recommend the use of motion-triggered, still photos at nest sites if the goal of the manager is to identify nest fates, document predation rates, or document presence of predator species. Video or time-interval set photos can provide additional details and full documentation of all events at a site but are incredibly power- and storage-intensive and time-sensitive to sort through to identify key events.

Our recommendation is based on the recognition that game cameras can be very effective, although not always perfect, at identifying specific nest predators (Sabine et al. 2006, Colwell et al. 2009, Moore and Reid 2009, Hillman 2012, Denmon et al. 2013, DeRose-Wilson et al. 2013, Strickland 2015, Protus 2016). Below, we identify resources that managers may use to compare cameras. We recommend motion triggered, rapid-fire technology, where 3 photos are taken immediately in succession after a trigger to best capture fast-moving predators such as crows, owls, and ghost crabs. The lag between the trigger and first photo of a camera will decrease as camera quality and prices increase; we recommend that managers use cameras with the fastest trigger speed that can be afforded, ideally 1 second or less. However, if trigger speed is slower, the data is still useful but managers should recognize that they may miss some predation events. Infrared, no glow cameras have two advantages: lower detection by humans in an area and less of a frightening effect on target species. However, if flash cameras are available or affordable, they also are valuable tools and result in high quality photo data. Quality cameras can range in price from $150 to >$800 per camera, depending on whether wireless download technology is desired. Benefits of more expensive cameras include durability in harsh coastal environments and faster trigger speed. Cameras can be rotated among nests and sites if budgetary constraints limit the number purchased.

Cameras can also be useful for correctly identifying nest fates and for determining the proportion of nests lost to specific predators. For example, at Cape Lookout National Seashore, Hillman (2012) found that researchers were overestimating Least Tern hatching success by 31% using information gathered at the

nest bowl when compared to camera data. Using video cameras to monitor Snowy Plover nests in California, Colwell et al. (2009) found that nest fates classified as 'unknown' using field evidence were in fact depredated by ravens. On rare occasions, game cameras used to monitor nests have also recorded depredation events of adult birds. For example, at Cape Hatteras National Seashore a camera recorded an American mink depredating an adult Piping Plover that was incubating its nest (C. Weithman, Virginia Tech Shorebird Program, unpublished data). Although game cameras can provide crucial information about nest predators and depredation rates, some research has indicated that they also can lower the success of Least Tern and Wilson's Plover nests (Hillman 2012, DeRose-Wilson et al. 2013), which may be a product of predators learning to associate cameras with nests (Hillman 2012, Strickland 2015). Moore and Reid (2009) also documented cameras deployed at American Oystercatcher nests on Chatham Island attracting both people and livestock to nesting areas and presumably increasing risk of disturbance and nest loss due to predation or trampling. However, other studies (see Spiegel et al. 2012) found no negative impact on nest success. To be cautious, we recommend concealing the cameras as beach trash' and the use of spikes on top of the cameras to discourage perching predators. Predators may still be attracted to the presence of an abnormal object on the beach, thus caution should be taken if nests are not exclosed. It should be assumed that there will be some effect of using game cameras, so users should minimize time spent setting up the camera and modifications to the surrounding vegetation (Cutler and Swann 1999). Users should also make attempts to reduce human scent on the camera by wearing gloves when handling any camera equipment and avoid wearing shoes or clothing with odors.

Pros:
- Can provide accurate documentation of confirmed predator species and nest fates and occasionally capture predation of adult birds.
- Minimizes risk of predation management effort expended on predator species that are not directly impacting beneficiary species.

Cons:
- In some cases, may attract predators and people to nests.
- Expense.
- Time commitment associated with camera deployment and maintenance (switching out

batteries and/or memory cards) and data processing time.
- Risk of vandalism or theft. If cameras used in an area of high human traffic, they should be locked to posts or exclosures to discourage theft.
- Will not provide more detailed information about predator ecology, abundance and occupancy at a site.
- Due to variability in detection rates of cameras, some species may go undetected.

Game cameras along systematic 'grids': Cameras can also be deployed in systematic grids to collect information about predator movements and allow one to model and estimate predator occupancy and abundance (Waldstein 2010, Gieder 2015). Resulting information is useful for understanding the ecology of the predator species at a site and can subsequently inform and increase the efficiency of the timing and location of predation management activities (as described in BP 5). The use of systematic camera grids is recommended as a best practice for monitoring the effectiveness of predation management activities (see BP 8) but should be used in conjunction with game cameras at nests to make decisions on which predators to manage. The number and spacing of cameras used in a grid will depend on the predator species of interest. A general rule for studies of predator occupancy, abundance, density, and movements is to place one camera station within each potential home range of a predator (Rovero and Zimmermann 2016).

Pros:
- Can provide valuable information about predator presence/absence, ecology, abundance and occupancy to inform and track the effectiveness of predation management (see BP 8).

Cons:
- Will not identify specific nest predators or predation rates, and alone should not be used to identify which predator species to manage
- Expenses per camera same as those placed at nest site, and the number and spacing of cameras will depend on the size of the study site.
- Time commitment associated with camera deployment and maintenance (switching out batteries and/or memory cards) and data processing time.
- May require expert level study design and data analysis; researchers familiar with design and analyses of camera trapping studies should be consulted for advice specific to your study site.

Resources for use of game cameras at nests or in systematic grids:

- Trolliet et al. (2014) provides a review of the uses of camera traps for wildlife studies.
- Trailcampro.com provides tools for comparing and selecting game cameras according to project goals and budget. We do not recommend any given device as technology improves drastically each year. We recommend the fastest trigger speed that a manager may afford, and no-flash infrared technology when feasible.
- Camera Trapping for Wildlife Research, Edited by Francesco Rovero and Fridolin Zimmermann (2016) Exeter: Pelagic Publishing, UK. This is a handbook written for wildlife researchers and includes tips and instructions for selecting the right type of camera for your needs, effective sampling design, camera deployment, data management, and basic occupancy, abundance, density, and behavioral analyses.
- Please see the demonstration site case study descriptions for North Carolina and Massachusetts; sites in both locations used game cameras in their predation management programs (Supplemental Material: Demonstration Sites).

2. Telemetry

Radio or GPS telemetry techniques can be used to monitor the movements of shorebird chicks and adults and/or actual or potential predator species to learn detailed information about the interactions between the two at a site.

Use of telemetry on beneficiary species: Because shorebird chicks are precocial and often highly mobile, it is often challenging to identify predators of chicks. Telemetry combined with the use of other techniques (i.e., tracks, sign, prey carcasses) can be an effective combination of tools. In the Netherlands, researchers attributed 70–85% of radio-tagged chick mortality of grassland-nesting shorebirds to predators and were able to identify 15 predator species (Schekkerman et al. 2008). Through radio tracking American Oystercatcher chicks at Cape Lookout National Seashore, Schulte and Simons (2015) were able to identify predators responsible for pre-fledged chick mortality and determined that ghost crabs, Great Horned Owls and Fish Crows played a larger role in chick predation than nest predation. Research at Cape Hatteras National Seashore also identified ghost crabs as shorebird chick predators or scavengers through the discovery of a radio-tagged Killdeer chick in a burrow (C. Weithman, Virginia Tech Shorebird Program, unpublished data). Similarly,

A radio-tagged Piping Plover chick. Chelsea Weithman

M. Durkin (SUNY ESF, personal communication) documented that radio-tagged Snowy Plovers chicks were depredated by ghost crabs at Gulf Islands National Seashore. Radio-tags have been used on Piping Plover chicks to track sources of predation as well (M. Stantial, personal communication, SUNY ESF).

Although radio telemetry combined with other sign can be incredibly useful in identifying shorebird chick and/or adult predators, there are drawbacks. Radio tags may be expensive (VHF: ~$195/tag: nanotag automated radio telemetry, *see* https://motus.org/: ~$150/tag) and require the use of a receiver (~$700). Using radio telemetry to monitor shorebird young will also require extra permitting and training as the process requires gluing the tags to the backs of chicks. Depending on the size of the chick, and therefore the size of the tag (generally < 3-5% of body weight recommended), the tag may not have a battery life long enough to span the pre-fledge period, and tag retention can also be problematic on pre-fledged chicks. The feasibility of using nanotags to detect mortality sources of pre-fledged chicks is still being tested at several sites along the U.S. Atlantic Coast.

Use of telemetry on predators: Radio or GPS telemetry can provide important information about predator movements and ecology to inform managers. For example, managers can use information from individually-tagged predators to map territories and evaluate the potential overlap with shorebird species of management concern. A study at Cape Lookout National Seashore tracked radio-collared raccoons and documented that seasonal activity patterns varied between males and females throughout the annual cycle, with the raccoon breeding season, and with varied levels of human activity and associated food sources available. The same study examined the

stomach contents of raccoons that had been removed and revealed that there was little direct evidence of predation on sea turtle and shorebird eggs by raccoons and what little predation occurred likely was the result of a small number of individuals (Waldstein 2010, Parsons et al. 2012). A similar study on red foxes is ongoing on Fire Island, NY using the movement, den and diet data of red foxes to best design predation management to benefit nesting Piping Plover (K. Miles, Virginia Tech, personal communication). On Martha's Vineyard, MA, radio-collaring of striped skunks led to valuable information about movement and denning ecology that helped to best inform predation management of this documented predator (Johnson 2016).

Pros:
- Telemetry has long been used in wildlife biology and is considered a reliable method for identifying fates of individual animals. For the purpose of predation management, it is a useful tool, when combined with interpretation of sign, to identify the cause of death for adults and precocial shorebird chicks.
- VHF or GPS telemetry is an important tool for tracking individual predators to best design predation management and to confirm whether assumed predators are actual predators.

Cons:
- Individual tags range in price but average ~$200 for radiotags and >$2000 for GPS tags; further, the accumulation of a decent sample size from which to make inferences can be costly.
- Capture, tagging, and monitoring can be time and resource intensive. Recovery of tags is challenging, and care must be taken to report and not make assumptions about fate of unrecovered tags.
- May require training and additional permits. Tagging birds comes with risk of injury or death, which must be weighed against the benefits of the data collected when permitting.
- Potential issues with short battery life and tag retention; technology and techniques for tag retention are always improving and lowering in cost so this tool will likely become more useful with time.
- By capturing the individual predator for a telemetry study, the individual may become more difficult to capture if managers determine it needs to be removed for predation management.

Resources:
- Wildlife Techniques Manual by Silvy (2012) for methodological considerations.
- Wildlife Radio-telemetry: Standards for Components of British Columbia's Biodiversity No. 5 (http://ericl-walters.org/telemetry.pdf). This manual is directed at land managers and researchers in British Colombia, but it gives a good overview of the technology and considerations for wildlife tracking studies.
- Commonly used, but not all inclusive, list of suppliers[1] for avian or predator tags:
    - ATS: https://atstrack.com/index.html
    - Lotek: https://www.lotek.com/index.htm
    - Microwave telemetry: http://microwavetelemetry.com/
    - Cellular Tracking Technologies: https://www.celltracktech.com/
    - Telonics: http://www.telonics.com/wildlife.php
    - Telemetry Solutions (GPS tracking devices): http://www.telemetrysolutions.com/
    - Biotrack http://www.biotrack.co.uk/
    - Sirtrack website: http://www.sirtrack.co.nz/
    - Wildlife Materials: http://wildlifematerials.com/home.html
    - Holohil Systems Ltd. (https://www.holohil.com/)
    - E-obs GmbH (http://www.e-obs.de/index.html)
    - PathTrack Ltd. (http://pathtrack.co.uk)[1]

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[1] Note: The above list is not an endorsement of any particular manufacturer.

3. Direct observations of predation or mortality event(s)

It is possible to identify nest predators through direct observations of a nest predation event (Colwell et al. 2009, Pearson et al. 2016); however, observations of such events are rare. Similarly, it is also possible on rare occasion to identify predators of chicks and adults through observations of predation (e.g. Kwon et al. 2018). Amat and Masero (2004) identified kestrels and dogs as predators of Kentish Plover in Spain after observing two predation events on incubating adults performing distraction displays. In the Great Lakes region, Merlin were identified as a predator of adult Piping Plover through direct observations of hunting (Roche et al. 2010). Observations of Gull-billed Tern, Fish Crow, and Laughing Gull depredating nests and chicks have been

A Piping Plover chick in a ghost crab burrow, located after direct observation of mortality. Chelsea Weithman

observed in Florida (R. Pruner, personal communication, Florida Fish and Wildlife Resources Commission). While this method is rare by its nature, direct observations clearly provide the strongest evidence of a direct predator-prey relationship and can be a valid line of evidence justifying a predation management program.

Pros:
• Inexpensive and confirmed evidence of an actual predator.

Cons:
• Extremely rare, opportunistic.
• Absence of observations does not equate to absence of activity.
• Cannot be used to identify the frequency or relative importance of a predator or predation event.

4. Predator tracks or sign at nests

Tracks or predator sign around or near the nest bowl can often be used to determine nest failure in the absence of game cameras as well as to identify predator species (Rimmer and Deblinger 1990, Patterson et al. 1991, Schulte and Simons 2015, Pearson et al. 2016). Predator 'sign' refers to evidence, other than tracks, that predators may leave at a site such as scat or fur. Please note that in the database of interviewee responses, different individuals used the term sign to include tracks. For example, corvids often leave beak scrapes and footprints in the sand when depredating a nest and ghost crabs leave imprints of eggs being rolled out of the nest and cashed nearby. Ghost crabs also have been observed to burrow adjacent to or immediately at a nest where they have depredated eggs, and have been observed to consume eggs at the nest

Raccoon tracks. Terry Ross

site, leaving jagged egg evidence in addition to newly cleaned or 'fluffed' sand where the ghost crab filtered the sand removing egg yolk (R. Pruner, personal communication, FFWRC). Accurately documenting predator sign in nesting areas typically requires a high frequency of site visits (i.e., daily), as this type of evidence can disappear quickly in coastal environments. As with track transects, this technique also requires a trained observer skilled at identifying common tracks and other predator sign. Finally, tracks or sign alone at a nest is not confirmation that the predator depredated the nest. At Cape Lookout National Seashore, Hillman (2012) found that multiple predators visited a depredated nest in a single night, but only the first predator

species depredated the nest. Similarly, M. Stantial (personal communication, SUNY ESF) reports that American Oystercatchers have been documented destroying nests, but American Crows came after the depredation and could have been confused as the actual predator without the use of cameras. N. Rowe (USDA Wildlife Services, personal communication) reported that he has observed photos of a ghost crab predation of a shorebird nest followed by a visit the same night from a coyote, but the ghost crab was the sole predator.

Pros*:*
- Can provide information about nest failure, including identification of possible predators.
- Can be an indication that predation is affecting beneficiary species and justify the need for use with other assessment tools (e.g., game cameras).
- Inexpensive and can be assessed at all nests in an area.
- Less invasive than use of cameras or telemetry.

Cons*:*
- Will require daily to every 3-day nest visits. Tracks and 'sign' may disappear quickly depending on substrate and weather conditions.
- Requires skill and knowledge of tracks and predator sign.
- Potential exists for misidentification of predator.
- Predator sign at nest is not confirmation that the identified predator did the depredation versus visited after the depredation.
- Not all predators leave sign or tracks equally.
- Increased human activity near nest sites may attract predators and increase predation rates.

Resources*:*
- Keeping and Pelletier (2014) for information on the use of tracks to understand animal movements.
- Peterson Field Guide to Animal Tracks: Third Edition, by Olaus J. Murie and Mark Elbroch (2005).
- Scats and Tracks of North America: A Field Guide To The Signs Of Nearly 150 Wildlife Species, by James Halfpenny; illustrated by Todd Telander (2008).
- Mammal Tracks and Sign: A guide to North American species, by Mark Elbroch (2001).
- Bird Tracks and Sign: A guide to North American species, by Mark Elbroch (2001).

5. Track/Sign transects

Monitoring track/sign transects is a relatively simple technique for collecting information about potential predator species present at a site, general frequency of use of a site by different predators, and potentially estimates of predator density if distance sampling analyses are used (see http://distancesampling.org). However, the documentation of predators at a site using track transects or other sign is not confirmation that the predator is depredating the beneficiary species, and thus using track transects alone to inform predation management should be used with caution.

Track/sign transects often involve walking systematic, randomized line transects through nesting areas or sites, identifying and counting tracks or other sign (e.g., scat, ghost crab burrows) present and measuring the distance from the transect to the track(s)/sign(s). Other methods involve recording where tracks/sign intersect a line transect. Although the use of tracks/sign surveys can be informative and potentially more cost effective than cameras or telemetry, this type of evidence can disappear quickly in a coastal environment making it difficult to locate and identify (Schulte and Simons 2015). If used, we recommend that repeat sampling is conducted at a site as predators with large home ranges (e.g., coyotes) may only infrequently pass through an area. Track/sign surveys also require the observer to have adequate training for identifying common predator tracks/sign at a site, a skill that is particularly challenging in the typically soft, sandy habitats of beach environments.

Pros*:*

- Can provide valuable information about predators' presence, distribution, and density at a site.
- Relatively inexpensive.

Cons*:*

- Tracks/sign do not equate to abundance of a predator, only presence in an area.
- Tracks/sign may disappear quickly depending on substrate and weather.
- Requires training and/or research on tracks and predator 'sign'.
- Scat can be easily misidentified.
- Tracks/sign do not provide confirmation that the predator is a threat to beneficiary species.

Resources*:*
See resources under method 4 above.

6. Incidental track sightings
Unlike 'track transects' or 'predator sign at nests', incidental track sightings refer to locating predator tracks in a nesting area or at a site while performing other activities. This method can provide information about what predators are present at your site (Struthers and Ryan 2005), but not necessarily information about specific predators targeting shorebird nests, chicks and/or adults. Again, this method will require training or a guide to identify tracks.

Pros*:*

- Inexpensive and can be accomplished while completing other monitoring or research activities (e.g., such as surveys for nests).

Cons*:*

- Requires training or research on tracks and predator 'sign'.
- Potential exists for misidentification of predator.
- Not all predators leave sign or tracks equally.
- Tracks/sign only provide evidence of predator presence at a site; thus, further study is required to determine whether the predator(s) is a threat to the beneficiary species.

Resources*:* See resources under method 4 above.

7. Incidental direct observations of predators
Unlike observations of predation or mortality events above, this refers to observing predators at your site or in a nesting area (Struthers and Ryan 2005). These observations may not provide the link

An incidental raccoon sighting. Robert Colona

between predation and specific predator species but may be important to document opportunistically nonetheless. We recommend use of this method only to identify presence of potential predators.

Pros*:*

- Inexpensive.
- Useful for avian predators, such as gulls and crows, which rarely leave physical tracks or other sign.

Cons*:*

- Rare and may not be appropriate in drawing conclusions about predation.

8. Prey carcasses
Carcasses of beneficiary species found in an area can sometimes be used to identify predator species or taxa. For example, Amat and Masero (2004) identified mammalian predators (to species in a few cases) through Kentish Plover adult carcasses left in the nesting area. Roche et al. (2010) identified Merlin as predators through adult Piping Plover carcasses left in nesting areas. Finding carcasses is rare and opportunistic, due to predators consuming or moving carcasses, or carcasses being degraded rapidly in a coastal environment. The identification of predators through prey carcasses will also require training on what carcasses look like when depredated by different taxa (e.g., mammalian vs. avian) and species (if possible).

Pros*:*

- Inexpensive.

Cons*:*

- Rare and may be difficult to identify predator taxa or species.
- Potential exists for misidentification of predator depending on quality of evidence on carcass.

Resources:
http://www.poultrydvm.com/predator-identifier.php for information on how to identify potential predators from kill signs at sites.

There are a number of resources for poultry farming that can be adapted for use by shorebird managers.
http://ouroneacrefarm.com/poultry-predator-identification-a-guide-to-tracks-and-sign/

9. Historical information

Historical information refers to site-specific past information regarding beneficiaries, predators or both that may influence a manager's decisions about predation management. This could include examining long-term trends at a site, such as whether average numbers of nests/chicks/adults depredated has increased, relative to corresponding increases in predator populations over time. While this technique was not found in the literature review, it was mentioned by interviewees as a way that they made decisions about whether to conduct predation management on a given predator species.

Pros:
• Inexpensive.

Cons:
• Historical information may not reflect current conditions at a site, regardless of the type, quality or quantity of information available.

BP 1 SUMMARY

The first steps in any successful predation management plan are to identify the beneficiary species and the predator species of management concern. In BP 1, we detail and recommend a tiered assessment of beneficiary species. Specifically, a manager should conduct avian species presence/ absence surveys, abundance estimation and productivity assessments to prioritize species that may benefit from predation management. The use of all three assessment methods will ultimately allow the identification of triggers or thresholds for management (*see BP 2*) and serve as a foundation for a robust monitoring and assessment of management efforts (*see BP 8*).

A radio collared red fox (Vulpes vulpes). Matt Kynoch

While managers along the Atlantic Coast have used a variety of methods to identify predators for management, we urge that managers recognize that not all techniques confirm that a predator is impacting and/or limiting the beneficiary species. We recommend managers use as many of the techniques described in this section as possible to identify which predators to manage. We also recognize that there are additional techniques available, and constantly being developed, to monitor predator populations which were not mentioned in our survey responses, but could be useful, including the use of track plates or scent stations to monitor predators. Based on feedback from the interviewees, we also believe that a shorebird-specific field guide of predation sign, although not error proof, would be a useful tool for managers that could be developed if funding were available. We also recommend managers be trained in identifying scavenging versus predation events, and be trained in identifying animal tracks and scat. Though, even with training, misidentification can occur (Morin et al. 2016), so using multiple methods to identify predator activity is recommended.

BEST PRACTICE 2: IDENTIFYING STRATEGIES, TRIGGERS, AND PRIORITIES FOR LETHAL AND NONLETHAL MANAGEMENT

WHY IS THIS IMPORTANT?
Managers often ask:
- *When should I start predation management at a site once beneficiary species and predators have been identified?*
- *When should I stop predation management at a site?*

These are important questions that a manager must consider prior to implementing predator management. These questions may lead managers to develop 'triggers' or 'thresholds' for starting and ending predation management. Although there are no simple rules to answer the questions of *'when should I start and/or stop?'* it will be beneficial to consider what triggers and/or thresholds are appropriate and feasible at your site(s). Often associated with these decisions is the need to identify an overall predation management strategy and a method for prioritizing sites if resources are limited. These topics are covered in this BP.

CONSIDERING PREDATION MANAGEMENT STRATEGIES PRIOR TO IDENTIFYING TRIGGERS
Many different types of 'strategies' exist for managing predators at a site. One of the biggest challenges that managers face is trying to decide between lethal and nonlethal control methods, and/or the mix of methods to use. The scientific literature offers some perspective, especially when it comes to the management of native predators. Foremost, managers should recognize that wide-scale human alteration of landscapes (e.g., connection of islands to mainland via causeways, human development, habitat fragmentation, human food subsidies) has caused many native predator species to increase in abundance such that they rival the impacts of non-native invaders in ecosystems (Carey et al. 2012, Goodrich and Buskirk 1995). Of course, these same drivers of altered predator populations also directly impact the populations of beneficiary species. Whenever possible, the most sustainable management strategy is to address the underlying drivers of the altered predation landscape (e.g., origin of non-native predators or drivers of unnaturally high predator densities) and to then use predation management as a last resort.

If predation management is necessary, setting appropriate triggers and thresholds depends entirely on the strategy being employed. It is essential to work closely with USDA-Wildlife Services, state furbearer biologists, and/or the group conducting predation management throughout this process, as they may have input on the most effective strategy for your site or situation. Below are a few commonly employed predation management strategies to discuss with your predation management partners.

1. 'Integrative' management
This management strategy, sometimes also called comprehensive management, recognizes that: 1) predators can be beneficial, damaging or both, depending on the situation, 2) monitoring and surveys are conducted to determine what predators are present, which predator species are causing predation, the level of predation, and predator population levels, 3) there are thresholds for action to help determine when a management response is needed, 4) a combination of lethal and nonlethal control techniques are implemented, and 5)

monitoring of predator and prey populations continues to determine effectiveness of control techniques utilized. Integrated management often includes multiple methods for short-term and long-term prevention of predation. The methods implemented can vary and are adapted based on monitoring efforts, predator species present, predation levels, and other factors. This strategy can include lethal removal of predator species known or suspected to predate nests, young and/or adults of beneficiary species at a site often in combination with nonlethal methods. For example, lethal and nonlethal techniques can be used to manage all potential predators at a site for the entire nesting season (A. Vashon, USDA Wildlife Services, personal communication). The intensity of and types of methods may change as a season progresses, either due to changes in predators and predation risk or increased use of beaches by humans. This strategy can involve individuals or agencies (e.g., USDA Wildlife Services) conducting the management activities at a site for the duration of a breeding season

A trapped Virginia opossum (Didelphis virginiana). Robert Colona

who are on call and available to adapt to emerging predation issues. The Maine Department of Inland Fisheries and Wildlife has used integrated predation management for the entire nesting and brood-rearing season with success and may serve as a resource for managers considering this approach (L. Tudor, personal communication, MDIFW; A. Vashon, personal communication, USDA Wildlife Services, see details in *Supplemental Material BP 2: Tools for Prioritizing Predation Management*). In some cases, managers may include 'maintenance management' in an on-going integrated management plan. A maintenance management strategy refers to repeatedly, often annually, managing a known population of predators at or near a breeding site of a beneficiary species. For example, if a manager is responsible for a shorebird breeding island and knows that the predator population source is on the mainland, the manager may choose to manage the mainland site annually to help reduce the level of recruitment on the island. In other contexts, maintenance management refers to annual predation management at a site based on a long-term management plan, even when predator abundances may be low at a given site.

Please review the Rhode Island demonstration site case study which compared the outcomes for nonlethal management alone versus a combination of lethal and nonlethal management (*Supplemental Material: Demonstration Sites, Rhode Island*). This study could help guide the design and assessment of an integrative management program.

2. 'Emergency response' or 'reactive' management
This strategy is conducted during the breeding season and entails targeting specific predator species, or sometimes individuals of a given species, that have been observed depredating nests/chicks/adults of beneficiary species. However, an emergency response can also be included in an integrative management plan for a site.

SHOREBIRD TRIGGERS AND THRESHOLDS (DB 2.1, 2.3)
Once an overall predation management strategy is selected, a manager may then design appropriate triggers or thresholds. Individual responses to the question of what types of triggers were used for lethal and nonlethal management are found in the database questions 2.1 and 2.3. We also searched the literature for evidence of triggers or thresholds.

There was no consensus on shorebird triggers or thresholds for management actions in the interviews or literature, and the majority of interviewees stated that none or only qualitative triggers or thresholds are used. Only 8 (28%) of interviewees indicated that any quantitative triggers were used for lethal management, and only 6 (21%) used quantitative triggers of any sort for nonlethal management. We recommend that the reader reviews the specific responses in the associated database in addition to reading the summary below.

Shorebird-related triggers were most often related to reduction in breeding productivity or population size. Below are the few examples of quantitative thresholds that we discovered during the development of this BP document. Some of these thresholds triggered immediate management while others delayed management

until the next season; details are provided in sections 2.1 and 2.3 (*Supplemental Material: Database of Interview Responses*)

- Predation management is implemented on Martha's Vineyard, MA by Biodiversity Works if Piping Plover productivity is less than 1.25 chicks/pair.

- Managers with Biodiversity Works on Martha's Vineyard, MA and Cape Lookout National Seashore, NC use a threshold of 26-50% of chicks depredated (MA) or nests depredated (NC) to institute predation management.

- Managers at Chincoteague National Wildlife Refuge, VA, Cumberland Island National Seashore, GA, and an anonymous site use a threshold of 0-25% of nests lost to trigger management; whereas, at some sites in FL a trigger of 76-100% of nests lost is needed to trigger management.

- Managers in Maine have triggers for both intensive and limited predation management (*Supplemental Material BP 2: Tools for Prioritizing Predation Management*). Maine defines intensive predation management as activities conducted using all available methods (lethal and nonlethal) for the entire nesting season. Maine's threshold for implementing intensive predation management at one or more sites is when the statewide nesting population of Piping Plovers is approaching <50 pairs, state productivity is <1.6 fledglings per pair, and predation is a primary cause of population decline or reduced productivity. Their individual site criteria for implementation of intensive predator management when predation is identified as a limiting factor is as follows: a) sites with productivity <1.6 chicks fledged/pair for at least two of the most recent three years; or b) sites where immediate removal is required due to adults being depredated, there is a sudden sharp increase in predator numbers, or a "smart predator" is depredating the site; or c) sites that have had four or more nesting pairs documented at least once since 1981; or d) sites that have functional habitat that can support 4 or more pairs.

Maine defines *limited predation management* as predation management activities only conducted on case-by-case basis primarily using nonlethal methods. Maine's threshold for limited predation management is when the statewide nesting population of Piping Plovers is > 60 pairs *and* annual productivity is > 1.6 chicks fledged/pair for at least two of the most recent three years.

- In other instances, flyway managers have examined trends in productivity (fledglings/pair) over time and have subsequently implemented predation management if there was a noticeable drop in productivity due to predation. Another future strategy, worthy of exploration, is to set quantitative triggers based on model-derived recovery-unit, or state-level targets for Piping Plover or American Oystercatcher productivity. However, if robust productivity estimates for beneficiary species are not available for a site, it may be difficult to utilize productivity data currently to set specific shorebird thresholds or triggers for management. Many factors in addition to predation can influence productivity rates, thus we recommend managers use techniques described in *BP 1* to identify the link between predation and beneficiary species.

An American Oystercatcher nest. Katie Walker

PREDATOR TRIGGERS AND THRESHOLDS (DB 2.2, 2.4)

We found that only a minority of flyway managers used quantitative or qualitative predator-related triggers or thresholds to initiate predation management.

- 34% of interviewees used an increase in predator track abundance as a trigger for management.

- 28% of interviewees used increased observation of predators as a trigger for management.
- 34% of interviewees used increased observation of predation events as a trigger for management.
- 31% of interviewees used increased observation of predator sign at nests as a trigger for management.
- 14% of interviewees used increased observation of prey carcasses as a trigger for management.
- 3% of interviewees used historical information on predators as a trigger for management as present-day data were unavailable.

We recommend readers review the database details in questions 2.2–2.4 (*Supplemental Material: Database of Interview Responses*) for more information.

HOW TO PRIORITIZE MANAGEMENT BY SITE AND/OR BENEFICIARY SPECIES (DB 1.3)

Managers are frequently responsible for multiple sites and/or beneficiary species at a single site. However, most managers have limited funding for predation management and therefore must often prioritize which sites, or for which avian species, to manage for predators in a given breeding season or year. These decisions can be based on a variety of factors that may be biologically based (e.g., beneficiary or predator species information) and/or logistically based (e.g., site access, funding). Most often several factors must be considered simultaneously at an individual site.

Below are considerations identified by managers along the Atlantic Flyway during the interview and review process. These considerations may be weighed differently depending on site- or project-specific objectives and constraints.

A Piping Plover chick. Jim Fenton

1. Presence of beneficiary species
What avian species are present at each site? At the very basic level, the presence of priority beneficiary species at certain sites versus others can help prioritize sites where management should occur.

2. Number or density of beneficiary species
How many pairs of avian species are nesting at each site? The number of nesting pairs at sites under consideration can help prioritize management. Sites supporting a greater number of pairs may yield a greater return on investment from implementing predation management, assuming other factors at the site are favorable. Several flyway managers referred to this as 'getting the biggest bang for your buck.'

3. Listing status of beneficiary species
What is the conservation status (federal and/or state and/or other rankings) of beneficiary species at each site? Managers used the listing or conservation status of species at a site to prioritize management. When beneficiary species are not state or federally listed, some managers use other conservation rankings. For example, in Florida, managers consider the biological vulnerability score of different species when prioritizing sites (Milsap et al. 1990).

4. Productivity information of beneficiary species
What was the target species productivity (e.g., # eggs hatched, chicks fledged/pairs monitored) at each site the previous year? What is the trend in productivity over time (multiple years)? How much nest/chick/adult loss can be attributed to predation, both in the previous year and over time? Managers use productivity information, both from the previous breeding season and over multiple years, to help prioritize sites for predation management. However, several other factors (e.g., weather, overwash, etc.) may also contribute to low productivity at a site. Therefore, it is important to identify to what extent nest/chick/adult loss was attributable to predation, both in the previous year and over time, if possible.

5. Landowner permission and/or stakeholder opinions

Do I have landowner permission to implement predation management? Would any of the stakeholders be opposed to predation management? Predation management can be a controversial topic, especially lethal methods, and therefore gaining permission and evaluating potential stakeholder opinions on the subject will be essential and may also help in site prioritization. For example, if a manager has a site where the landowner is not comfortable with predation management, regardless of avian species productivity or other factors, then that site might be given lower priority.

6. Human use at the site

Is there a high level of human use at the site? Due to safety concerns as well as the sometimes controversial nature of predation management, the amount or type of human use at a site may affect prioritization. Public outreach at these sites (**as described in** *BP 6*) is appropriate to educate recreationists and discourage behaviors that may attract predators to the area, such as leaving trash behind, feeding wildlife, etc.

7. Logistics

Does it make sense logistically to conduct predation management at the site? How difficult is the site to access? The logistics of a site may influence a manager's prioritization decisions.

8. Location of site relative to others/Degree of isolation

How close is this site to other sites, for beneficiary species and recolonizing predators? Is this site close to unoccupied or under-occupied sites? If predation management is effective in increasing reproductive output of beneficiary species, will the chicks produced have locations close by to nest? If predators are removed, will they quickly recolonize? In some instances, considering the proximity of a site to other sites may factor into a manager's decision to implement predation management. For example, if the manager is hoping to increase the distribution of nesting pairs, or to increase the number of pairs at unoccupied or under-occupied sites, she/he may prioritize a site higher if it is closer to other sites with active management. On the other hand, the manager may choose not to select a site if it is surrounded by other sites that are not actively managed. In this case, the benefits of predation management may be diluted by those adjacent to unmanaged areas, as predators may quickly recolonize if the site is not isolated by sufficient barriers, e.g. deep water or strong currents.

9. Previous predation management attempts

Have you implemented predation management at this site before? Was it effective at decreasing nests/chicks/ adults lost to predators or increasing productivity? Were management techniques effective at removing or deterring predators? The knowledge gained from previous attempts at predation management at a site can provide information to help prioritize sites.

10. Will removal efforts increase the health and viability of the targeted predator population at a given

site? Many times, managers are making challenging decisions to lethally or nonlethally manage native predator populations to benefit native beneficiary species. In some cases, the native predator populations are overabundant due to human subsidies. In others, they may be experiencing density-dependent diseases (e.g., sarcoptic mange) due to artificially high densities. In these cases, lethal management of the predators may reduce the predator population below carrying capacity and actually improve the health and viability of the native predator population.

11. Additional resources for determining how to prioritize sites for management

During interviews and the review process of this document, numerous partners shared details on how their entities make decisions about predation management. These tools are valuable and should serve as models of how managers integrate numerous factors in their adaptive decision-making. Each is described briefly below and provided in *Supplemental Material: BP 2: Tools for Prioritizing Predation Management*.

> **A. Florida panhandle predator matrix (see details in *Supplemental Material: BP 2: Tools for Prioritizing Predation Management*)***:* Florida developed and uses a standardized method for distributing funding for predation management among land managers in the Florida Panhandle, where

productivity estimates are not available for all sites. This tool uses a ranking system for five state-listed coastal-nesting bird species (American Oystercatcher, Wilson's Plover, Snowy Plover, Least Tern, and Black Skimmer). The tool allocates 'points' based on the number of breeding adults for each species at each site, site access logistics, and predator recolonization rates (e.g., site remoteness such as barrier island versus mainland beach).

B. Predation management decision tree *(see details in* *Supplemental Material: BP 2: Tools for Prioritizing Predation Management*)*: This tool was developed to guide allocation of resources to predation management in an unspecified state. It takes the user through a series of questions to assess what type of predation management would be useful and needed. An example of its use is provided.

C. Maine Piping Plover Protection Management policy *(see details in* *Supplemental Material: BP 2: Tools for Prioritizing Predation Management*)*: This tool was developed by biologists in Maine to guide predator management decisions to benefit Piping Plovers. Details are provided on rationale, methods, triggers, and assessment of predation management.

D. Predation management structured decision-making (SDM) workshop summary *(see details in* *Supplemental Material: BP 2: Tools for Prioritizing Predation Management*)*:
In October 2017, a predation management workshop was held at Parker River National Wildlife Refuge to devise a structured decision making (SDM) framework for determining when, where, and how much (lethal) predator removal to undertake to efficiently meet specific productivity objectives for Piping Plovers and Least Terns in Maine and Massachusetts. Participants included managers and scientists from various organizations (state and federal agencies, NGOs, and universities). A large part of the workshop was dedicated to using previously collected productivity data to examine quantitative methods to help determine site prioritization. The workshop was considered a pilot effort, with methods that could be expanded for use with additional species and states. This framework is presented here and may be helpful to others throughout the flyway who have previously collected or are planning to collect extensive productivity data.

BP 2 SUMMARY

Before selecting an overall predation management strategy, managers should attempt whenever possible to first identify the driving factors behind the altered predator populations and communities that are impacting the beneficiary species and use lethal and nonlethal control only when those underlying factors cannot be addressed and when predation is limiting the beneficiary population.

When a predation management strategy is selected, it is ideal for managers to have detailed information about the interactions between predators and beneficiary species to guide predation management decisions (*see BP 1*).

However, the scenarios that managers more typically face are characterized by imperfect information, inadequate resources, and the necessity of making decisions based on minimal available information. Additional work across the flyway is needed to take the data collected during site assessment (*BP 1*) and project monitoring (*BP 8*) to develop triggers or thresholds for management, ideally in a structured decision-making framework as described in *Supplemental Material BP 2: Tools for Prioritizing Predation Management*. Managers use a variety of qualitative and quantitative metrics to prioritize sites for management when resources are limited. We strongly recommend the local adaptation of the Florida Panhandle Predation Matrix, the Predator Management Decision Tree, the Maine Piping Plover predation management plan and potentially the use of a strategic decision-making framework if prioritization is needed.

BEST PRACTICE 3: METHODOLOGICAL CONSIDERATIONS FOR LETHAL PREDATION MANAGEMENT

WHY IS THIS IMPORTANT?

After you have determined the beneficiary species, the predator species you would like to manage, the site(s) where you would like to implement management, the type of management strategy that is most appropriate, and triggers for starting or stopping predation management, you may need to consider different types of lethal management techniques.

Ninety-seven percent of Flyway managers interviewed are currently using, or have used in the past, some form of lethal predation management, including trapping, shooting, egg and nest destruction (e.g., egg oiling, egg addling, physical destruction of nests/eggs, etc.), poisoning, and fumigants (see Table 2 below for frequency of use). Common questions for managers who are new to predator management include: 1) what lethal techniques are used for specific predator species? 2) who do managers use to conduct the predation management? and 3) what is the known or perceived effectiveness of lethal control methods? Below is a summary of interviewees' responses to these questions and a comprehensive review of different methods of lethal control. As with nonlethal control methods (see BP 4), we strongly encourage managers to work with predation management partners to design an overall management strategy (see BP 2) that combines the appropriate methods.

1. What lethal techniques are used for specific predator species?

The type of predator or predators you are attempting to target will determine what specific technique or techniques are used. Table 2 provides a summary of the frequency of techniques used by interview respondents to target specific predator species throughout the flyway.

Table 2. Lethal management techniques used to target specific predators along the Atlantic Flyway as indicated by 29 interview respondents.

Lethal Predation Management Techniques						
	Trapping	Shooting	Nest/Egg Destruction	Poisoning	Fumigants	**Total # Techniques by Predator**
Raccoon	X	X	-	-	-	**2**
Red Fox	X	X	-	-	X	**3**
Coyote	X	X	-	-	-	**2**
Feral cat	X	-	-	-	-	**1**
Dog	-	-	-	-	-	**0**
Bobcat	-	-	-	-	-	**0**
American Mink	X	X	-	-	-	**2**
Feral Hog	X	X	-	-	-	**2**
Virginia Opossum	X	X	-	-	-	**2**
Striped Skunk	X	-	-	-	-	**1**
Rat	X	X	-	-	-	**2**

	Trapping	Shooting	Nest/Egg Destruction	Poisoning	Fumigants	Total # Techniques by Predator
Nine-banded Armadillo	X	X	-	X	-	3
Herring Gull	X	X	X	-	-	3
Great Black-backed Gull	X	X	X	-	-	3
Laughing Gull	X	-	X	-	-	2
Crow spp.	X	X	X	X	-	4
Common Raven	-	-	-	X	-	1
Common Grackle	X	-	-	-	-	1
Great Horned Owl	X	X	-	-	-	2
Northern Harrier	-	-	X	-	-	1
American Kestrel	-	-	-	-	-	0
Merlin	-	-	-	-	-	0
Peregrine Falcon	-	-	-	-	-	0
Black-crowned Night Heron	-	X	X	-	-	2
Heron spp.	-	-	-	-	-	0
Iguana spp.	-	-	-	-	-	0
Snake spp.	-	-	-	-	-	0
Ghost Crab	X	-	-	-	-	1
Fire Ant spp.	-	-	-	-		0
Total Responses by Technique	**17**	**13**	**6**	**3**	**1**	

2. Who should conduct the management?

The lethal management technique or techniques used may determine the agency or group to conduct management. Table 3 summarizes the agencies or groups that flyway managers interviewed have used or are currently using to conduct management. It is extremely important when considering lethal techniques that you work with the appropriate USDA Wildlife Services and/or other experienced personnel prior to and during implementation. Every state differs in permitting processes for mammalian, avian, and other predator management, and certain techniques may not be allowed in certain states. Before beginning any lethal control of predators, land managers should contact the appropriate personnel to seek advice on permitting for and implementation of all types of predation management. Please see *BP 7* for details on permitting requirements.

Table 3. Agencies or groups chosen to conduct lethal management activities along the Atlantic Flyway as indicated by 29 interview respondents. Unless 'Own Staff,' then these organizations conducted the activities on behalf of the interview respondent.

Lethal Predation Management Techniques						
	Trapping	Shooting	Nest/Egg Destruction	Poisoning	Fumigants	Total # Techniques by Predator
USDA Wildlife Services	18	16	3	3	1	41
Own Staff	11	9	6	1	0	27
Private Contractor	7	3	0	0	0	10
State Wildlife Services	1	1	0	0	0	2
State Agency Staff	2	1	1	0	0	4
USFWS	1	0	0	0	0	1
Volunteers	0	2	0	0	0	2
Total Responses by Technique	**40**	**32**	**10**	**4**	**1**	

3. Is there any information about the effectiveness or perceived effectiveness of lethal techniques?

Although the effectiveness of methods may vary depending on the site and year, we have provided summary information in Table 4 from flyway managers regarding the perceived effectiveness of lethal techniques they use. In BP 8, we discuss methods for measuring effectiveness in detail.

Table 4. Number of interview respondents (n=29 total interviewed) using specific lethal techniques, and reported affects of each technique on beneficiary and predator metrics in the same season that management was conducted along the Atlantic Flyway.

Lethal Predation Management Techniques					
	Trapping	Shooting	Nest/Egg Destruction	Poisoning	Fumigants
Increased/High Rates of Hatching	18	10	2	4	0
Increased/High Rates of Fledging	15	9	2	3	0
Increased/High Rates of Adult Survival	8	3	1	1	0
Increased/High Beneficiary Population Size/Pairs	3	2	1	0	0
Beneficiary Recolonization of Sites	3	2	0	0	0
Decrease in Predator Occupancy/Abundance	15	5	5	3	1
None	0	6	2	0	0
N/A (Did Not Assess)	4	4	1	0	0
Number of Respondents by Technique	**27**	**23**	**9**	**5**	**1**

METHODS OF CONTROL (DB 3.1-3.6)

In the sections below, we present specific methodological information regarding each of these different lethal techniques for predation management. There is no simple recommendation as to which technique is preferred over another. We also note that in most cases, the actual capture technique itself is not lethal, but after the capture the animal is humanely dispatched. The technique used will depend on the predator species, location, and the experience and personal preference of the individual(s) implementing the management action. See Tables 2–4 above, and the detailed responses in the database for sections 3.1–3.6, if you seek details on how different respondents use these techniques. This section is a reference tool for managers to discuss and evaluate which specific lethal tools would be appropriate at their site(s).

TRAPPING (DB 3.2)

Of those utilizing lethal management techniques, trapping (using either killing traps or restraining traps with subsequent dispatch) was the most implemented method with 96% of respondents indicating that they are currently or have used trapping in the past. Humane dispatch guidelines are provided by the American Veterinary Medical Association (AVMA, see S7.6, Free ranging wildlife, https://www.avma.org/KB/Policies/Documents/euthanasia.pdf) and is generally defined as the ending of the life of an animal in a way that minimizes or eliminates pain and distress.

Trapping Mammalian Predator Species

If lethal management techniques are utilized, trapping is an efficient, effective, and selective method to implement. One reason is that unlike other lethal tools (e.g, shooting), once a trap is set, it can operate 24 hours a day/7 days a week or as permitted. Traps can be used to capture animals in areas where shooting is not an option due to local ordinances, regulations, and/or human safety concerns. Regulated trapping is supported by the Wildlife Society (https://wildlife.org/wp-content/uploads/2016/04/SP_TrapsTrappingandFurbearerManagement.pdf) and by the Association of Fish and Wildlife Agencies (AFWA). Trappers should be required to reference Best Management Practices (BMPs) for trapping mammals that can be found on the Association of Fish and Wildlife Agencies (AWFA) website (https://www.fishwildlife.org/afwa-inspires/furbearer-management and https://furbearermanagement.com). Trapping BMPs are intended to inform professionals about trap-types and trapping systems considered to be state of the art in animal welfare and efficiency. Evaluations and recommendations in the trapping BMP documents are based on animal welfare, efficiency, selectivity, practicality, and safety. The trapping BMPs provide a list of traps by species that

meet or exceed the BMP criteria and trappers should be required to use BMP-approved traps. BMP-approved traps can be found at http://furbearermanagement.com/bmp-search-portal/. In addition, most Animal Care and Use Committees now require that only BMP-approved traps can be used for capture efforts.

State furbearer biologists, or their equivalents, should be consulted to ensure all proper permits, procedures, regulations, and state laws are followed. Private, state, and federal lands are not exempt from state-specific regulations and laws regarding trapping. All trapping methods require skill and experience in order to ensure efficient, selective, safe, practical, and humane capture and handling of the target and non-target animals. Individuals not highly experienced in these methods must seek professional training and assistance. Inexperienced individuals attempting to trap risk causing injury to both target and non-target animals, as well as causing the target animal to become trap-shy, making it more difficult to remove. Most states offer free trapper education courses and this should be a required class for any trapper conducting predator management.

1. Foothold traps can be effectively used to capture a variety of mammals if individuals using the traps are properly trained by experienced trappers. The two most commonly used foothold traps are the longspring and coil-spring traps. Each has two jaws, a pan-trigger device, base plate, and one or two springs, although some coil-springs can be fitted with four springs. There are also enclosed foothold traps, also called foot-encapsulating traps, that are species-specific. These traps are designed to specifically capture only raccoons, though they can incidentally capture opossums and gray foxes . Enclosed foothold traps have a hole with a trigger mechanism that is either pushed or pulled to capture the foot.
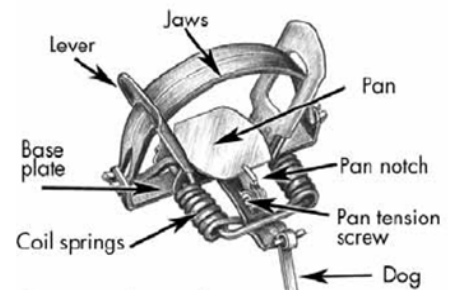
Typical coil-spring foothold traps with components labeled.

Most new traps require adjustments and modifications to operate correctly, efficiently, humanely, and selectively. For example, removing sharp edges, adding swivels, welding J-hooks, and modifying the chain length. Set location of traps is contingent upon the habits of the respective target species, habitat conditions, and presence of non-target animals. Foothold traps should be set so the captured animal does not become entangled. Avoid setting near fences or other entangling objects, such as small trees and rooted, woody stems. Foothold traps can be placed beside of, or in some situations in, travel ways being actively used by the target mammalian predator species. Effective set location and adjustment (e.g., adjusting pan tension), and the use and placement of appropriate baits and lures by trained personnel, also contribute to the efficiency and selectivity of foothold traps. Scent lure or bait is often, but not always, used. An additional advantage is that foothold traps can allow for either the on-site release of non-target animals since animals are captured alive, or the humane dispatch of captured target animals.

2. Passively-Activated Cable Devices are typically made of stranded steel cable and can be set so that the loop of the cable captures an animal by the neck, body, or foot. Passively-activated cable devices, also called non-powered, use the forward movement of the animal to place and close the cable loop on the animal's body or limb. Passively-activated cable devices may be used as either lethal or restraining devices depending on how or where they are set and the construction of the device. Live capture depends on proper use of loop stops, on the trap check time interval, device set location, and device design features, including cable design type, cable diameter, cable length, lock type, lock size, loop size, anchoring height, anchoring method, shock springs, swivels, and the species captured. A live capture would be desired if the management objective was to trap

Diagram of a passively-activated cable device.

and relocate or if there was a chance of capture of non-target animals. Passively-activated cable devices positioned to capture the animal around the body can be a useful live-capture device. Passively-activated cable devices can incorporate a breakaway feature to release non-target wildlife and livestock where the target animal is smaller than potential non-targets (Phillips 1996). Passively-activated cable devices can be effectively used wherever a target animal moves through a restricted travel lane (e.g., under fences or trails through vegetation). However, if the cable device is set as a restraining trap, avoid setting it under or near fences, as

that will likely result in death of the captured animal due to entanglement. When an animal moves forward into the loop formed by the cable, the device tightens and the animal is held. Cable devices must be set in locations where the likelihood of capturing non-target animals is minimized, but when the possibility exists, the device must be set to safely capture and restrain, but not kill both target and non-target animals. Most states have restrictions or prohibitions on the type and set location of of cable devices; BP 7 provides details and contact information on permit requirements for each state. AFWA provides a reference document on cable devices that discusses the factors that influence cable device performance: https://www.fishwildlife.org/application/files/5515/2002/6134/Modern_Snares_final.pdf

3. Power-Activated Cable Devices use a mechanical feature (e.g., spring) to place or close the loop of the cable on the animal's body or limb. A pushing or pulling force is applied by the animal to trigger the mechanism. It is important to note that power activation only controls the speed and/or direction in which the cable loop is propelled or closed on the animal. The power activation does not constrict or close the loop on the animal. These devices are activated when an animal places its foot on the trigger or pan (e.g., Belisle foot snare) or when an animal pulls a trigger with its mouth (e.g., Collarum®). Power-activated cable can be nonlethal restraining devices when set properly to avoid entanglement situations or if various components are added (e.g., breakaway device, loop stops, relaxing locks, etc.) as described in the paragraph above. In some situations, using foot cable devices to capture wildlife is impractical due to the behavior or morphology of the target species, or the risk of bycatch of non-target mammals. Collarum®-type traps can be very selective due to the triggering mechanism and are primarily used to target red foxes, gray foxes, coyotes, and dogs.
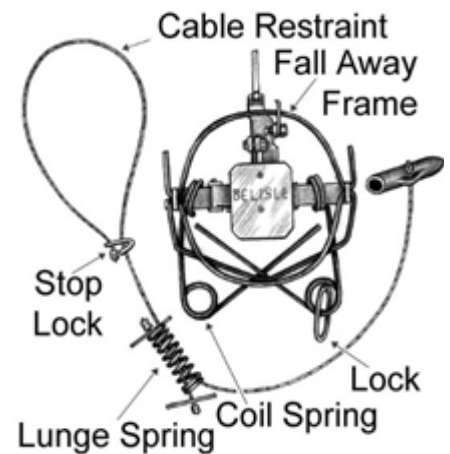
Example of a cable foot device (Belisle foot snare).

4. Cage or Box Traps are restraining traps and come in a variety of styles to live-capture animals. They are designed so that when the animal enters the trap, it will step on a treadle, causing the trap door to close and preventing the animal from exiting. Cage or box traps are usually rectangular and are made from various materials, including metal, wire mesh, plastic, and wood. These traps are well suited for use in residential areas and work best when baited with foods attractive to the target animal. Cage or box traps are generally portable and easy to set-up, especially for species smaller than a coyote (e.g., raccoons). However, they are also more expensive and bulkier to transport than other trap-types (i.e., foothold, cable devices), which may limit the number of cage or box traps that can be set on a trapline. They are also not very effective or efficient for capturing larger mammals (e.g., coyotes), except for the young or juveniles.

5. Bodygrip Traps, including the name brand Conibear®, are designed to cause the quick death of the animal that activates the trap. Bodygrip traps operate in a similar manner as the common mouse trap. Bodygrip traps consist of a pair of rectangular wire frames that serve as rotating jaws and are powered by one or two springs. When the trigger is activated, the rotating jaws strike the animal's neck or chest, killing the captured animal with a quick body blow. Bodygrip traps should be placed to ensure the rotating jaws close on either side of the neck of the animal to ensure a quick death. Bodygrip traps are lightweight, remain functional in adverse weather conditions, and can be easily set, depending on the size of the trap. Because they are quick-kill traps, bodygrip traps minimize the amount of time an animal is live restrained and the animal captured and the trap are more likely to go undetected by the public. A bodygrip trap is also effective at capturing target animals that have become trap-shy to other trap-types. Safety hazards and risks to people using bodygrip traps are usually related to setting, placing, checking, or removing the traps. Bodygrip

Standard bodygrip trap with components labeled.

traps present a risk to non-target animals and will kill any non-target captured. The selectivity of the traps can be enhanced by set location, trap size, trap set type, lures, and baits. When using bodygrip traps, risks of non-

target capture can be reduced by using recessed sets (placing trap inside a cubby, cage, or burrow), restricting openings, or by elevating traps. For more information on techniques and recommendations for improving bodygrip trap selectivity, including designs on recessed sets, go to: https://www.fishwildlife.org/application/files/9215/2106/2322/AFWA_Bodygrip_2017_final_compressed.pdf. Most states have restrictions on size and set location of body-grip traps. Massachusetts prohibits their use except in emergency situations related to human health (https://www.mass.gov/service-details/trapping-information); *BP 7* provides details and contact information on permit requirements for each state.

6. Snap Traps are recommended as a trapping BMP for weasels; https://www.fishwildlife.org/application/files/4415/2105/3337/WeaselBMP_final.pdf. Snap traps may be placed inside plastic or wooden boxes to selectively target weasels as needed.

Trapping Avian Predator Species

Federal and state permits are required to "take" any migratory birds. "Take" includes capture and relocation and lethal removal/dispatch. Additional permits from the U.S. Geological Survey Bird Banding Laboratory are necessary if banding birds, which is recommended for relocation efforts. Land managers should contact appropriate state and federal (See BP 7 for details) agencies before beginning any lethal control or relocation of birds. As with trapping mammals, only permitted and skilled individuals should conduct activities to ensure humane treatment of target and non-target animals, and safety of field staff. The traps described below are nonlethal and thus require subsequent humane dispatch if animal is not relocated. There is no simple recommendation for which trap will be used in a given situation. The target predator species and experience and personal preference of the trapper will often determine which trap is used.

1. Bal-chatri traps are a relatively small, versatile, and effective trap that can be modified to capture individual species of hawks and owls. Live small mammals or birds are used to lure raptors into landing on the trap, where nylon nooses entangle its feet and hold the bird until it is released.
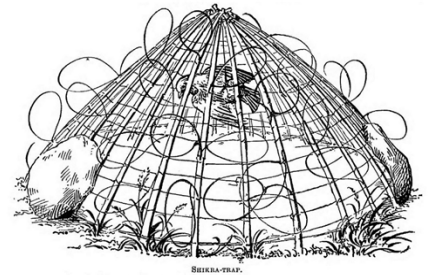
An example of a bal-chatri trap. Wikipedia commons.

Bal-chatri traps are commercially available, but also are fairly easy to construct. There are several different sizes and shapes of bal-chatri traps, including the square-shaped, cone-shaped, and Quonset hut type bal-chatris. Camouflaging traps is important; spray paint them before nooses are attached to match the background. Bal-chatri traps should be weighted or secured with a 5– to 10–lb weight (exercise and barbell weights work well) or tied to a flexible branch to keep a trapped bird from dragging the trap and breaking the nylon nooses.

The Quonset hut type bal-chatri was designed for trapping large hawks and owls. The trap is often made from 1–inch chicken wire, formed into a cage that is 18 inches long, 10 inches wide, and 7 inches high at the middle. The floor consists of 1-inch mesh welded wire with a lure entrance door and steel rod edging for ballast. The top is covered with about 80 nooses of 40–pound test monofilament fishing line.

Selection of bait animals used in bal-chatri traps depends on the size and shape of the bal-chatri, as well as the species of hawk or owl being targeted. Rock pigeons (*Columba livia*), European starlings (*Sturnus vulgaris*), farmed quail, house mice (*Mus musculus*), and other small rodents can be used as bait.

Bal-chatri traps are effective only when placed where a perched or hunting raptor can see them. When placing traps, consider issues such as vehicles, large animals, and people who might crush, damage, or move the trap. These traps must be monitored continuously and caught birds removed as soon as possible, as the nooses will eventually break and release the bird.

2. Bow nets are remotely triggered from a nearby observation site to capture targets within range of the net. Once the net is triggered, the net envelopes the target birds similar to a suitcase when closed. These nets are normally used for raptors but may also be used for European Starlings, shorebirds, and other species using visual bait and/or conspecific decoys.

3. Drop nets are suspended over a pre-baited site and manually or remotely triggered to drop on target birds from a site that overlooks the net, such as a bridge or rooftop, or from a blind. Decoys may also be used to enhance the effectiveness of drop nets.

4. Cannon/rocket and 'Whoosh' nets use bait or decoys to attract a target species to an area that is completely contained within the dimensions of the extended net ('capture zone'). When triggered, explosives or an air pressure cannon propel cannon and rocket nets at a high rate, preventing most birds from escape. Cannon or rocket netting is normally used for larger birds such as turkey or waterfowl but can be used to capture a wide variety of bird species. 'Whoosh nets' provide an alternative to cannon or rocket netting with a similar set up using bait or decoys and a capture zone but are generally smaller and are deployed using tension-related force (e.g., bungie cords or springs) as opposed to explosives or air pressure cannons.

A bow net example that is commercially available for bird capture. © Wildlife Control Supplies. We do not endorse this company but use as an illustration.

5. Pole traps are effective, especially where perching sites are limited. Pole traps consist of a specially modified foothold trap secured onto the top of a post or pole (using a wooden post, a metal pole, or PVC pile) to attract hawks and owls that use it for a hunting perch. When landing on the pole, the bird depresses the trap pan and the padded trap jaws will firmly but safely capture it. The trap is secured to a wire 'slide' that allows the trap and captured bird to slip to the ground (for images of this and other avian capture devices, see http://www.raptorresearchfoundation.org/files/2015/10/Chapter-12.pdf).

Making adjustments to a drop net system. U.S. Air Force

Foothold traps (a 1½ double-coil spring is a useful size) must be weakened by removing one spring or by heat-treating before they are used for capturing hawks and owls. The jaws must be well padded with surgical tubing and wrapped with electrician's tape or foam rubber to protect the bird's leg.

The use of pole traps is prohibited in some states, and the USFWS has issued guidelines on their use for capturing problem hawks and owls. See *BP 7* for details on who to contact within your local USDA Wildlife Services office, state wildlife agency, and the regional USFWS permits office for authorization to use this capture method.

6. Mist nets are more commonly used for capturing small-sized birds, but larger mesh sizes are also available for capturing larger birds, such as small raptors. A mist net is a fine black silk or nylon net usually between 3 and 10 feet wide and 25 and 35 feet long. Net mesh size determines the bird species that could be caught and overlapping pockets in the net cause birds to entangle themselves when they fly into the net. Attractants such as decoys and electronic calls may also be used to enhance the effectiveness of mist nets.

7. Swedish Goshawk traps are a relatively large, semi-permanent trap that consists of two parts: a bait cage (such as a 3 x 3 x 1-foot cage made from 1-inch mesh welded wire) and a trap mechanism consisting of a wooden or metal "A" frame, heavy springs to pull the doors closed, nylon netting or chicken wire, and a trigger mechanism (often a hinged stick) mounted on top of the bait cage. A hawk or owl dropping into the trap will trip the trigger mechanism and safely be trapped inside. Rock pigeons are good bait because of their size, activity (movement is important for attracting hawks and owls), pest species status, and ease of care.

A Swedish goshawk trap. USDA

8. Other traps are varied in form and function and include, but are not limited to verbail traps, phai traps, dho-gaza traps, spring-net traps, noose carpets, ladder traps and the

German "butterfly" trap. These traps are less commonly used and thus we recommend further details be explored at https://www.fws.gov/migratorybirds/pdf/policies-and-regulations/MBPM-4.pdf, if interested in these additional methodologies.

Trap Monitors

Trap monitors and cellular game cameras are devices that send a radio signal or picture to a receiver or cell phone if a set trap is disturbed and alerts field personnel that an animal may be captured. It is important to check state regulations as different states allow or disallow this technique to count as a 'trap check.' For example, in North Carolina, a trap must be physically checked. Trap monitors can be attached directly to the trap or attached to a string or wire and then placed away from the trap in a tree or shrub. When the monitor is hung above the ground, it can be detected from several miles away, depending on the terrain in the area. Cellular game cameras can be placed near trap sites. There are many benefits to using these remote monitoring techniques, such as saving considerable time when checking traps, decreasing fuel usage, prioritizing trap checks, and decreasing the need for human presence in the area. In addition, the resulting increased efficiency of trap checks could decrease the amount of time captured target or non-targets would be restrained. By reducing the amount of time targets and non-targets are restrained, pain and stress can be minimized, and captured wildlife can be addressed in a timely manner, which could help ensure non-targets are released unharmed. However, trap monitors are subject to failure and users need to test the trap monitor often to assure it is working properly. Batteries need to be checked and replaced frequently to prevent monitor failures from occurring. This assures that an animal won't succumb in a restraining trap due to the monitor failing to detect it. Many companies that sell trapping supplies will also sell trap monitors when applicable. While we do not recommend any specific supplier[1], see the list below for examples of trap monitoring devices:
- https://www.trapmon.co.nz/trapmontraps
- https://www.wildlifecontrolsupplies.com/removal/Trap-Alert-Packages.html
- http://trapsmart.com/
- https://www.servsensor.com/
- http://www.remotisystems.com/

[1] Note: The above list is not an endorsement of any particular manufacturer".

Disadvantages of Trapping

There are common disadvantages to trapping that all the above methods share. Some animals, species, and/or age groups avoid certain traps (i.e., coyotes and cage traps). Some traps (e.g., cage traps) are non-selective and will likely capture non-targets. Some animals (e.g., coyotes, foxes) can become trap-shy if a trap is not properly bedded or if they experience, but escape a trap, becoming highly challenging to trap successfully. Non-target animals may become trap-happy as they associate the trap with the bait award they receive. Not only does this make the trap unavailable to catch target animals, but can result in the unintended starvation of the non-target species, as the bait is not sufficient to provide minimum nutritional needs. Traps must be checked frequently, or remotely monitored if allowed by law, to ensure that captured animals are not subjected to extreme environmental conditions. State laws or regulations often require traps to be checked every 24 hours or daily. Some animals may become injured in the trap and thus require treatment (if release is intended) or dispatched (even if not intended). Trapping can be costly depending on trap-type and number of traps needed. Public perception can vary widely by trap-type (e.g., foothold versus cage traps, with the latter often perceived better by the public). Further, while most laypersons can use cage traps safely and successfully with little risk of direct unintended injury, the other methods described above require extensive training and practice to implement safely and successfully. If trapping is selected as the preferred management action, then land managers should seek to be trained by, or hire, experts (e.g, licensed trappers, USDA-Wildlife Services, private Wildlife Damage Control Agents) in these trapping techniques well in advance of the planned timing of trapping given the extensive contracting and permitting (see BP 7) needed. Land managers should consider opening up areas to licensed recreational trappers during the applicable trapping season through free permits. This would allow pro-active management of target species populations at little to no cost to the governing agency. This would also allow the species to be utilized (e.g., fur, meat, skull, glands) and removed during a time of year when young predators are independent of parents, and there is less public use of a site.

SHOOTING (DB 3.3)

Shooting was the second most implemented lethal predator control method used by interviewees, with 82% of respondents indicating that they currently use this method or have in the past. Trapping and shooting often occur concurrently. Managers often contract an organization or agency such as the USDA Wildlife Services to conduct lethal predator removal for a set period, during which they may utilize a number of lethal techniques (generally trapping and shooting). Shooting in this context may be determined to be the preferred method of dispatch for a live-trapped predator. However, there are other instances where land managers may determine that shooting should be used because it is a selective method for a problem predator that has keyed in on beneficiary species. Although shooting often can be relatively expensive because of extensive staff hours required, it may at times be one of the only methods available to selectively address a predation problem. However, shooting is limited to locations where it is legal and safe to discharge a firearm.

Shooting Mammalian Predator Species

Shooting mammalian predators with firearms is very selective for the predator species being managed and can be conducted with rifles, handguns, and shotguns. Safety concerns are significant, including ricochet, need for an adequate backdrop, and the need to know what is within the shooting perimeter (e.g., occupied buildings, people). However, shooting often provides immediate relief from the targeted predator. Methods may require use of illuminating devices, firearm suppressors, predator calling, and/or night vision/thermal equipment to increase efficacy and reduce risks.

1. Illumination and night vision/infrared: Shooting at night can increase the selectivity of direct management by targeting those animals most likely responsible for causing damage. Shooting in conjunction with an illumination device, night vision, or Forward Looking Infrared (FLIR) may be used in sensitive areas that have high public use or other daytime activities which make daytime shooting unsafe. Spotlights can be covered with red lenses, which nocturnal animals may not be able to see, making it easier to locate them undisturbed. Night vision and FLIR are effective in complete darkness.

2. Predator calling: Calling refers to the use of mouth or electronically recorded and mechanically amplified animal calls or sounds to attract animals into shooting range.

3. Suppressors: Sound suppressors or silencers are devices that attach to or are part of the muzzle of a firearm or gun's barrel. These tools reduce the noise signature (muzzle report) and the flash generated by the gun's firing. Use of these devices can reduce conflicts with surrounding areas such as neighboring communities. Suppressors are typically constructed of a metal cylinder with internal baffles which decreases the muzzle blast. The application process to possess a suppressor is administered by the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF). Suppressors are illegal in certain states for civilians.

Shooting Avian Predator Species

Shooting of avian predators is generally conducted with shotguns, rifles, or air rifles, and is typically used to remove a single offending bird. When large numbers of birds are present, shooting often is more effective as a dispersal or hazing technique than as a way to reduce bird densities by removal. However, at times, multiple birds may be shot from a flock to make the remainder of the birds wary and to help reinforce nonlethal methods. Similar to shooting mammals, shooting avian predators is selective for target species and may be used in conjunction with the use of spotlights, decoys, and calling. The birds are killed as quickly and humanely as possible.

Disadvantages of Shooting

There are common disadvantages to shooting that all the above methods share. The shooter should be trained and experienced in knowing the appropriate firearm, ammunition, caliber, shooting distance, and shot placement to use to quickly dispatch the targeted animal. The shooter must also be skilled in various methods that can be used to increase the chance of a successful removal. These methods include knowledge on the time of day shooting attempts should take place, wind direction, appropriate calls and baits to use to attract the targeted animal, and location of the shooter. Unlike traps, shooters are subject to fatigue and are more likely influenced by bad weather. To assure human safety, shooters must also be aware of firearm discharge

ordinances and areas of human activity and dwellings. Shooting requires extensive staff hours that are often outside of normal working hours.

NEST AND EGG DESTRUCTION (DB 3.4)

Of those utilizing lethal management techniques, 32% reported that they currently use some form of nest or egg destruction or have in the past. Nest destruction is defined as the removal or destruction of nesting materials and/or eggs during the construction phase of the nesting cycle. This method is used to discourage avian predators such as gulls from constructing nests and establishing colonies in areas where beneficiary species are nesting. Heusmann and Bellville (1978) reported that nest removal was an effective but time-consuming method because problem bird species may be highly mobile and can easily return to sites from long distances, or are hard to eliminate because of high populations. Also nest destruction may lead to renesting, either at the same location or elsewhere, thereby creating a potential conflict for nearby shorebird protection efforts. In the following sections, we discuss in detail colony relocation and egg oiling as two common tools used to benefit avian species of conservation concern.

1. Nest or egg destruction and overhead wire grids are commonly attempted to protect avian beneficiary species. The most effective methods to disperse gull colonies suspected of negatively impacting nearby breeding beneficiary species appeared to be, either singly or in combination, nest and egg destruction and overhead wire grids. Nest and egg destruction or oiling (see below) have been used to disperse or reduce the number of nesting Ring-billed and Herring Gulls (Blokpoel and Tessier 1991). Forbes et al. (1993) and Belant and Ickes (1996) have used overhead wire grids over nesting colonies to disperse Ring-billed and Herring Gulls in 1-3 years. Laughing Gulls in some cases have been unaffected by overhead wires (Dolbeer et al. 1988). Pochop et al. (2001) used parallel lines at 5m spacing with hanging ropes, similar to a curtain, to reduce the number of nesting Ring-billed Gulls on an island. Other techniques to discourage nesting by avian predators have been used with less success. For example, mylar flags (Belant and Ickes 1997), distress calls, effigies, shooting (Thomas, 1972) and tethering raptors to areas within a gull nesting colony (Blokpoel and Tessier 1986) all had varied success and were logistically challenging.

2. Egg addling or oiling suppresses reproduction of predator bird species. A small quantity of food grade vegetable oil or mineral oil applied to eggs in nests prevents exchange of gases and causes asphyxiation of developing embryos. Egg oiling has been found to be 96-100% effective in reducing hatchability (Pochop et al. 1998). An advantage of this method when compared to nest destruction is that incubating birds generally continue incubation and do not renest. The U.S. Environmental Protection Agency (EPA) has ruled that use of corn oil for this purpose is exempt from registration requirements under Federal Insecticide, Fungicide and Rodenticide Act (FIFRA). To be most effective, the oil should be applied anytime between the fifth day after the laying of the last egg in a nest and at least five days before anticipated hatching. Some interview respondents commented that they have used small nails to puncture eggs in the past to achieve the same goal. These methods are extremely target specific and reduces or eliminates the reproductive success of the targeted predator, but it does not eliminate the target avian predators' presence from a site. Further, this method often needs to be conducted each year, and over many years, to result in reduction or dispersion of a colony of avian predators.

POISONING (DB 3.5)

Of those utilizing lethal management techniques, 17% reported that they have used or are currently using poisoning as a method to control predators of nesting shorebirds. Details are provided below on several commonly used poisoning or fumigants used to control predators of beneficiary species. We urge managers to carefully consider the details and potential drawbacks of how each poison or fumigant functions. In the past, managers have experienced unexpected negative backlash when poisoning resulted in animals dying in public view due to the time lag between exposure and death of the target predators (see http://www.nytimes.com/1996/05/27/us/gulls-are-cast-as-threat-to-avian-neighbors-agency-is-cast-in-a-badlight.html). If poisons are used, users must check with state and federal laws to see if these poisons are restricted or prohibited in that state.

1. Avitrol® (4-aminopyridine) is listed by the EPA as a chemical frightening agent, although the chemical is lethal to any birds that ingest it. Before dying, affected birds make distress calls, engage in irregular flight, and/

or show other signs of distress that frighten the rest of the flock away from the area. This chemical is registered for use on crows and gulls. Avitrol is a restricted use pesticide that can only be sold to certified applicators and is available in several bait formulations where only a small portion of the individual grains carry the chemical.

2. Denning and fumigants (DB 3.6). Denning is the practice of locating and lethally removing animals from inside the den or burrow. Den or burrow sites are used by coyotes, striped skunks, and red fox for bearing and rearing young. Coyotes, skunks, and red foxes are territorial, and each territory is typically controlled and maintained by a dominant breeding pair (Lloyd 1983, Gese and Ruff 1997, 1998). The breeding pair produces a single litter each spring (Cypher 2003, Bekoff and Gese 2003). Studies have demonstrated that the need to feed pups is an important factor for motivating coyotes to kill prey (Till and Knowlton 1983, Bromley and Gese 2001). One respondent we interviewed indicated that they use fumigants at fox dens as a lethal technique. In this instance, the procedure was conducted by USDA Wildlife Services concurrently with trapping and shooting activities and was used opportunistically (e.g., if a den was found), not as a blanket strategy. Denning is highly selective for target species and individuals. However, dens can be difficult to locate rendering the method labor intensive.

Fumigants such as the large gas cartridge (EPA Reg. No. 56228-62) and regular gas cartridge (APHIS-Only Gas Cartridge; EPA Reg. No. 56228-21) are registered by USDA Wildlife Services with many states and are often used to treat dens or burrows of coyotes, striped skunk, and fox. Only the large gas cartridge is labelled for red fox, coyotes, and striped skunks. The regular gas cartridge is registered for use in rodents such as woodchucks, ground squirrels, and prairie dogs. When ignited, the cartridge burns in the den of an animal and produces large amounts of carbon monoxide, a colorless, odorless, and tasteless, poisonous gas. The combination of oxygen depletion and carbon monoxide exposure kills the animals in the burrow or den. Sodium nitrate is the principle active chemical in gas cartridges and is a naturally occurring substance. Although stable under dry conditions, it is readily soluble in water and likely to be highly mobile in soils. In addition, dissolved nitrate is very mobile, moving quickly through top sediment layers to the underlying water table (Bouwer 1990). However, burning sodium nitrate used in gas cartridges is believed to produce mostly simple organic and inorganic gases, using all of the available sodium nitrate. In addition, the human health drinking water tolerance level for this chemical is 10 mg/L, a relatively large amount, according to EPA Quality Criteria for Water (EPA 1986a, EPA 1986b). The gas along with other components of the cartridge, are likely to form oxides of nitrogen, carbon, phosphorus, and sulfur. These products are environmentally non-persistent because they are likely to be metabolized by soil microorganisms or enter their respective elemental cycles. Sodium nitrate is not expected to accumulate in soils between applications, nor does it accumulate in the tissues of target animals (EPA 1991).

BP 3 SUMMARY
Nearly all Atlantic Flyway managers that we interviewed are using lethal control as a component of their predation management strategy. Not every method is appropriate or feasible for all management scenarios. As managers work with their federal, state, or private predation management expert, it is important to systematically consider and evaluate how all available options may assist in meeting the goals of their plan. Managers should also pay close attention to additional details provided in *BP 7* regarding permitting requirements and restrictions, as these may dictate which methods are potential options in a given area.

BEST PRACTICE 4: METHODOLOGICAL CONSIDERATIONS FOR NONLETHAL PREDATION MANAGEMENT

WHY IS THIS IMPORTANT?

Seventy-six percent (76%) of flyway managers interviewed are currently using, or have used, some form of nonlethal predation management, including exclusion, harassment, chemical aversion, trap and relocate, anti-perching, shock aversion, and other techniques such as trash management. Common questions when considering nonlethal management techniques include: 1) what nonlethal techniques are used for specific predator species? 2) who do managers use to conduct the nonlethal predation management? and 3) what is the known or perceived effectiveness of nonlethal control methods? We detail interviewees' responses to these questions below and then provide a comprehensive review of different methods of nonlethal control. As with lethal control methods (*see* *BP 3*), we strongly encourage managers to work with predation management partners to design an overall management strategy (*see* *BP 2*) that combines the appropriate methods.

Every state differs in permitting processes for control of mammalian, avian, and other predators. Before beginning any nonlethal control of predators, land managers should contact the appropriate personnel to seek advice on permitting for and implementation of mammalian and avian predation management. Please also see *BP 7* for details on permitting.

Wilson's Plover. ©Kat Vitulano

1. What nonlethal techniques are used for specific predator species? The type of predator or predators you are attempting to target will determine what specific technique or techniques are used. Table 5 summarizes the frequency of nonlethal techniques used to target specific predator species throughout the flyway, as reported by our interview respondents and reviewers.

Table 5. Nonlethal predation management techniques used to target specific predators along the Atlantic Flyway as indicated by 29 interview respondents.

Nonlethal Predation Management Techniques							
	Exclusion	Harassment	Chemical Aversion	Trap and Relocate	Anti-perching	Shock Aversion	Total # Techniques by Predator
Raccoon	X	-	-	X	-	-	2
Red Fox	X	-	-	-	-	-	1
Coyote	X	-	X	-	-	-	2
Feral cat	X	-	-	X	-	-	2
Dog	X	-	-	-	-	-	1
Bobcat	-	-	-	-	-	-	0
American Mink	X	-	-	-	-	-	1
Feral Hog	X	-	-	-	-	-	1
Virginia Opossum	X	-	-	X	-	-	2
Striped Skunk	X	-	-	-	-	-	1
Rat	-	-	-	-	-	-	0
Nine-banded Armadillo	X	-	-	X	-	-	2
Herring Gull	X	X	-	-	-	-	2
Great Black-backed Gull	X	X	-	-	-	-	2
Laughing Gull	X	X	-	-	-	-	2
Crow spp.	X	X	X	-	X	X	5
Common Raven	-	-	-	-	-	-	0
Common Grackle	-	-	-	-	-	-	0
Great Horned Owl	X	-	-	X	X	-	3
Northern Harrier	-	-	-	-	X	-	1
American Kestrel	-	-	-	-	X	-	1
Merlin	X	-	-	-	X	-	2
Peregrine Falcon	-	X	-	-	X	-	2
Black-crowned Night Heron	-	-	-	-	-	-	0
Heron spp.	-	-	-	-	-	-	0
Iguana spp.	-	-	-	-	-	-	0
Snake spp.	-	-	-	-	-	-	0
Ghost Crab	-	-	-	X	-	-	1
Fire Ant spp.	-	-	-	-		-	0
Total Responses by Technique	**16**	**6**	**2**	**6**	**6**	**1**	

2. Who should conduct the management? The nonlethal management technique or techniques used may determine the agency or group to conduct management. Table 6 provides a summary of the agencies or groups that flyway managers have used or are currently using to conduct nonlethal management.

Table 6. Agencies or groups conducting nonlethal management activities along the Atlantic Flyway, as indicated by 29 interview respondents.

Nonlethal Predation Management Techniques							
	Exclusion	Harassment	Chemical Aversion	Trap and Relocate	Anti-perching	Shock Aversion	Total # Responses by Group
USDA Wildlife Services	0	1	0	1	0	0	**2**
Own Staff	19	8	2	6	1	1	**37**
Private Contractor	0	0	0	0	0	0	**0**
State Wildlife Services	0	0	0	0	0	0	**0**
State Agency Staff	0	0	0	0	0	0	**0**
USFWS	0	0	0	0	0	0	**0**
Volunteers	0	0	0	0	0	0	**0**
Total Responses by Technique	19	9	2	7	1	1	

3. Is there any information about the effectiveness or perceived effectiveness of nonlethal techniques? Although the effectiveness of methods may vary depending on the site and year, we have provided summary information in Table 7 from flyway managers regarding the perceived effectiveness of nonlethal techniques. In BP 8, we discuss methods for measuring effectiveness in detail.

Table 7. Frequency that respondents felt that specific nonlethal techniques were affecting beneficiary and predator metrics in the same season that management was conducted along the Atlantic Flyway, as indicated by 29 interview respondents.

Frequency Reporting that Nonlethal Predation Management Techniques Resulted in Beneficiary/Predator Response Metrics						
Number of respondents that reported:	Exclusion	Harassment	Chemical Aversion	Trap and Relocate	Anti-perching	Shock Aversion
Increased/High Rates of Hatching	11[a]	1	1	2	1	0
Increased/High Rates of Fledging	4	1	0	3	1	0
Increased/High Rates of Adult Survival	2	0	0	1	0	0
Increased/High Beneficiary Population Size/Pairs	1	1	0	0	0	0
Beneficiary Recolonization of Sites	0	0	0	1	0	0
Decrease in Predator Occupancy/Abundance	0	3	1	2	1	0
None	2	4	0	2	0	0
N/A (Did Not Assess)	3	1	2	1	0	1[b]
Number of Respondents by Technique	**19**	**8**	**2**	**5**	**1**	**1**

[a] 11 out of 19 respondents for this nonlethal technique reported increased or high relative rates of hatching after the technique was conducted. Each number is a frequency of reports for that metric out of the total number of respondents by technique (bottom column).

[b] 2017 was the first season that shock aversion has been conducted and therefore results haven't been analyzed. For more information regarding shock aversion, please see the Florida Demonstration Site case study in Supplemental Material: Demonstration Sites, Florida.

METHODS OF NONLETHAL CONTROL (DB 4.1-4.6)
Exclusion (DB 4.2)
Exclusion was the most widely used form of nonlethal management, with 86% of respondents who use nonlethal methods using some form of exclusion. Exclusion methods included nest exclosures, electric fencing, and predator fencing.

Please see the Georgia demonstration site case study, **_Supplemental Material: Demonstration Sites_**, Georgia for details on how nest exclosures were used for Wilson's Plover.

1. Nest Exclosures. There is a long history of exclosure use for the protection of Atlantic Coast beneficiary species. Nest exclosures are typically wire mesh cages that are set up to surround a single ground nesting bird or turtle nest in order to exclude predators and prevent egg predation.

An extensive body of literature exists for the use of nest exclosures to protect ground-nesting birds (Rimmer and Deblinger 1990, Melvin et al. 1992, Larson et al. 2002, Maslo and Lockwood 2009, Smith et al. 2011, Beaulieu 2012, Burns et al. 2013, Dinsmore et al. 2014, 2017, Cohen et al. 2016). Much of this work has focused on coastal or riverine species; however, researchers have also examined non-coastal dwelling species (Mabee and Estelle 2000, Johnson and Oring 2002, Niehaus et al. 2004, Isaksson et al. 2007, Pauliny et al. 2008). In nearly all studies surveyed, the use of nest exclosures was correlated with higher daily nest survival rates. However, there were some notable exceptions, including Nol and Brooks (1982) and Burns et al. (2013), where predators gained access to the interior of exclosures. Few studies looked beyond hatching to determine the success of exclosures on survival to fledging. The studies that did investigate the longer-term effects of exclosures found that the benefits of increased hatching success rarely extended to increased fledging success (Dinsmore et al. 2014, Larson et al. 2002).

Across many studies, researchers also noted the important consideration of balancing increased adult mortality with increased hatching success (Burns et al. 2013, Johnson and Oring 2002, Maslo and Lockwood 2009). One mechanism for increased adult mortality was that nest exclosures provided a cue for attracting potential predators to nest sites (Murphy et al. 2003b, Niehaus et al. 2004, Beaulieu 2012, Burns et al. 2013, Cohen et al. 2016). When coupled with the lack of long-term reproductive success, the increase in adult mortality exceeded the short-term benefits of increased hatching success yielded from exclosure use.

Cohen et al. (2016) offers a structured decision-making model (https://esajournals.onlinelibrary.wiley.com/doi/pdf/10.1002/ecs2.1499) for managers deciding whether nest exclosures will be beneficial at their sites. In areas where nest exclosures are deemed beneficial (Cohen et al. 2016), efforts to protect early nests may yield the best results for productivity (Rimmer and Deblinger 1990, Pearson et al. 2016).

Additional information from the literature review suggests some additional guidelines on when exclosures may be recommended versus discouraged. First, not all beneficiary species (e.g., American Oystercatcher) will return to exclosed nests, thus this technique will not be useful for all beneficiaries. Nest exclosures should be used cautiously in areas within 2 km of forest cover or in places where raptors can perch and are known predators (Murphy et al. 2003b). Managers should consider the innate predator-response behavior of the beneficiary species and cautiously use exclosures when a beneficiary species is unlikely to flee when a predator is present (Isaksson et al. 2007). For example, Isaksson et al. (2007) found that Redshanks at protected nests suffered higher adult mortality than Northern Lapwing at protected nests because Redshanks tended to remain on the nest for longer than Northern Lapwing in the presence of predators.

The size and shape of nest exclosures and the beneficiary species or predator are important considerations (Nol and Brooks 1982, Melvin et al. 1992, Murphy et al. 2003b, Malpas et al. 2013, Dinsmore et al. 2014). For example, some predators like mink, striped skunks, or ghost crabs can penetrate the typical 2x4, 2x3, or 2x2 inch mesh sizes used on Piping Plover exclosures. However, 2x2 inch mesh has been used successfully to exclude striped skunks from nesting Piping Plover on Martha's Vineyard, with no obvious deleterious effects on plover hatch rates or adult survival (L. Johnson, personal communication, Biodiversity Works).

Nest exclosures may draw unwanted public attention to a nesting beneficiary species in an area where public closures are weakly or not enforced.

Managers may also need to consider logistical constraints when evaluating the use of exclosures at sites with limited access. For example, at remote sites with no vehicular access, the ability to transport exclosure materials to nesting areas may be prohibitive or smaller exclosures may be used, as done in the Missouri River by the U.S. Army Corps of Engineers.

2. Electric Fencing. Electric fencing has been shown to be generally effective at repelling predators from nests and increasing daily nest survival rates (Larson et al. 2002, Murphy et al. 2003a, Maslo and Lockwood 2009, Malpas et al. 2013). Electric fences can be built for temporary or permanent use. Temporary electric fences can be constructed of polywire, poly tape, or ElectroNet™. Permanent fences can be constructed with either multiple single strand wires or a combination of woven wire or wire mesh and single strand wires. There is evidence of the ability of electric fences to protect sheep (e.g., Dorrance and Bourne 1980, Linhart et al. 1982, Acorn and Dorrance 1994) or other prey (Matchett et al. 2013) from coyotes. In general, these studies found electric fencing to be effective at reducing predation, but no fence was 100% effective at excluding all coyotes because animals that were willing to expose themselves to electric shock, could avoid electric wires while passing through, digging under or jumping over fences or exploiting times when the fence wasn't charged, rendering the fencing ineffective. Similarly, red foxes will continually test electric fences after receiving electric shocks (Poole and McKillop 2002). Avian predators can fly over predator resistant or electric fences.

The utility of this method is limited by several additional factors. Because of the labor-intensive nature of establishing and maintaining the electric fence, it is most commonly used for colonial nesting rather than solitary nesting beneficiaries. The maintenance time and costs of the fences, especially due to the dynamic nature of coastal habitats along the Atlantic Flyway, should be considered in the total costs estimates as the fence must remain free of vegetation and be frequently checked to make sure it is still intact and working. The need for frequent maintenance and checks can be challenging in some remote settings where limited access prohibits frequent maintenance and checking of the fencing.

Cost and labor-intensive set-up and maintenance are drawbacks to this method, but this is a valid option for managers seeking an alternative to nest exclosures because of adult mortality concerns (Murphy et al. 2003a).

3. Predator Fencing. Predator-resistant fences are woven wire that are at least 4 feet tall and may have barbs along or at the top and the bottom of the fence to deter digging under by predators. There is little published information regarding predator fencing and coastal beneficiary species, except for Smith et al. (2011) which found that exclusion methods (nest exclosures vs. predator fencing) were both effective for increasing daily nest survival rates. The same cost- and labor-related challenges described above for electric fencing apply for this method.

Harassment (DB 4.3)
Of the respondents who indicated they use nonlethal predation management methods, 36% are using some form of harassment. The goal of harassment techniques is usually to induce predatory animals to flee from the site or remain at a distance while not scaring the beneficiary species. They usually employ extreme noise or visual stimuli. Unfortunately, many of these techniques are only effective for a short time before wildlife habituate to them (Conover 1982). Also, care must be taken such that the harassment of predators does not deter the beneficiary species.

Devices used to modify predator behavior include electronic guards (siren strobe-light devices), propane exploders, pyrotechnics, laser lights, scarecrow-like effigies, effigies of predators, and the noise associated with the discharge of a firearm. Generic sounds, whether recordings of actual events (e.g., gunshot, car horn) or synthetically made noises, may show immediate results, but avian predators tend to habituate quickly to them unless the sounds cause or are accompanied by pain or discomfort (Peterson and Colwell 2014).

As with many nonlethal harassment methods, managers should integrate other control activities into programs using sounds or visual harassment. Devices that produce ultrasonic sounds are not effective against avian predators because birds do not hear within the ultrasonic range.

Below we discuss several harassment techniques that were referenced during our interview process.

1. Auditory scaring devices such as propane exploders, pyrotechnics, electronic guards, and audio distress/ predator vocalizations are effective in many situations for dispersing damage-causing or predatory bird species. These devices are sometimes effective but usually only for a short period before birds become accustomed and learn to ignore them (e.g., Schmidt and Johnson 1984, Bomford and O'Brian 1990).

Pyrotechnics are a commonly used and effective bird dispersal tool. Pyrotechnics are specially designed explosives that may be fired from shotguns or adapted firearms (e.g., starter pistols) that shoot only pyrotechnics. Common pyrotechnics include shell crackers, screamers, bird bangers, and bird bombs. Each of these produces a loud sound and some also produce a flash of light and puff of smoke as they are fired or explode. Screamers usually make a wavering noise, leave a trail of smoke, and fly erratically. Bird bangers create a blast that mimics the sound of a shotgun. The most effective type of pyrotechnic for any given situation depends upon the location where it is to be fired, the types of birds to be scared, and the range that is required to reach the birds. Although mixing different types of pyrotechnics can slow habituation, eventually most birds become habituated, especially if the site being defended is highly attractive to the birds and the same style of pyrotechnics is used repeatedly. In such situations, some species of birds may again react to pyrotechnics if limited lethal control via a shotgun or rifle is used against the flock. Research has shown limited lethal control works well against gulls, but not as well against corvids. Local and national restrictions on the purchase, storage, and transport of pyrotechnics may preclude use by some people. Local ordinances may also limit use of pyrotechnics. Care must be taken because pyrotechnics can cause fires.

Propane cannons or gas exploders generate a blast that sounds like a shotgun from a stationary location. Cannons may be timed to go off at specific intervals or be remotely fired by observers when birds are near the cannons. Although propane cannons are effective in some situations, habituation is common, especially with cannons timed to go off at specific intervals. The time to habituation may be extended by moving the cannons periodically, by firing cannons only when birds are present, and by integrating other scare tactics to supplement cannons.

2. Visual Scaring Techniques. Techniques such as use of Mylar tape (highly reflective surface produces flashes of light that startles birds), eye-spot balloons (the large eyes supposedly give birds a visual cue that a large predator is present), flags, and effigies (scarecrows) are sometimes effective in deterring predator birds. Mylar tape has produced mixed results in its effectiveness to frighten birds (Dolbeer et al. 1986, Tobin et al. 1988, Belant and Ickes 1997). Pochop et al. (2001) tested a visual barrier made of woven black polypropylene fabric in parallel rows 5 meters apart to discourage gull nesting to protect salmon smolt along the Columbia River in Washington State. The zone with fencing had 84% fewer nests than the control zone. Generally, birds quickly learn to ignore visual and other scaring devices if the birds' fear of the methods is not reinforced with shooting or other tactics. Moreover, care must be taken to ensure the Mylar products used do not become a source of trash on the landscape.

3. Lasers. Lasers are a nonlethal predator management technique recently evaluated by the USDA National Wildlife Research Center (NWRC; see http://www.laserpointersafety.com/tips/tips-birds.html). The low-powered laser (Class 2M or lower) has proven to be effective in dispersing a variety of bird species in a number of different environments. The low-powered laser is most effective before dawn or after dusk when the red or green beam of the laser is clearly visible. Bright sunlight will "wash out" the laser light rendering it ineffective. Although researchers are not sure if birds see the same red or green spot as people, it is clear that certain bird species elicit an avoidance response in reaction to the laser. The birds view the light as a physical object or predator coming toward them and generally fly away to escape. Research, however, has shown that the effectiveness of low-powered lasers varies depending on the bird species and the context of the application.

Lasers have proven effective for dispersing geese and some long-legged wading birds as well as crows, vultures, and gulls at landfills. In Hawaii they have been tested as a potential means for moving endangered species out of industrial areas and airports where their foraging activities put the birds themselves at risk and pose a safety threat to air traffic. In Maine, USDA Wildlife Services has successfully used lasers to disperse gulls near Piping Plover and least tern nest areas (A. Vashon, personal communication, USDA Wildlife Services).

Chemical Repellents (DB 4.4)
Of the respondents who indicated they use nonlethal predation management methods, 9% are using chemical aversion or repellents.

Most commonly interviewees mentioned using the chemical repellent Mesurol to deter egg predation by crows and ravens. Mesurol is registered and permitted by USDA Wildlife Services for use to repel American Crow and Common Raven from bird nests of threatened and endangered avian species. Product labeling requirements in your state may differ from federal requirements, thus be sure to check your state's specific guidelines and requirements for all products and consult with local, state and federal wildlife authorities to ensure that the use of this product for the protection of regulated species from predation does not present a hazard to other state or federally listed Threatened or Endangered Species. Do not apply in areas where eggs treated with this product may be consumed by Threatened or Endangered Species.

Dimmick and Nicolaus (1990) showed that breeding pairs of crows could be conditioned with aversive chemicals to avoid eggs; however, Avery and Decker (1994) observed increased consumption of eggs treated with higher doses of Mesurol by Fish Crows. Sullivan and Dinsmore (1990) reported bird nests greater than 700 meters from crow nests were relatively safe from crow predation; thus, nests beyond 700 meters from active crow nests may not need to be treated.

If using Mesurol as a management technique, USDA Wildlife services would treat eggs similar in appearance as those eggs of the species needing protection. The active ingredient is injected into eggs, which are placed in artificial nests or upon elevated platforms. Upon ingestion, birds develop malaise (Mason 1989) and crows develop an aversion to consuming similar looking eggs (Dimmick and Nicolaus 1990). Repeated exposures may be necessary to develop and maintain aversion to threatened or endangered species eggs as the learning curve for crows can take from 23 days to 3 months (Dimmick and Nicolaus 1990, Avery and Decker 1994). Treated areas should be posted with warning signs at access points to exclude people from nesting areas. Treated eggs should not be placed in locations where avian species of concern may eat the treated eggs. Mesurol is highly toxic to birds and mammals and toxic to fish. It is also highly toxic to honey bees. The benefit of this method is that it is a nonlethal taste aversion repellent. However, its use is limited to American crows and Common Ravens, it is labor intensive, and may not be registered for use in all states.

Chemical repellents are most effective when they are applied directly to foods with the aim of reducing consumption. There is almost no evidence that they cause animals to abandon areas, except occasionally when highly palatable alternative foods are readily available at locations distant from the treated site (Milunas et al. 1994). When alternative foods are scarce or not especially palatable, animals typically return to treated areas and often resume feeding on treated vegetation (El Hani and Conover 1998).

Live trap and relocate (DB 4.5)
Twenty-three percent (23%) of respondents used trap and relocate as a nonlethal method of predation management. When referring to trap and relocate, we mean restrain trap throughout the document. Trap and relocate was mentioned by a number of interviewees as a useful tool for native avian predator species. In these cases, USDA Wildlife Services recommends transporting hawks and owls as far away from the trapping site as reasonably possible and banding the avian predators before release. A recent study by USDA Wildlife Services showed red tailed hawks relocated between 50-125 miles from their point of capture were equally likely to not return. Similar research for American Kestrel is ongoing (N. Myers, personal communication). Based on these studies, N. Myers currently recommends a distance of 50 miles from the capture site to minimize the probability of the bird returning. Choose a release site that provides appropriate habitat and is not near an airport, poultry production facility, or major highway where future problems might ensue.

Migratory birds trapped in the fall should be transported southward and birds trapped in the spring should be moved northward to help them along their migration path. Obtain permission from the landowner to release birds onto private land and always carry a copy of your permits.

Do not transport birds or mammals across a state line, as this is a violation of federal wildlife laws. Before transporting birds or mammals off the property of capture, check state laws and regulations regarding movement of wildlife.

OTHER NONLETHAL METHODS (DB 4.6)
Fourteen percent of respondents utilizing nonlethal methods indicated that they were using another method that did not fall into any of the above categories. The 'other methods' included removing avian predator perches from nesting areas, placement of effigies, shock aversion, and trash management.

1. Shock Aversion. The successful use of shock aversion as a novel nonlethal predation management technique to deter Fish Crows from depredating waterbirds and sea turtles in Florida is described in detail as a demonstration site in *Supplemental Material: Demonstration Sites, Florida*.

2. Anti-perching. Habitats may be made less attractive to crows, hawks, owls, and other avian predators by removing hunting perches from nesting sites. Removal of natural hunting perches can be accomplished by cutting down snags and trees on which hawks and owls are commonly observed. Poles and other non-natural perch sites, including fence posts for symbolic fencing and signage, should be modified with anti-perching devices, such as sheet metal cones and electric shock strips and devices, to deter hawks and owls from using them and be as short as possible to still accomplish their objective. Several anti-perching devices are commercially available, including Nixalite®, Cat Claws®, and inverted spikes that help deter hawks and owls from using buildings, roofs, and other structures as perching and hunting sites. L. Johnson (Biodiversity Works) reported that they use plastic-roll up sleds cut into strips and arched over poles as an effective perching deterrent at their sites on Martha's Vineyard, MA.

3. Trash removal and management. As noted elsewhere in this document, human-related food subsidies (e.g., trash, fish cleaning stations) and habitat manipulation have created artificially inflated populations of commensal predators in many areas used by beneficiary species. Elimination of food/garbage is one of the primary nonlethal solutions used in Florida (N. Douglass, personal communication, Florida Fish and Wildlife Conservation Commission). This includes moving trash bins off beaches, ensuring waste receptacles have predator-proof lids, and working with local businesses to ensure food scraps are safely disposed. This is a simple, relatively inexpensive solution that has been effective on municipal beaches.

4. Removal of avian predator nesting substrate. Removal of nesting substrate used by avian predator species has been employed in Florida. Florida managers removed the exotic *Casurina sp.* on beaches which provided nesting substrate for Fish Crow and night herons adjacent to habitat used by beneficiary species (N. Douglass, personal communication, Florida Fish and Wildlife Conservation Commission).

BP 4 SUMMARY
Over three quarters of the Atlantic Flyway managers interviewed are using some sort of nonlethal control as a component of their predation management strategy. As managers work with their federal, state, or private predation management expert, it is important to systematically consider and evaluate how all available options may assist in meeting the goals of your plan. In this section, we provided details on exclusion, visual and acoustic harassment, chemical repellents, trap and relocate, shock aversion, anti-perching, and other nonlethal methods that have or are being used by Atlantic Flyway managers. All should be considered before a final decision is made. It is important to consult *BP 7* to review permitting requirements as management decisions are made.

Simply keeping the beach clean of trash and debris can reduce predators. USFWS

BEST PRACTICE 5: TIMING OF PREDATION MANAGEMENT AND UNINTENDED SECONDARY IMPACTS

WHY IS THIS IMPORTANT?

When planning predation management activities, it is important to consider the year-round phenology of the beneficiary species and associated predators, as well as known and potential interactions of the species of management interest with other species of birds and predators at your site. These considerations can be especially important when attempting to determine optimal timing for implementing management.

At many sites, the beneficiary species have been monitored and/or studied for many years, resulting in extensive knowledge of breeding timing and ecology. Long-term datasets can provide information needed to estimate variables for these species such as average arrival dates, average clutch initiation dates, and average peak hatching dates, all of which can help determine when management activities should occur. If managers do not have these types of data from their site, similar information from nearby sites can help guide their management.

In many instances, less is known about predator ecology at a site, including movement and dispersal behavior, daily and seasonal activity patterns, breeding/denning status, and food resource availability. Previous research has indicated that the composition and dynamics of predator populations are relatively site-specific, therefore, studies on predator ecology are important to determine whether predation management is warranted and when it would be most effective (Parsons et al. 2012). For example, in northern California, extensive research has been conducted on both the ecology of beneficiary species of management need (Snowy Plovers and Marbled Murrelets), and the ecology of abundant corvids in the area, enabling effective management recommendations (Colwell et al. 2009). Concurrent work on raccoon management and American Oystercatcher populations at Cape Lookout National Seashore demonstrated that multiple factors impacted Oystercatcher productivity and that the raccoon management alone did not drive population trends in this beneficiary species (Stocking et al. 2017). Similarly, an on-going study on Fire Island, NY of red fox ecology and behavior was designed to inform best management of this predator to benefit nesting Piping Plover (Kat Miles, Virginia Tech, pers. comm.). It is also important to consider relationships between and among predator species (e.g., competition, avoidance/territoriality, niche partitioning, etc.) and the potential secondary effects that the management may have on these inter- and intra-species dynamics see section 1.6 in _**Supplemental Material: Database of Interview Responses**_).

Studies on how to best time predation management remain relatively rare. We recommend reviewing the demonstration site case study for South Carolina that examined the best timing of predation management activities to benefit both the avian beneficiary species and nesting sea turtles (_**Supplemental Material: Demonstration Sites, South Carolina**_) to see how managers are using the best available information to time their management actions.

UNDERSTANDING THE ECOLOGY OF BENEFICIARY SPECIES WHEN TIMING MANAGEMENT ACTIONS (DB 5.1)

Most flyway managers (89%) we interviewed have considered the phenology and ecology of beneficiary species when planning and implementing the timing of predation management. A number of variables are used to inform management efforts, including average arrival date, average clutch initiation, and peak hatching. It is important to note that depending on the number and taxa of species, these variables may differ, and considering all may help make management more effective.

An incubating Snowy Plover. Audrey Albrecht

1. Average arrival date

Understanding average arrival dates of any migratory species at your site can be helpful when timing the implementation of predation management. The purpose would be to avoid disturbing beneficiary species during management activities if they are occurring prior to species arrival.

2. Average clutch initiation

Knowing when nests are initiated at your site can also be helpful when timing the implementation of predation management in order to minimize disturbance to nesting beneficiary species and potentially other resources of concern at the site. Flyway managers we interviewed often attempted to perform lethal (e.g., predator shooting, trapping) management activities prior to or right at the start of the shorebird nesting season. Many managers cited that management earlier than right before arrival of beneficiary species can result in new predators moving into vacant territories, essentially negating any potential positive effects and 'wasting' resources dedicated to supporting the management. An ancillary benefit of conducting management activities prior to the nesting season is that this timing also does not typically overlap with peak

Wilson's Plover chicks. Audrey DeRose-Wilson

periods of public recreation, thereby avoiding any potential conflict with visitor activities. Several respondents did indicate that if specific 'problem predators' were preying on nests and chicks, even after management had been implemented prior to nest initiation, then emergency management activities were conducted throughout the breeding season to remove these specific individuals. Flyway managers that waited until the nesting season had begun to implement management indicated that they wanted to remove predators at the times when the beneficiary species were most vulnerable (nests and chicks).

3. Peak hatching

Knowing the timing of peak hatching (the period when most nests are hatching) at your site can also be helpful when timing the implementation of predation management. As stated above, flyway managers that waited until the nesting season had begun indicated that they wanted to remove predators at the times when the beneficiary species were most vulnerable (nests and chicks). If specific 'problem predators' were preying on nests and chicks, even after lethal techniques had been implemented prior to nest initiation, respondents indicated that activities were then conducted throughout the breeding season to remove these specific individuals.

Recommendations from Prior Research

Previous research on Piping Plovers suggests that predation management is most effective when conducted early in the nesting season and before the first chicks hatch. On the Missouri River, Catlin et al. (2011) found that the positive effect of Great Horned Owl removal (nonlethal trap and relocate) decreased with increasing ages of chicks, indicating that trapping should be performed as early in the plover season as practicable to maximize results. This study supported work from the Great Lakes where Struthers and Ryan (2005) found that chicks of Piping Plover (and many other shorebird species) were most vulnerable to predation within 0–10 days of hatch and recommended that removal of chick predators should occur prior to the first nests hatching. Similar patterns were observed for American Oystercatcher chicks in North Carolina (Schulte and Simons 2015). In Massachusetts and on the Missouri River, Piping Plover nests had lower survival earlier in the season and chick survival was higher earlier in the season, indicating that predation control to protect earlier-laid nests may increase productivity more than predation control to protect nests later in the season (Rimmer and Deblinger 1990, Catlin et al. 2015). Similarly, Cohen et al. (2009) found that Piping Plover reproductive output (chicks/pair) was positively correlated with the number of predators removed early in the breeding season. While these studies focused on Piping Plover, several temperate breeding beneficiary species share similar breeding characteristics (though the timing of breeding may vary at some sites). Therefore, information presented above also may be useful for the timing of management activities for other coastal-nesting beneficiaries.

In addition to shorebirds, there is evidence that breeding success of several species of sea turtles is improved by optimizing the timing of predator removal relative to dates of nesting and hatching (Engeman et al. 2012). Lastly, work with California Least Terns (*Sterna antillarum browni*) has suggested that higher nest success is achieved with 'proactive' versus 'reactive' predator removal (Butchko and Small 1992).
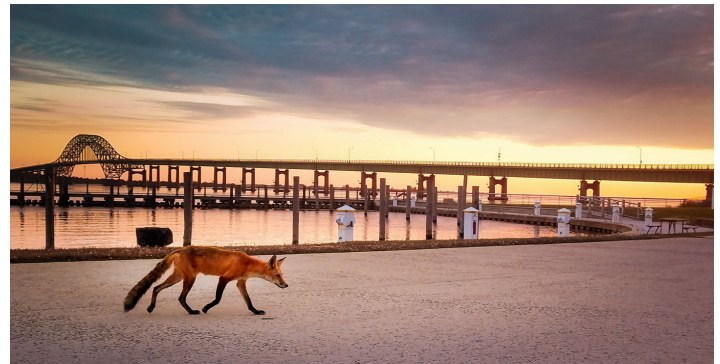
A red fox moves through a park. Braelei Hardt

PREDATOR SPECIES ECOLOGY (DB 5.2)

Before implementing predation management, it is also important to understand the phenology and ecology of predators at specific sites, to the greatest extent possible. Using information about predator ecology to guide management can maximize the likelihood of removing resident predators and ultimately reduce the impact of predation that is localized around the beneficiary species. This concept has been demonstrated in the United Kingdom where the well-timed removal of foxes and crows has promoted nest success of Northern Lapwings (*Vanellus vanellus*; Bolton et al. 2007).

Most flyway managers (86%) that we interviewed considered the ecology of predator species when planning and executing predation management activities. Below are a few examples of variables that they considered. It is important to note that many of these considerations refer primarily to lethal mammalian predation management. The importance of each metric in effective predation management depends on the composition of predator species present and the type of predation management used.

1. Movement and dispersal behaviors

Understanding movement and dispersal patterns of predators at your site will help inform where and when management should be implemented and potentially provide information about the efficacy of management at the site. At Assateague Island National Seashore, camera traps were used to determine that occupancy rates of red foxes did not change after an intensive eradication program and that individually-identifiable foxes travelled the greatest distances following eradication efforts, indicating that foxes were perhaps moving into newly vacated territories (Gieder 2015). Johnson (2016) used radio-telemetry to study the movements of striped skunks on Martha's Vineyard, MA and found that some female skunks foraging on nesting beaches at night were coming from natal dens over 2 km from the nesting beach. On Parramore Island, VA, a study using camera traps similarly showed that occupancy rates of raccoons did not change significantly before and after raccoon removal activities, but detection probabilities did decrease. This decrease in detection

rates was interpreted as a potential behavior shift in response to trapping efforts, but it was not a change in occupancy (Karpanty et al. 2016).

2. Activity patterns

Understanding seasonal activity patterns of the predator species at your site can help inform the ideal timing for implementing predation management for shorebirds and other coastal-nesting species. Protus (2016) used nest cameras on exclosed Piping Plover nests at Jones Beach, NY to identify different daily activity patterns between mammalian and avian predators. This work also indicated that, unlike other predators at the site, crows exhibited seasonal variation in activity. Crows were only present at the beginning and middle of the plover breeding season, which the author suggested was influenced by changes in crow activity during the breeding season. Similarly, crow presence and associated predation on Missouri River Piping Plover nests was higher during the early part of the nesting season (D. Catlin, Virginia Tech Shorebird Program, unpublished data). Nest predation by different gull species has also been shown to vary by time within the breeding season. A predator removal study at Eastern Egg Rock, ME indicated that the success of lethal gull removal was species-dependent, and that different species of gulls had different probabilities of actively depredating tern species, depending on the time of the season (Donehower et al. 2007).

3. Breeding/denning status

Understanding when predators breed at a site can help managers determine when to manage these species during the annual cycle. For example, managers may opt to use lethal control before the breeding season for mammalian predators as removal of adults before the breeding season removes the adults as potential predators and also reduces reproductive output of those predators (Johnson 2016). Using lethal control before the breeding season or once young are independent avoids the orphaning and starvation of young. Targeting breeding individuals and/or those with young can be controversial. Therefore, having information about breeding and denning can also help you determine when management should not be implemented if managers decide to avoid or limit removals during this life stage.

4. Food resource availability

Understanding what food resources are available to predators at a field site during different seasons can also be helpful when determining when best to implement predation management. Many predators are food limited during winter months, and thus it may be easier to remove them during this time if using food bait to attract animals for lethal removal. At Cape Lookout National Seashore, efforts to control raccoon populations were most effective during the winter months when populations were low and animals were in poor physical condition (Waldstein 2010). In contrast, some beaches may be described as seasonally urban habitats (SUH) where managers and biologists see a pulse of food resources onto the beach once people start to visit. Some predators may not appear at a site until these predictable anthropogenic food subsidies (PAFS) appear and thus management prior to that influx would be ineffective (Johnson 2016).

Although information about predators at your site can be useful for informing effective management decisions, such information may not be available or feasible to obtain. In these instances, it is highly recommended that you consult with experienced personnel that specialize in predation management, field experts (including USDA-Wildlife Services officials), state furbearer biologists, and/or local trappers. These experts can provide a wealth of information on how to best incorporate predator ecology into implementation of effective management at your site(s).

RISK MANAGEMENT (DB 5.3)

An important component of predation management involves identifying and mitigating the risk of unintended consequences to the beneficiary species, other species in the area, and predators. Managers should consider how to best avoid negative impacts, for example by shifting the timing or location of management activities in response to other species' breeding seasons or the presence of humans and/or pets. In some cases, there is no viable alternative to conducting predation management activities during the breeding season of the beneficiary species. Several flyway managers we interviewed indicated the importance of training those conducting management to minimize disturbance. Managers may need to consider altering management activities due to unintended consequences to non-target predator species. For example, results from a study using baiting and poisoning to control Norway rats (using brodifacoum) and enhance waterbird populations on Langara Island, British Columbia found that Ravens were also poisoned from feeding directly on the bait as well as scavenging poisoned rats. Samples taken from bald eagles also indicated detectable levels of the poison. However, no apparent adverse effects

were observed for bald eagles. It was concluded that the use of brodifacoum for rat removal on waterbird islands can pose a risk to avian scavengers (Howald et al. 1999).

UNINTENDED SECONDARY EFFECTS (DB 1.6)

In some instances, the removal of predators from a system may cause unintended secondary effects. Although secondary effects are difficult to measure, it is important to consider these when planning, implementing, and monitoring the effects of predation management and its timing. Most flyway managers we interviewed (76%) said they considered unintended secondary effects in their management efforts in some way, but several indicated that measuring and quantifying such effects is extremely difficult. In general, flyway managers indicated that they are very interested in finding techniques to better quantify these effects for inclusion in future management planning. Below are some examples of unintended secondary effects reported during predation management activities.

1. A change in predator population or community dynamics

When mammalian or avian 'top' predators are removed during management, 'mesopredator release' may occur. For example, if the number of coyotes or red foxes is reduced at a site, there is potential that the number of other smaller predators, such as raccoons, will increase as they are no longer being limited by those top predators.

A 7-year study of the impacts of mesocarnivores on Bobwhite Quail (*Colinus virginianus*) in the southeastern U.S. found that when management reduced predation risk by one predator type, that other predator species increased predation rates on the quail (Ellis-Felege et al. 2012). Similarly, Marzluff and Neatherlin (2006) found that controlling corvids was ineffective because other predators in the diverse predator assemblage increased predation rates on the beneficiary species when corvids were reduced. Thus, compensatory predation responses may be likely in communities with more than one functionally-similar predator present.

A raccoon on a beach. Audrey DeRose-Wilson

In Florida, raccoons were removed to protect loggerhead sea turtle nests. Subsequent research revealed that raccoon abundance and ghost crab density were inversely related, and that larger ghost crabs were present at sites with the fewest raccoons. The highest rate of egg predation by both predators was found to occur where raccoon abundance was lowest and ghost crab abundance was highest (Barton and Roth 2008).

In Northeast Scotland, researchers suggested that removing Common Gull (*Larus canus*) and Carrion Crow (*Corvus corone*) in an attempt to increase hatching success of Golden Plover (*Pluvialis fulva*) actually resulted in an increase of nest predation by fox, which were not controlled. The number of nests lost to foxes actually exceeded the number of nests originally lost to the gulls and crows (Parr 1993).

Strickland (2015) found that the predator community threatening Wilson's Plover nests at Cumberland Island National Seashore was shifting through time to include more coyote than raccoon, and suggested that coyotes might then be reducing the effects of other nest predators.

In Connecticut, trapping of coyotes and foxes at one beach was associated with increased egg predator activity (e.g., rats, weasels) for two subsequent nesting seasons at an adjacent beach (L. Saucier, personal communication, CT DEP).

On Martha's Vineyard, MA, managers have documented 'replacement predation.' For example, managers used 2x2 inch mesh exclosures to protect Piping Plover nests from striped skunks, but then observed American

Crows depredated hatchlings as they emerged from exclosures resulting in complete loss of young (L. Johnson, personal communication, Biodiversity Works).

These results highlight the importance of understanding food web connectivity and predator ecology in developing effective management strategies.

2. Prey switching by predators
Removal of colonial avian predators (e.g., Herring Gull, Laughing Gull, Great Black-backed Gull, etc.) at a site can decrease or eliminate those prey resources for mammalian predators, resulting in them switching to prey more heavily on shorebird nests and chicks.

3. A change in prey community dynamics
Many predators are generalists and forage on multiple species of avian, mammalian, and herpetofauna prey. In Maine, predation managers have received complaints from landowners about unintended consequences. For example, when predators are removed to benefit beneficiary species, other non-beneficiary prey (e.g., rodents) then increase and become a nuisance. While these reports have not been verified with field data, it is worth mentioning the potential for this unintended effect or perception of effect (A. Vashon, personal communication, USDA Wildlife Services).

BP 5 SUMMARY
Timing the implementation of predation management can be greatly improved by incorporating knowledge about the phenology and ecology of both the beneficiary and predator species, as well as community dynamics to the fullest extent possible. Appropriate timing also can help manage risks and unintended consequences associated with predation management. The best information on the ecology of beneficiary and predator species often results from long-term monitoring efforts and systematic research projects (see recommendations in *BP 1* and *BP 8*). As previously mentioned, monitoring and/or research may not be possible at your site due to specific time and resource constraints. In these cases, using information about prey and predator species from nearby sites often can help guide management.

Removing predators from beaches also benefits species like Loggerhead turtles. BLM

BEST PRACTICE 6: COMMUNITY ENGAGEMENT, OUTREACH, AND COMMUNICATION

WHY IS THIS IMPORTANT?

Many Atlantic Coast managers have the responsibility of managing public or private lands for the dual purposes of wildlife conservation and human recreation. Therefore, many interview respondents expressed the desire to best communicate with the public and private landowners as needed, and also the need for more guidance on this issue given the often misunderstood nature of predation management.

Although none of our interview questions asked respondents to speculate about why predation was an issue for them, many managers spoke unprompted about artificially high predator populations around areas used by beneficiary species due to human subsidies that have created super-optimal forage and shelter resources, especially for commensal predator species such as red fox, raccoon, opossum, skunk, crows and gulls. Whether these human subsidies are small bites of food left by daytime beachgoers or larger trash cans, trash dumps or structures that allow shelter, the unintended effect is to bolster predator populations over what would be naturally present with deleterious effects to native beneficiary species (Marzluff and Neatherlin 2006). As many Atlantic coast managers have experienced, this creates a formidable management challenge; one that place them at odds with some members of the public or certain advocacy organizations.

Managers are often hesitant to share predation management methods with the public, especially lethal predator control actions (Leopold and Chamberlain 2002). There is a perception among interview respondents that public support for lethal control of predators is generally low. However, studies have consistently shown that the reality of the general public's view on predation management is much more nuanced and related to place of origin (e.g. urban vs. rural), age, gender, and context for the management (Mankin et al. 1999). For example, Messmer et al. (1999) found that while the general public strongly supports the rights of predators to exist, that the same respondents also did not generally support an outright ban on predator hunting or trapping. Public support for lethal control of predators is often strongest when conducted to benefit threatened or endangered prey species (Messmer et al. 1999, Isaksson 2009). These same studies found that public support for lethal control of raptors was lowest among all predator species (Messmer et al. 1999, Isaksson 2009).

More recent surveys of the public have continued to find nuanced support for lethal predation management when the rationale is clearly explained and placed in context. For example, Koval and Mertig (2004) surveyed the attitudes of both the general public and wildlife agency personnel in Michigan towards lethal predation management. They found seven areas for which there was support for lethal removal of predators: 1-2) to control disease and wildlife damage, 3) to benefit imperiled species, 4) to keep the public safe, 5) to manage population levels of wildlife, and 6) for food (Koval and Mertig 2004). Again, the findings were nuanced among different public and professional groups in this Michigan study, but the authors concluded that lethal management should be feasible with few conflicts as long as managers consider public attitudes when designing their actions (Koval and Mertig 2004). Further, surveys of the general public over time showed increasing support for regulated lethal control via trapping, presumably as a result of efforts to communicate effectively with the public on the importance and need for regulated trapping (Responsive Management 2001, 2016, 2018). In their most recent survey of the public, Responsive Management (2018) found that while 54% to 75% of the general public had heard nothing about trapping, a majority (54% to 68%) think the state wildlife

agency is a credible source of information and approved (68% to 84%) of trapping for ecological reasons, which includes predator removal to protect sensitive species.

These findings show that managers should not be hesitant in engaging the public in predation management methods, as agency managers have credibility and the public has demonstrated an ability to understand and support trapping as a beneficial wildlife management tool. Agencies and NGOs should be aware of the need for transparent communication between managers and the public where the goals and consequences of various management actions are clearly stated. One challenge that is rarely addressed is the need to further train professional managers, not just the general public, on the nuanced details of lethal predation management. For example, Muth et al. (2006) surveyed 1000 wildlife professionals from The Wildlife Society, American Fisheries Society, the North American Wildlife Enforcement Officers' Association, and the Society for Conservation Biology on the issue of whether or not to outlaw foothold traps. The use of foothold traps to restrain wildlife can be a lightning rod issue among varied groups and has sometimes resulted in proposals of anti-trapping legislation. Muth et al. (2006) found that wildlife professionals appeared just as conflicted on the use of foothold traps as the general public, with 46% of respondents favoring the outlaw of these traps, 39% opposing the outlaw of these traps, and 15% having no opinion.

As a result of research and surveys, The Association of Fish and Wildlife Agencies (AFWA), and associated Furbearer Working groups (e.g., Northeast Furbearer Technical Committee, Southeastern Association of Fish and Wildlife Agencies Furbearer Working Group), along with the Atlantic Flyway Council, have embraced the importance of educating both the public and professional groups through a variety of materials and courses. For example, these groups have organized numerous scientific papers, reports and training materials on the issue of furbearer management in easy to access locations. Many of the reports cited in this section of the BP document, as well as Best Management Practices (BMPs) for trapping furbearers in the U.S., and links and dates for annual *Trapping Matters Professional Development Workshops* can be found at https://furbearermanagement.com/. The purpose of the *Trapping Matters Workshops* is to advance awareness and communication skills related to regulated trapping among agency professionals and to increase understanding of Best Management Practices for regulated trapping in the United States. AFWA also provide a second outlet, see https://furbearermanagement.com/furbearer-reports, at which the user may access relevant reports, human dimensions studies, trapping BMPs, effective communication messages and tips, and information about furbearer management and regulated trapping. For example, on this website, users can easily search the Best Management Practices for Furbearers portal to find BMP-approved traps by furbearer species, specific trap, or trap type (e.g., foothold, bodygrip, snare).

In the this section, we outline general guidelines and resources for public outreach communications materials.

TO ANNOUNCE, OR NOT ANNOUNCE?

There are instances where it may not be necessary to publicly announce predation management. For example, when a location is fairly isolated or management is conducted during a low-human use season or time. Managers should weigh their options in these cases to decide if proactive communication with the public is necessary.

When asked whether they publicly announced predation management, 31% of flyway managers interviewed indicated that they did so. Of those that did announce predator management activities, on average the intensity of the public response was ranked as a 3 (on a scale from 1 (low)–5 (high)). Responses from the public often varied for a variety of reasons, including the management type (lethal vs. nonlethal), specific activity type, and species being targeted. See DB sections 6.1–6.5 (Supplemental Material: Database of Interview Responses) for detailed responses.

Flyway managers indicated several reasons that they chose not to publicly announce predation management implementation, including working on private lands where the landowner was supportive and public access was prohibited, perceived negative public perception towards predation management (see discussion earlier in this BP 6 section), previous negative experiences with the public, and the cost and time investment of effective public outreach.

Flyway managers mentioned that predation management activities often were part of Environmental Assessments (EA), Comprehensive Conservation Plans (CCP), and Environmental Impact Statements (EIS), which allow for public comment. It should be noted that flyway managers also indicated that although they may not have publicly announced management activities, they were also not necessarily hiding it and engaged with the public when approached with questions.

OUTREACH TOOLS

There are a number of outreach tools already available to inform the public of predation management activities and educate the public on how to avoid artificially increasing predator populations which may then negatively impact beneficiaries. These include but are not limited to: signs, beach stewards, field trips, pamphlets/educational materials, public forums, social media, news outlets, and FAQ documents. Examples of predation management messaging provided by interviewees and reviewers are shown in Supplemental Material BP 6: Predation Management Outreach Tools.

AFWA (see http://furbearermanagement.com/) has developed and tested messaging relation to regulated trapping with the general public. A key part of the aforementioned *Trapping Matters* workshop are lessons on communicating effectively with the public; these messages are provided in ***Supplemental Material BP 6: Predation Management Outreach Tools***.

North Carolina Audubon worked with school children to develop shorebird signs for coastal beaches. Walker Golder

The Atlantic Flyway Shorebird Initiative's human disturbance working group, and the Piping Plover communication team of the USFWS, are also currently working towards developing a unified Atlantic Flyway sign campaign, and thus consulting these groups is recommended before developing new signage (D. Reynolds, personal communication, USFWS).

Some reviewers noted that their agencies do have outreach tools that focus on the links between feeding wildlife and the potential need to lethally control that wildlife when it becomes habituated and attracted to high human use areas (e.g., Black Bears (*Ursus americanus*), American Alligators (*Alligator mississippiensis*, N. Douglass, personal communication, Florida Fish and Wildlife Conservation Commission). However, we did not discover any materials that explicitly link the feeding of wildlife to lethal control to benefit the beneficiary species in this document. This is an area in need of further work across the Atlantic Flyway. Organizations devoted to the protection of native predator populations (e.g. Urban Coyote Initiative, https://urbancoyoteinitiative.com/, BearWise, bearwise.org) may offer unique resources and models for such an outreach campaign.

The best messaging campaigns make specific behavioral requests, are simple yet eye-catching in design, and are consistent across all forms of media (signs, social media, verbal messaging, etc.). When designing outreach materials, use the following sets of guidelines to create clear and effective communications materials (Ward et al. 2011). These guidelines are useful for any public outreach materials that you may design and are not meant to be predation management-specific. We also recommend that managers, when possible make every attempt to work with partners that have expertise in outreach and marketing.
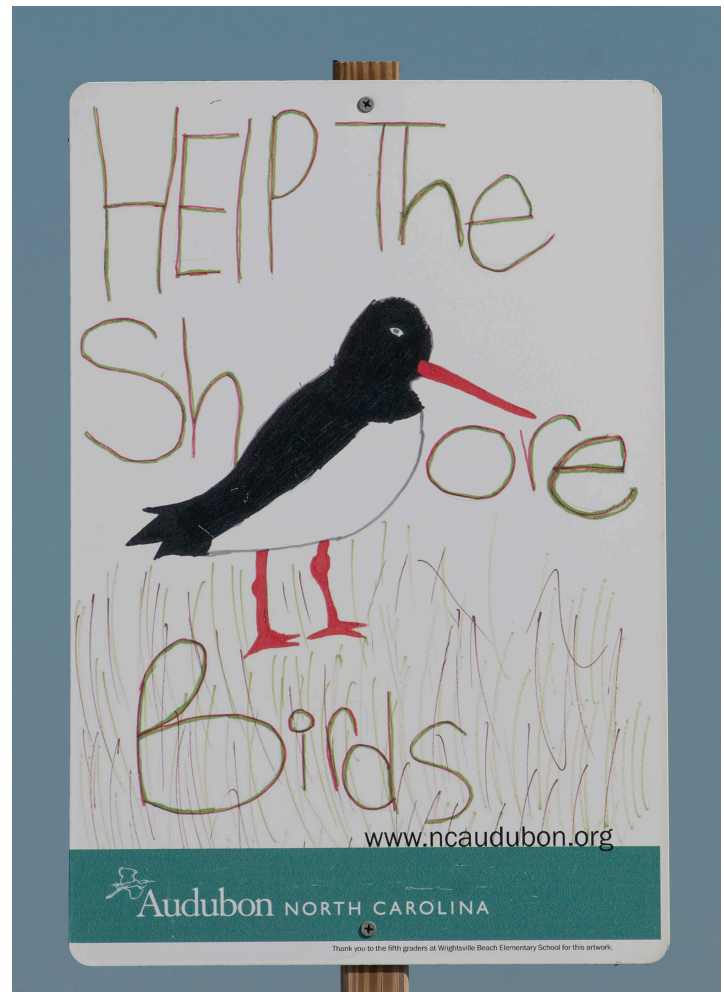
Signs and Other Written Materials (brochures, information sheets, postcards, etc.)
Have a thematic heading that conveys the overall message in a concise and memorable way.
Sign heading text should be printed in a large, easily read font to facilitate reading from a distance and by children.

Signs should be placed near beach access points and/or where any problem behavior occurs.
• State your message early and often.
• Use color and pictures to catch people's attention and to reiterate your overall theme.
• Keep text to fewer than 300 words.
• Use no more than 15 words per sentence and five sentences per paragraph.
• Text should not exceed an 8th grade reading level.

Verbal Messaging

Consistency in training is paramount, as message efficacy can vary dramatically between presenters.

Make very specific and targeted requests if behavioral change (not feeding wildlife, picking up food, etc.) is desired.

Resources:

• Association of Fish and Wildlife Agencies. 2019. Furbearer Management. https://www.fishwildlife.org/afwa-inspires/furbearer-management This is a great resource to education the public and professionals about the why's and how's of furbearer management, including lethal management.
• Association of Fish and Wildlife Agencies. 2019. Furbearer Management and Best Management Practices for Trapping Program. http://furbearermanagement.com/ This is a great resource to education the public and professionals about the why's and how's of furbearer management, including lethal management
• Ham, S. H., T. J. Brown, J. Curtis, B. Weiler, M. Hughes, M. Poll. Promoting Persuasion in Protected Areas: A guide for managers who want to use strategic communication to influence visitor behavior. 2009. CRC for Sustainable Tourism Pty Ltd. Gold Coast, Queensland, Australia. A great resource manual for thinking about public opinion and promoting a behavioral change. The manual also includes information on how to evaluate the success of a public outreach campaign. http://researchrepository.murdoch. edu.au/id/eprint/26313/1/Promoting_Persuasion_in_Protected_Areas_WEB.pdf
• Northeast Furbearer Resources Technical Committee. 2016. Trapping and Furbearer Management in North American Wildlife Conservation. Second Edition. The Northeast Furbearer Resources Technical Committee, 60 pp. Available at https://www.fishwildlife.org/application/files/8815/2944/8183/Trap-Fur-Mgmt_final.pdg
• Ward, C., J. Taylor, S. Martin. 2011. Evaluation of Communication Strategies to Mitigate Visitor Use Impacts on Marbled Murrelets. Humboldt State University.
• USDA Wildlife Services, Do Not Feed Wildlife Materials https://www.aphis.usda.gov/aphis/ourfocus/wildlifedamage/sa_program_overview/ct_dontfeedwildlife
• The Atlantic Coast Piping Plover Strategic Communications Plan to reduce human disturbance (https://www.fws.gov/northeast/pipingplover/pdf/Communications_Plan_for_Reducing_Human_Disturbance_to_Atlantic_Coast_Piping_Plovers.pdf) is a useful tool that could be adapted or modified to deliver messaging linking human disturbance and predation management.

BP 6 SUMMARY

We recommend that managers review the many examples provided in *BP 6 *and associated *Supplemental Material BP 6: Predation Management Outreach Tools *as they develop outreach campaigns related to predation management. It is important to note is the apparent gap in outreach efforts aimed at making the connection between people mishandling trash or other human subsidies (e.g., fish cleaning stations, structures that create shelter) in coastal environments and the subsequent need for lethal predation management to protect beneficiary species. Although our interviews and literature review did not address the many complex underlying reasons for elevated levels of predation on beneficiary species (e.g., habitat degradation and loss, altered native predator communities, human food and structure subsidies), some managers specifically mentioned that artificially high native and non-native predator populations was a result of attraction to

human activity and refuse. Many interview respondents also mentioned the support of feral cat colonies in close proximity to beneficiary species as a major unaddressed challenge in need of a coordinated communications campaign. Many public beaches feature anti-littering signs and signs prohibiting feeding of wildlife, but few, if any, connect this message to the problem of artificially inflated predator abundances in important shorebird and turtle nesting areas.

Programs like the Crumb Clean campaign in the Redwoods National and State Parks (https://www.nps.gov/redw/learn/nature/crumb-clean.htm) and Leave No Trace (https://lnt.org/) are great examples of public outreach campaigns that target specific behaviors related to threatened species and conservation and preservation of natural areas, respectively. Similarly, the Fed Bear is a Dead Bear (https://lnt.org/blog/fed-bear-dead-bear) slogan is a popular campaign across the United States and may be a model for predation management messaging if adapted to local situations. However, some states have discontinued the use of this slogan as the public does not always understand that the garbage itself does not kill the bears, but rather the feeding-related habituation of bears leads to the need for lethal removal. Thus, further work is needed. At Crane Beach in Ipswich, MA, the management entity does deliver a leave no trace campaign and tells users that they must carry in and carry out all food and trash when using the beach (http://www.thetrustees.org/places-to-visit/northeast/crane-beach.html); raccoon and skunk predation at the site is currently minimal (J. Denoncour, personal communication, Trustees).

Consistent, simple, and targeted messages are most likely to be effective. For example, agencies across the Southeastern U.S. have recently developed the BearWise (bearwise.org) initiative to educate people on how to live with bears. An excellent example of such messaging as it relates to regulated trapping and furbearer management is presented in *Trapping Matters* workshops, offered by the AFWA, and included in *Supplemental Material BP 6: Predation Management Outreach Tools*. We strongly encourage managers to work with public relations and/or marketing specialists if they decide to pursue a public outreach campaign for their predator management program.

Keeping beaches free of predators allows many species, including Common Tern, to raise their chicks with fewer threats. USFWS

BEST PRACTICE 7: LAWS, REGULATIONS, LAND ACCESS, AND PERMITS

WHY IS THIS IMPORTANT?

Laws, regulations, land access, and other permitting requirements for predation management activities can vary widely between projects and geographic locations. Variables that impact which permits are required include the project location, who is conducting the management, and the source of the funding supporting the work. This BP summarizes the important permitting procedures that managers need to consider when developing a predation management program; however, each project should contact local, state and/or federal experts to confirm details. Permitting processes often take a significant amount of time to complete so these contacts should be made early in the planning process, even before exact methods are identified. Please consult ***Supplemental Material BP 7: Permit Details and USDA Contact Information by State*** for additional details; this document is maintained as a separate excel database as the information changes frequently.

FEDERAL AND STATE LAWS, REGULATIONS AND PERMITS

1. National Environmental Policy Act (DB 7.1)

The National Environmental Policy Act (NEPA) requires federal agencies to evaluate environmental impacts into their decision-making processes and ensures that environmental information is available to public officials and citizens before decisions are made and actions are taken. All federal actions are subject to NEPA (Public Law 9-190, 42 USC 4321 et seq.). Specifically, all federal agencies are to prepare detailed statements assessing the environmental impact of and alternatives to major federal actions significantly affecting the environment. These statements are commonly referred to as Environmental Impact Statements (EIS) and Environmental Assessments (EA).

An Environmental Assessment (EA) is a concise public document that briefly provides sufficient evidence and analysis for determining whether to prepare an Environmental Impact Statement (EIS) or a Finding of No Significant Impact (FONSI). If a proposed action does not have a significant impact on the environment, a FONSI may be prepared and the project can move forward. Otherwise, a more detailed and involved EIS and Record of Decision (ROD) should be prepared before the action is implemented.

Understanding the NEPA process is important for managers implementing predation management activities since it applies to any project funded with federal funds, including many projects funded through the National Fish and Wildlife Foundation (NFWF). The process could involve reaching out to the relevant USFWS field offices, and other partners, to conduct a review of potential risks to threatened and endangered species. If predator management is being conducted by USDA Wildlife Services, existing Environmental Assessments prepared by that agency may cover the planned activities. Most states on the Atlantic Flyway should have an active EA that would cover bird-related predation management activities (N. Rowe, personal communication, USDA Wildlife Services). For example, if a federal agency requests USDA Wildlife Services assistance with predator management on property they own or manage, the requesting agency would be responsible for analyzing those activities in accordance with NEPA. However, USDA Wildlife Services' EAs could cover such actions if the requesting federal agency determined the analyses and scope of the EA was appropriate for those actions and the requesting federal agency adopted the EA through their own Decision based on the analyses in the EA.

When a non-federal entity (e.g., non-profits, municipalities, counties, private companies, individuals, or any other non-federal entity) takes an action to alleviate predator damage or threat of damage, the action is not subject to compliance with NEPA unless federal funds are being used to support the work. However, we urge such groups to still coordinate with any federal or state partners that may be also undertaking predation management in your region as these regional partners will be invaluable with regard to partners, strategies, evidence to support need, messaging, and outreach for local audiences.

2. U.S. Endangered Species Act

Under the Endangered Species Act (ESA), all federal agencies will seek to conserve threatened and endangered species and will utilize their authorities in furtherance of the purposes of the Act (Sec.2(c)). Agencies will consult with the USFWS pursuant to Section 7 of the ESA to ensure that *"any action authorized, funded or carried out by such an agency . . . is not likely to jeopardize the continued existence of any endangered or threatened species . . . Each agency will use the best scientific and commercial data available"* (Sec.7 (a)(2)). If threatened or endangered species might be impacted during predation management activities, consult with the regional USFWS office as provided below to determine if Section 10-related incidental take or other permits are required.

3. The Migratory Bird Treaty Act (MBTA)

The MBTA makes it illegal for anyone to take, possess, import, export, transport, sell, purchase, barter, or offer for sale, purchase, or barter, any migratory bird, or the parts, nests, or eggs of such a bird except under the terms of a valid permit issued pursuant to Federal regulations. The migratory bird species protected by the Act are listed in 50 CFR 10.13. If migratory bird species might be impacted during predation management activities, consult with the regional USFWS office as provided below to determine if incidental take or other permits are needed. If needed, a **federal depredation permit (3-200-13)** authorizes the manager to capture or kill birds to reduce damage caused by birds or to protect other interests such as human health and safety or personal property. A depredation permit is intended to provide short -term relief for bird damage until long-term, nonlethal measures can be implemented to eliminate or significantly reduce the problem. As part of the Depredation permit process, WS provides a "Form 37 Permit Review Form". This form is required as part of your Depredation Permit application. You must call WS (866-487-3297) to obtain a Form 37. See https://www.fws.gov/forms/3-200-13.pdf for the Migratory Bird Depredation Permit Application.

Federal agencies like USDA Wildlife Services maintain Federal Depredation Permits issued by the USFWS. In some cases, the resource owner or manager may obtain the permit and list Wildlife Services as a subpermittee. Private trappers, NGOs, or contractors may not apply for the depredation permit but may be listed as and conduct the work as a subpermittee. Your Federal permit is not valid unless you are also in compliance with State requirements. This often means you must hold a valid State permit in order for your Federal permit to be valid. It is your responsibility to contact the appropriate state agency to fulfill permitting requirements and become familiar with state wildlife laws and regulations.

5. U.S. Bird Banding and Marking Permit

Banding birds, for the purpose of trapping and relocation of raptors, is controlled under the MBTA and requires a Federal Bird Banding and Marking Permit along with a depredation or scientific collection permit under the MBTA. There is no fee for this three-year permit. Some states require a state permit as well. Only official federal bands may be legally placed on relocated birds released within the United States. Bird banding permits, supplies of bird bands, and bird banding data are administered by the Bird Banding Laboratory.

A U.S. Federal Bird Banding and Marking Permit will only authorize the capturing of wild birds for the purpose of banding or marking and to salvage birds that are found dead or that are accidentally killed as a result of *normal banding activities.* You will be required to maintain and submit, electronically, detailed records of any birds banded. You will be required to maintain records on salvaged birds (or parts thereof) and turn them over to a public, scientific or educational institution in accordance with instructions from the Bird Banding Laboratory.

For the Atlantic Flyway states requesting permits, you will need to contact one of the offices listed below. See https://www.fws.gov/permits/ for more about FWS permits and the Federal laws and Treaties that relate to migratory birds.

Permit Contacts			
FWS Region	Area of Responsibility	Mailing Address	Contact Information
Region 4	Florida Georgia North Carolina South Carolina Virgin Islands Puerto Rico	P.O. Box 49208 Atlanta, GA 30359	Tel. (404) 679-7070 Fax (404) 679-4180 Email: permitsR4MB@fws.gov
Region 5	Connecticut District of Columbia Delaware Maine Maryland Massachusetts New Hampshire New Jersey New York Pennsylvania Rhode Island Virginia Vermont West Virginia	300 Westgate Center Drive Hadley, MA 01035	Tel. (413) 253-8643 Fax (413) 253-8424 Email: permitsR5MB@fws.gov

6. State Laws and Regulations

For the most part, the regulation of wildlife is under the authority and jurisdiction of the state wildlife agency. State regulations and/or or laws regulate most wildlife species, including their take. Always check with your state wildlife agency to determine if a permit is needed to conduct lethal management activities. Most states have restrictions on method (e.g, trap-type) of take that managers must abide by, unless exempted under a state permit. Because of differences among states, *Supplemental Material BP 7: Permit Details and USDA Contact Information by State* provides information on state specific requirements and contact information to start the process. State permits may be issued by the state wildlife agency for the taking of wild animals that are destroying or damaging private or public property, wildlife habitat, game species, timber, crops, or other agriculture so as to be a nuisance, or for scientific, research, or for wildlife management purposes. In many cases, there is no cost for this permit. Permit holders are required to adhere to the conditions set forth in the permit. This may limit the type of traps, size of trap, and whether an animal can be released, relocated or dispatched.

LANDOWNER PERMISSION (DB 7.3)

In addition to federal and/or state permitting requirements, separate landowner permission also may be required in order to conduct predation management activities. If USDA Wildlife Services is conducting the work, a Work Initiation Document (Form 12-A) is required and must be signed prior to any management activities being conducted. The form ensures that all parties involved have agreed upon what activities are acceptable, that the property boundaries are identified and that contact information is shared. In other cases, a formal written agreement prepared with legal assistance should be in place between the landowner and entity or individual performing the work. If private contractors are used, similar work or contract documents are advised as well. Additionally, private contractors may need liability insurance.

- Proactive communication and outreach to a community of landowners on project goals and details is often effective for establishing understanding and trust of landowners prior to attempting to gain permission to conduct activities on or adjacent to their lands.

- On Martha's Vineyard in Massachusetts, where most sites are privately owned, Biodiversity Works has found success initiating open and informative lines of communication early in the management planning process. Through this communication, Biodiversity Works identified that landowners were primarily concerned about how management activities (e.g., traps, avicide, etc.) may affect their pets' safety. The organization's outreach efforts have included educating landowners about how humans have altered the landscape, leading to an unnaturally high density of predators that are adversely affecting shorebirds. Their messages have also emphasized that other options for conserving shor birds have been exhausted, that lethal management is a last resort, that a minimal number of predators will be removed, and that removal will not target breeding adults with young or neonates When approaching landowners, this group has samples of any forms needed to consent to activities; for example, USDA Wildlife Services forms. See *Supplemental Material BP 6: Predation Management Outreach Tools* for an example of a landowner consent form.

• Flyway managers we interviewed highlighted the importance of compiling and being able to effectively convey scientifically sound information and data to landowners to support the need for and effectiveness of predation management when proposing to initiate it on private property, or sites adjacent to private property. This information often will require productivity data as well as predation management data, which will be detailed in *BP 8*.

- The Florida Fish and Wildlife Commission has undertaken lethal control of crows for beneficiary species on urban beaches. The Commission contacted adjacent private property landowners to make them aware of impending activities. They showed the landowners photos of crows taking eggs and chicks of beneficiaries to help justify the need for the management. After completing this outreach, there was no opposition to the actions. The Commission engaged local law enforcement during the management to ensure public safety and also coordinated closely with Audubon Florida so that they could help explain the management actions as needed (N. Douglass, personal communication, Florida Fish and Wildlife Commission).

BP 7 SUMMARY
Permitting requirements and permissions needed to implement predator management can vary widely across the Atlantic Flyway and should be addressed carefully and early in program development. Things to consider include securing appropriate federal and state permits, complying with National Environmental Policy Act (NEPA) requirements, and consulting with the USFWS under the Endangered Species Act (ESA) or state equivalent, if necessary. Each site or project will be unique and complying with these requirements will vary from state to state. In this section, we highlight some key federal and state laws and regulations to consider, but we recommend you contact the regional USFWS permitting office, the state USDA Wildlife Services office, and your state's furbearer biologist early in the predation management planning process.

BEST PRACTICE 8: MONITORING, MEASURING, AND REPORTING EFFECTIVENESS

WHY IS THIS IMPORTANT?

To implement effective and adaptive predation management, it is important to regularly assess and evaluate the success and efficiency of the management strategies. Evaluating and reporting effectiveness of predation management is also a crucial component of gaining public trust and support.

Although lack of resources may make it difficult to study predation management and the responses of the beneficiaries, thoughtful consideration of the complex dynamics that affect species interactions is necessary to ensure that the appropriate predation management strategy is in place at your site(s).

The following section outlines some of these considerations and some metrics you may collect to help determine the relationship between your predation management program and the demographic response of the beneficiaries and the predators.

MEASURING AND REPORTING ON EFFECTIVENESS USING METRICS RELATED TO THE BENEFICIARY SPECIES

There are several metrics that have been used to measure the effectiveness of predation management on the beneficiaries. Some of the most common include:

- **Nest or hatching success** (Nol and Brooks 1982, Parr 1993, Jackson 2001, Bolton et al. 2007, Moore and Reid 2009, Waldstein 2010, Whitworth et al. 2013, Pearson et al. 2016)
- **Chick survival or chick/fledging counts** (Neuman et al. 2004, Struthers and Ryan 2005, Moore and Reid 2009, Engeman et al. 2010, Catlin et al. 2011, Dinsmore et al. 2017)
- **Changes in population size or pair numbers** (Parr 1993, Nordström et al. 2003, Neuman et al. 2004, Bolton et al. 2007)

According to Lavers et al. (2010), only a small fraction (n=112; 14%) of the more than 800 predator removal programs reported demographic responses of the bird populations that the removal program was seeking to benefit. Of all responses, changes in productivity was the most commonly reported (25.3%; Lavers et al. 2010). Confounding factors often are mentioned as reasons for not seeing, or not looking for, a response to predation management. The following are commonly mentioned confounding factors; however, we recommend that these factors also can and should be assessed and accounted for in a monitoring program whenever resources and capacity allow.

Piping Plover chicks. Chelsea Weithman

1. Simultaneous Management Activities

It is important to take into consideration other management activities occurring simultaneously with predation management at your site, such as habitat manipulation/creation and human disturbance management. The effects of simultaneous management activities on reproductive output and subsequent population growth may be difficult or impossible to tease apart. For example, at predation management sites in the Great Lakes, Piping Plover fledging success increased following removal of crows and gulls. However, the authors acknowledged that it was difficult to assess the effectiveness of predation management, as it was just one component of an intensive recovery program (Struthers and Ryan 2005). Few studies have long-term datasets necessary to assess the contributions of different management strategies to population growth (Dinsmore et al. 2014). However, with coordinated monitoring as outlined in this BP and implemented in the demonstration sites (*Supplemental Material: Demonstration Sites*), such analyses will become feasible in the future.

2. Other Factors Affecting Beneficiary Species

It is also important to consider other environmental and anthropogenic factors responsible for demographic responses of bird populations. A study examining Great Horned Owl removal to benefit Piping Plover chick survival in the Great Plains reported that the removal program significantly increased chick survival in 2008, but not 2009, potentially due to differences in nesting densities and storm activity between years and its effect on chick survival (Catlin et al. 2011). Stocking et al. (2017) reported that while predation management, coupled with nest and chick protection, may help increase American Oystercatcher populations at Cape Lookout National Seashore, many other confounding factors influence reproductive success at that site. Flyway managers we interviewed identified that, in addition to predation, the following variables influenced demographic parameters: weather, flooding/overwash, human disturbance, management-related changes, and habitat-related changes. The effect of these variables differed substantially across sites and years.

Snowy Plover nest near the high tide line. Audrey Albrecht

It is important to use caution when drawing conclusions about the effectiveness of management efforts given the complex interactions of myriad factors, known and unknown. However, attempting to document responses of beneficiary populations to decreased predation pressure is important and should be a component of every management program.

When possible, we recommend collecting data for two to three years prior to implementing predation management, during implementation, and two to three years after implementation. To achieve the most meaningful comparison, collecting multiple years of data before and after is necessary to account for some variation and the confounding factors listed above. If you have multiple sites, you could also consider setting up an experimental design, in which some sites receive predation management and others do not and compare differences between them.

We recognize that for some federal or state-listed beneficiaries, for which predation is identified as a threat to site persistence collecting pre-data, or the using a control site, may not be possible. However, we recommend this information be collected whenever possible to serve as a basis of comparison for your management outcomes.

Below we have listed three reproductive endpoints that can be estimated to help measure the effectiveness of predation management activities, as well as several resources to aid analyses. The three scenarios are listed in order of least resource intensive to most resource intensive and the least to most statistically robust. We have listed some of the most common analytical techniques. However, it should be noted that there are other

analytical tools that can be used for analyses and we recommend managers work with statisticians with relevant experience when possible.

1. Apparent estimates of productivity

Managers can obtain apparent estimates for both nest success, brood success and productivity or fecundity rates with relative ease by collecting monitoring data that documents the final fate (hatched vs. failed) of each nest monitored and the total number of fledged chicks from all pairs monitored. Such an analysis requires fewer nest or brood checks than the methods listed below and therefore is less resource intensive, however these types of analyses will not allow one to account for imperfect detection and thus the parameters involved in these apparent estimates are biased in some unknown fashion.

Data collection
- Nest or brood fate (hatched vs. failed for nests, fledged vs. failed for chicks)
- Failure type

Analytical Tools
Nests and broods:
- **Logistic regression:** Hosmer D. W., and S. Lemeshow (2004). Applied logistic regression.
- **Chi-squared test:** Ramsey F. L and D. W. Shafer (2002). Chapter 19: More tools for tables of counts. The statistical sleuth.

2. Daily survival

Similar to apparent estimates of productivity, it is relatively easy to obtain estimates of daily survival rates. In addition to information regarding the ultimate fate of the nest or brood, you will also need to have information about the 'exposure time' or the amount of time between when you found a nest to when it hatched or failed. This information will allow you to account for nests that you were unable to find, particularly those that failed before discovery. These analyses will provide you with estimates for daily survival, which can then be raised to the number of days from laying to hatch to calculate overall nest success, and the number of days from hatch to fledge to calculate chick survival. It also allows you to conduct basic group comparisons (e.g., predation management vs. no predation management, exclosures vs. no exclosures).

Data collection
Nests and broods:
- Nest fate (hatched vs. failed)
- The number of chicks fledged per the number hatched for each brood
- Exposure time

Analytical Tools
Nests and broods:
- **Mayfield method:** Mayfield, H. (1961). Nesting success calculated from exposure. Wilson Bulletin 73:255–261; Mayfield, H. (1975). Suggestions for calculating nest success. Wilson Bulletin 87:456–466.

3. Improved estimates of daily survival

For these analyses, you will need to collect additional information for both nests and chicks, such that your nest and brood checks will need to increase to at least two times per week. However, more checks will allow you to better determine when nests fail or when chicks/broods disappear. These analyses will provide you with estimates of daily survival which can then be raised to the number of days from laying to hatch to calculate overall nest success, and the number of days from hatch to fledge to calculate chick survival. These analyses also account for imperfect detection and allow you to add covariates of interest (e.g., weather data, whether or not predator management was occurring, etc.) resulting in more statistically robust estimates of nest success and chick survival than the previous methods.

A Snowy Plover chick. Audrey Albrecht

Data collection

Nests:
- Nest checks ≥ 2 times/week to confirm whether or not the nest is active
- Date of every nest check
- Date the nest was found
- Date the nest was initiated (ideal, but not necessary)
- Date of last nest check when nest was known to be active
- Date the nest hatched or failed
- The number of eggs at each visit (if possible); we recognize that managers do not always check egg counts after the full clutch is complete for a variety of reasons. Partial nest loss can occur thus the recommendation to account for partial failure.
- Date the nest was exclosed (if applicable)
- Cause of failure (if applicable)
- Other covariates of interest

Chicks:
- Brood checks ≥ 2 times/week
- Date of every brood search (record the date you searched, even if you didn't locate any chicks)
- If chicks are banded, band resightings of all chicks present
- If chicks are unbanded with known adults and/or known territories, a count of all chicks in each brood present
- Hatch date of the chicks
- Other covariates of interest

Analytical tools

Nests:
- **Nest survival models in Program MARK**: Program MARK – a 'gentle introduction' Chapter 17 (http:www. phidot.org/software/mark/docs/book/pdf/chap17.pdf)
- **Logistic exposure:** Shaffer, T. L. (2004). A unified approach to analyzing nest success. The Auk121:526–540.
- **Multinomial logistic exposure:** Darrah, A. J., J. B. Cohen, and P. M. Castelli (2017). A Bayesian multinomial logistic exposure model for estimating probabilities of competing sources of nest failure. Ibis 160:23–35. (https://onlinelibrary.wiley.com/doi/epdf/10.1111/ibi.12510)

Chicks:
- **Cormack-Jolly-Seber model in Program MARK (if chicks are banded):** Program MARK – a 'gentle introduction' Chapter 4 (http://www.phidot.org/software/mark/docs/book/pdf/chap4.pdf)
- **Young survival model in Program MARK (if chicks are unbanded):** Program MARK – a 'gentle introduction' Chapter 19 (http://www.phidot.org/software/mark/docs/book/pdf/chap19.pdf)

MEASURING AND REPORTING ON EFFECTIVENESS USING PREDATOR METRICS

For many lethal techniques and to a lesser extent some nonlethal techniques such as translocation, there are a variety of ways to measure and report on the effectiveness of predation management using predator metrics. Below are a few examples. It should be noted that other than with translocation programs, it may be challenging to measure or report predator metrics for many nonlethal methods as the individuals are not being removed. For methods such as exclusion, harassment, and chemical taste aversion it may be best to report on the number of applications (nests exclosed, individuals harassed, chemical applications, etc.). We recommend that predator metrics are collected concurrent with metrics for beneficiary species so that they can be related to each other in analyses.

- **Ages** (Barton and Roth 2007, Waldstein 2010, Engeman et al. 2010), **sexes** (Barton and Roth 2007, Waldstein 2010, Engeman et al. 2010), **and numbers of individuals removed** (Jackson 2001, Nordström et al. 2003, Struthers and Ryan 2005, Barton and Roth 2007, Waldstein 2010, Engeman et al. 2010, Catlin et al. 2011, 2015)
- **Effort or 'catch rate' per trap days/nights** (Nordström et al. 2003; Catlin et al. 2011, 2015)

- **Timing of management activities** (Catlin et al. 2011)
- **Demographic effects of long-term removal programs on predator species of interest; changes in abundance, survival rates, reproductive rates** (Barton and Roth 2007, Engeman et al. 2010)
- **Changes in occupancy following removal** (Geider 2015)
- **Proportion of nest fates attributed to predation at control vs. predator removal sites, or before or after predation management instituted.**
- **Total number of predation events per season at control vs. predator removal sites or before vs. after predator removal (may compare between seasons but would have to adjust for potentially different number of beneficiaries and rate of predation events across seasons).**

Information regarding demographic effects on predators and changes in occupancy or abundance from predation management will likely require research and/or a long-term dataset. While funding is often a challenge to collecting these data, they are required to adequately assess the efficacy of the resources spent on the predation management program and should be considered as part of the total cost of predation management rather than externalities.

STANDARDIZED DATA COLLECTION (DB 8.2-8.3)

Flyway managers are willing to adopt a standardized method of collecting data as it relates to beneficiary (74% of those interviewed) and predator (69% of those interviewed) species. However, managers recognize that there are a number of hurdles to standardized collection of data across the U.S. Atlantic Flyway. These difficulties include limited accessibility of breeding sites, limited funding for shorebird monitoring, varying priorities of management entities and the lack of a solid communication and information sharing structure. However, a streamlined and standardized method of data collection that could be tailored to meet site-specific needs would greatly add to our current knowledge of the effectiveness of predation management along the Atlantic Flyway.

As part of this project to develop BPs for predation management along the Atlantic Flyway and to develop standardized methods of data collection, six BP demonstration sites collected beneficiary species and predator data in a standardized manner during the 2017 nesting season (see *Supplemental Material: Demonstration Sites*). All data were reported to the USFWS using a pilot version of a database being tested for widespread application. These data are available for use upon request to the USFWS. The standard operating procedures for the data collection and reporting is provided (*Supplemental Material BP 8: Standard Operating Procedures for Demonstration Sites*).

In addition to our recommendation to adopt the Data Collection SOPs used in the Demonstration Sites, we recommend managers consider several other examples of ongoing standardized data collection at the state level. These programs include:

1. PIPLODES AND TERNODES: (Summary adapted from the PIPLODES User Manual) "Piping Plover Online Data Entry System" and "TERNODES"- "Tern Online Data Entry System," are data entry methods used by Massachusetts managers for state-wide, standardized data entry and reporting for Piping Plover and Least Tern census data. The Natural Heritage and Endangered Species Program of the Massachusetts Division of Fisheries and Wildlife developed an on-line data entry system that allows shorebird cooperators who monitor Piping Plovers and Least Terns to complete and submit state census forms through a web portal. These systems increase efficiency of data submission by shorebird cooperators throughout the state who can submit census form data online via a structured submission process. In addition, the system provides census form documentation for the state based on a normalized set of inputs, enables standardized reporting and new analytics, and offers improved quality of quantitative and qualitative census data. Standardized data collection and reporting facilitates analyses of statewide census data. One of the goals of the system is to continue to grow with the needs of the Massachusetts shorebird cooperators.

2. FL Shorebird Database: (Summary adapted from the Florida Shorebird Database Metadata) The Florida Shorebird Database (FSD) collects occurrence information and productivity data on six focal species of solitary nesting shorebirds (American Oystercatcher, Black-necked Stilt, Killdeer, Snowy Plover, Willet, Wilson's

Plover) and 14 species of colonial nesting waterbirds (Black Skimmer, Bridled Tern, Brown Noddy, Brown Pelican, Caspian Tern, Gull-billed Tern, Laughing Gull, Least Tern, Magnificent Frigatebird, Masked Booby, Roseate Tern, Royal Tern, Sandwich Tern, Sooty Tern). The FSD also collects occurrence data on wintering species of shorebirds and waterbirds using coastal habitats in Florida. The FSD is managed by the Florida Fish and Wildlife Conservation Commission (FWC) and is maintained as a free online resource for information on Florida's shorebirds and waterbirds. The original online database, the Florida Beach-nesting Birds Website, was launched in 2005. This database was designed as a management tool providing real-time information to managers and

Black Skimmer and chick. David Pieser

permit reviewers to help them respond to situations involving nesting shorebirds and waterbirds. However, as use of the database expanded, its potential as a research tool soon became evident. In 2010, FWC collaborated with multiple partners to create the FSD. By restructuring the old database and standardizing monitoring protocols, the FSD can serve as the tool that will provide answers to important questions about the status of shorebirds and waterbirds in Florida while continuing to function as a management tool.

3. NestStory (Description provided by Michelle Stantial, SUNY ESF): NestStory is a long-term storage and data management platform that allows users to collect data using their cellular devices while in the field. The data collected by NestStory in the field is the same type of data that was previously collected using datasheets and/or field notebooks. The most basic feature of NestStory allows users to complete nest checks by recording the number of eggs, chicks, and adults observed at each nest during a site visit. In the event of a nest loss, users can record the loss type and the associated evidence for how the loss was determined. NestStory allows users to record notes, take photos, and record band combinations of individuals at both the site-level and nest-levels. NestStory has a powerful mapping tool that allows users the ability to mark the locations of nests, individual birds, and broods throughout the season. NestStory can also be customized to each individual organization by creating data collection modules that allow user groups to collect data outside of the base features that are provided. All data collected in the field can be stored long-term for the life of the project and viewed through the online desktop platform. Alternatively, data can be downloaded in the form of customized reports for offline storage. Finally, NestStory allows users the ability to then export their data to other databases through customizable spreadsheets. Each spreadsheet is tailored to the specific database that it will be linked to, allowing for seamless transfer of data between groups. NestStory has the potential to improve communication and collaboration both within organizations and between organizations through standardized data collection, real-time data entry, and customizable spreadsheets for data-sharing.

4. Other state databases: Many managers and biologists interviewed described how they use standardized procedures for collecting data on beneficiary species. For example, North Carolina Wildlife Resources Commission (NCWRC) has an online database for shorebird and colonial waterbird data (CWB); data are from both standardized surveys and permit-related surveys. CWB data are breeding season data and shorebird data are from winter or migratory surveys (Sara Schweitzer, personal communication, NCWRC).

BP 8 SUMMARY RECOMMENDATIONS
We have listed a number of metrics that managers may consider recording to assess the effectiveness of their predation management program. Like other decisions regarding predation management, what is appropriate for your site will depend on the time and resources you are willing/able to commit, the availability of funding, and your goals for the predation management program.

Before you add to your data collection protocol, carefully consider what each metric tells you about predator presence, predation pressure, target species productivity, etc. at your site(s) and what is feasible for you to collect. Although you may not be able to design a formal study to address the demographic responses of

target species to predation management, it is important to consider changes in predation pressure and target species population dynamics over time and adjust your predation management program as necessary.

Until flyway-wide standardized data collection becomes a reality, the most important step you can take to monitor your predation management program will be to collect thoughtful, organized, and consistent data over time to facilitate comparisons between and across years.

We recommend in a best practice that shorebird and predator data be collected at least at the level done by the demonstration sites in this BP (see *Supplemental Material BP 8: Standard Operating Procedures for Demonstration Sites* for details) to responsibly assess and update the efficacy of your predation management program each year. Managers at the flyway level should work to evaluate existing standardized data collection protocols and databases to decide whether a flyway-level predation management database can and should be maintained with other collaborators.

Monitoring nest success and chick survival should be key components of effective predation management planning. ©Mark Vance

BEST PRACTICE 9: COORDINATION OF MANAGEMENT AND FUNDING ACROSS AGENCIES AND AT MULTIPLE SCALES

WHY IS THIS IMPORTANT?

Communication among groups conducting predator management can significantly improve the efficiency and outcomes of management activities at multiple scales. Good communication will result in a better understanding of who is conducting predator management, where the control is occurring, and at what scales. Information sharing will help inform the effectiveness of specific methods, the availability of new methods, and general information about current practices in predator management. For example, in Florida, managers identified that predation by raccoons was limiting beach-nesting birds at a state-level preserve. In exploring the issue, managers identified that the raccoons impacting the state-preserve were part of the same population impacting nesting birds at an adjacent County Park and an adjacent National Wildlife Refuge. Communication among managers at this local level then led to the design and implementation of a coordinated raccoon management program that likely would not have been effective if only conducted at a single of the three connected sites (N. Douglas, personal communication, Florida Fish and Wildlife Conservation Commission).

Although much of the predator management conducted along the Atlantic Flyway targets protection of nesting beneficiary species, it is also important to remember migratory beneficiary species may benefit from predator management as well. This reality highlights the importance of flyway-wide coordination to best manage for the largest number of beneficiaries.

Communication between groups is also important in terms of funding sources as it could provide the opportunity to share benefits and drawbacks of specific funding sources. It could also initiate conversations and bring people and groups together to apply for local, state, regional, or even flyway-wide funding opportunities.

COMMUNICATION BETWEEN GROUPS (DB 9.1-9.2)

Although responses varied, flyway managers generally expressed that, especially within states, there was adequate to good communication
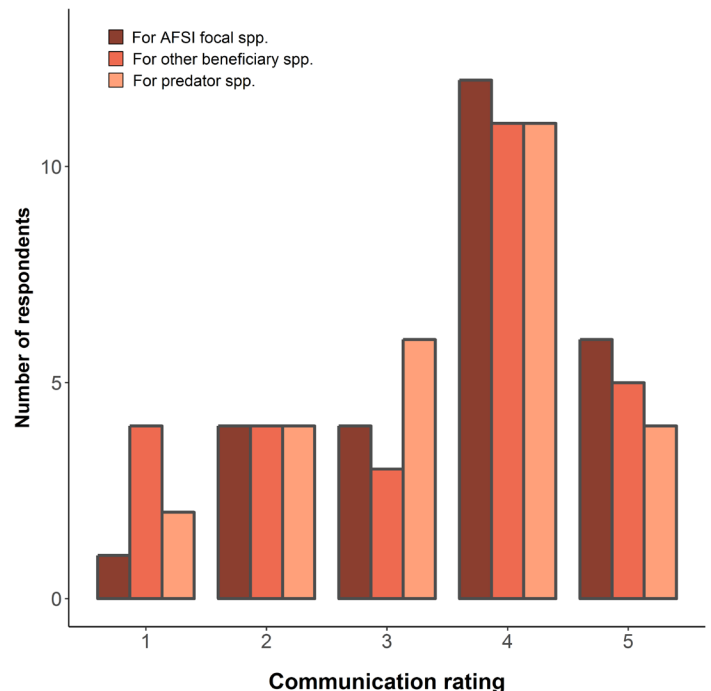
Figure 5. Likert scale ratings for communication between groups that have performed predator management along the Atlantic Flyway as indicated by 29 interview respondents. A rating of 1 indicated perceived poor communication and a rating of 5 indicated perceived excellent communication. See sections 9.1 and 9.2 in the BP predator database for specific responses.

between groups regarding predator management as it related to the AFSI target species, other prey species, and predator species (Fig. 5). When asked about suggestions for facilitating communication between groups, interview respondents expressed the importance of regular, open and transparent communication in a variety of forms. Below are examples of ways to facilitate communication between groups implementing predation management.

- *Meetings*: Meetings are an excellent way to bring people together and facilitate communication and should be held regularly (annual or biannual). It will be beneficial to hold meetings within the states, but also attempt to organize working groups of symposia at professional meeting. The biannual Atlantic Coast Piping Plover and Least Tern Workshop offers an excellent opportunity for communication and collaboration regarding predator management. Although, given the nesting species targeted by this meeting, the southeast states of the Atlantic Flyway (South Carolina, Georgia, and Florida) may not be included. Therefore, if future meetings are to focus on predator management, a concerted effort should be made to ensure that representatives from the southeast states are included. It will be important to include predator control specialists, USDA-Wildlife Services personnel, and state furbearer biologists in any meeting where predation management is discussed.

- *Webinars and phone calls*: As in-person meetings are not always possible due to costs as well as travel logistics, the use of webinars and phone calls could be effective tools in facilitating communication. Even with in-person meetings, regular phone calls between partners, groups, and states can be beneficial in facilitating communication. It may also be cost-effective to host an annual flyway-wide webinar to discuss the benefits and drawbacks of specific predator management techniques.

- *Listservs, emails, and other project collaboration sources:* Another way to facilitate communication with a large group of people could be to set up a predator management listserv where people could ask and answer questions regarding predator management as well as discuss and get information about specific techniques. This option would require little effort, once the

listserv was operational, and may be an option for disseminating information to the larger group. As some managers may be (understandably) wary of listservs or email chains, another option could be creating a 'private' Google folder where documents could be shared or the use of project management software such as Basecamp, Slack, or others. Although incredibly useful, these software programs can potentially be expensive, especially with multiple users.

- *Training workshops*: At any level of organization, from local to flyway, training workshops may help bring together experienced and novice predation managers. For example, managers in Florida hold interagency workshops to train staff on predator management field techniques. The Florida Trappers Association, Inc. holds an annual event to train biologists from across the state in field-techniques of trapping ((N. Douglas, personal communication, Florida Fish and Wildlife Conservation Commission). Training events that bring together experts from often separated disciplines can build skills, knowledge and valuable partnerships.

FUNDING SOURCES AND LINKAGES (DB 9.3)

At many sites, predator management may be necessary each breeding season and therefore securing funding, especially long-term funding, can be difficult. This is especially concerning as some sites have observed direct benefits from predator management in terms of beneficiary species productivity, and a gap in funding may negate these positive effects. Although there are a number of ways to secure funding for predator management, below are a few examples mentioned by interviewees and reviewers:

Example 1: State Wildlife Grants: The State Wildlife Grant (SWG) Program provides Federal grant funds to State fish and wildlife agencies for developing and implementing programs that benefit wildlife and their habitats, including species that are not hunted or fished. SWGs can provide funding for predation management as long as it is included in the state Wildlife Action Plan and benefits focal species. https://wsfrprograms.fws.gov/subpages/grantprograms/swg/swg.htm

Example 2: Federal funds provided to states for general wildlife management: Some states noted that they are able to access monies from Federal Aid in Wildlife Restoration (i.e., commonly call

Pittman-Robertson funds) or Section 6-related U.S. Endangered Species Act Funds. Interviewees noted that decisions on how these funds are spent in each state are often made at the highest levels of the state fish and wildlife agency, but understanding that there is a precedent to use funds for predation management may be a starting point for discussions between managers and administrators.

Example 3: Atlantic Flyway Shorebird Initiative support: The National Fish and Wildlife Foundation's Atlantic Flyway Shorebird Initiative has funded multiple predation control efforts focused on enhancing nest success for nesting shorebirds, in particular American Oystercatchers. Projects range from predator fencing on Martha's Vineyard in Massachusetts to large-scale removal of raccoons on North Carolina barrier islands to multi-predator control on the Georgia coast. https://www.nfwf.org/amoy/Documents/afsi-business-plan.pdf

Example 4: Opportunistic/Localized mitigation finding: Natural Resource Damage Assessments (NRDA) from oils spills or other contamination often result in local or regional conservation funding opportunities. The largest such example is the Deepwater Horizon spill in the Gulf of Mexico, which has resulted in billions of dollars in damages and several new conservation funding sources, including the Gulf Environmental Benefit Fund. Most NRDA funding sources are smaller and localized, such as the Bouchard spill in Buzzard's Bay, Massachusetts. https://darrp.noaa.gov/oil-spills/bouchard-barge-120

Extensive funding remains available related to the Deepwater Horizon oil spill recovery program for work on the U.S. Gulf Coast; see below for a list of funding sources that could be leveraged towards predation management projects in that region.

- **NFWF** http://www.nfwf.org
- **Gulf Environmental Benefit Fund** http://www.nfwf.org/gulf/Pages/home.aspx
- **Atlantic Flyway Shorebird Initiative** http://www.nfwf.org/amoy/Pages/home.aspx
- **ConocoPhillips Spirit of Conservation** http://www.nfwf.org/spirit/Pages/home.aspx
- **Gulf Coast Conservation Grants Program** http://www.nfwf.org/gulfconservation/Pages/home.aspx
- **Southern Company Power of Flight Program** http://www.nfwf.org/power/Pages/home.aspx
- **Gulf Coast Ecosystem Restoration Council** https://www.restorethegulf.gov/council-select-ed-restoration-component
- **Deepwater Horizon NRDA** http://www.gulfspill-restoration.noaa.gov/restoration/give-us-your-ideas

Example 5: Small non-profit/foundation grant opportunities: Foundations may offer small grants that would enable a group to purchase supplies needed for predation management or monitoring. For example, Idea Wild offers small equipment grants to conservationists around the world (http://www.ideawild.org/history.html). Many zoos offer small conservation grants, especially focused on species in their collections or related to conservation issues in local communities. For example, see the American Zoological Association's Conservation Grants Fund (https://www.aza.org/cgf).

BP 9 SUMMARY

Clear and consistent communication and collaboration with other groups conducting predator management should be an important part of your overall strategy for managing predation. Funding for predator management is consistently a challenge for managers. By collaborating with other managers, you may be able to target larger and longer-term funding sources than would be feasible in isolation. By coordinating with neighboring, regional, and national partners you may be able to extend the effects of predation management at your site both spatially and temporally. In addition to resource sharing, ongoing communication and information sharing will keep you up to date on current practices and opportunities, which will improve the efficiency of your work and position your program to take advantage of new opportunities.

FUTURE DIRECTIONS

- The purpose of this predation management guidance document is to provide managers with the framework for designing, implementing, assessing and updating their predation management activities. The need to lethally or nonlethally control predators as part of an overall management strategy for a beneficiary species often arises from human-driven landscape changes that lead to artificially abundant predator populations or altered predator communities. The most effective and sustainable predation management strategy is to address the underlying landscape-level drivers of altered predation pressure (e.g., connectivity to source populations, human food subsidies, artificial shelters for predators) in both the short-term and long-term management of beneficiary species. When predation pressure is demonstrated to be limiting the persistence and recovery of a beneficiary species in the short-term and long-term, then this BP offers details on planning for a detailed predation management strategy.

- We stress throughout the document the need to collect robust and scientifically-defensible data linking the predation management actions with positive changes in the demographic parameters of concern for the beneficiary species. Data are also needed to demonstrate that predation management activities are not having negative secondary effects on native predators or other wildlife. The existence of such data is still rare on the Atlantic Flyway, and much work is needed to develop defensible triggers or thresholds for starting and stopping predation management and minimizing unintended secondary impacts.

- Across the flyway, there are several existing protocols and databases for standardized data collection; we recommend that flyway managers focus on potentially combining the existing programs into a flyway-level database for predation management so that the combined data may be used to make defensible decisions as stressed above, perhaps in a structured decision-making framework.

- This predation management BP will be served on the Atlantic Flyway Shorebird Initiative and on their website. We recommend that if additional funding is available, this document is formatted as a "living document"that can be easily updated through time by the AFSI predation management working group as additional data and case studies are available.

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SUPPLEMENTAL MATERIAL: DATABASE OF INTERVIEW RESPONSES

The database of interview responses is maintained as a stand-alone excel file associated with this document. We highly recommend its use as the detailed responses of interviewees provide excellent information above and beyond what was summarized in this document. Database of interview responses available at https://atlanticflywayshorebirds.org/documents/Interview_Responses.xlsx

SUPPLEMENTAL MATERIAL: DEMONSTRATION SITES

INTRODUCTION AND OVERVIEW OF DEMONSTRATION SITES

During the breeding season of 2017, six sets of sites throughout the flyway participated in the BP project as 'demonstration sites'. Each demonstration site was chosen because they were trying a novel method or testing unique hypotheses related to predator management (see below) that will help further future predation management discussions, techniques, and implementation. Each demonstration site provided a detailed description of their project, and each component of their report relates to BP's 1–9 as described in the predation management BP main document. Each demonstration site also collected standardized data on the avian species of concern, the predators, and the management actions as detailed in BP 8. The data from each demonstration site is available in a separate database which is housed at the USFWS; the data is available upon request and is not part of the database of interview respondents associated with this document.

What was unique about each demonstration site?

Florida: The Florida demonstration site explored the effectiveness of a relatively new method of non-lethal control, conditioned electric stimulus aversion, to deter Fish Crows from depredating shorebird and seabird nests and chicks.

Georgia: The Georgia demonstration site experimentally tested the effects of nest exclosures on Wilson's Plovers nest success and chick survival. Although exclosures are often used in Piping Plover management, they have not been used frequently in Wilson's Plover management.

South Carolina: The South Carolina demonstration site examined the chronology of lethal management activities to determine the ideal timing to benefit both beach nesting birds as well as sea turtles.

North Carolina: The North Carolina demonstration site increased nest and chick monitoring efforts to better quantify nesting activity and success of shorebird species in response to increased predator management efforts and used nest cameras to help identify predation events as well as predator species.

Rhode Island: The Rhode Island demonstration site focused predator management efforts at sites where limited predator management had previously occurred, and compared productivity at sites where a combination of lethal and non-lethal management was used versus sites where only non-lethal management was used.

Massachusetts: The Massachusetts demonstration sites evaluated the relationship between human disturbances and predation and tested the hypothesis that greater human disturbance of nesting birds contributed to increased predator impacts. These sites used camera traps to assess these questions; full analyses were not completed by the time of this publication, but each site can be contacted for information on their full analyses.

A. FLORIDA: ELECTRIC STIMULUS AVERSION ON FISH CROWS
Author(s): Beth Forys (forysea@eckerd.edu) with contributions from Nancy Douglass and Craig Faulhaber
Site(s): Siesta Key, Lido Key, Anna Maria Island, Ft. De Soto, St. Pete Beach, Sand Key

I. Site Introduction (BP 1)

Name of Site[a]	Geographic Location	Approximate Size (ha)	Landowner	Bird Monitors/Stewards[b]
Siesta Key	coastal barrier island	20	Sarasota County	Audubon Florida steward working with local volunteer group
Lido Key	coastal barrier island	10	Sarasota County	Audubon Florida steward working with local volunteer group
Anna Maria Island	coastal barrier island	30	Manatee County	Anna Maria Sea Turtlewatch and Shorebird volunteers
Ft. De Soto	coastal barrier island	15	Pinellas County	Audubon Florida steward working with local volunteer group
St. Pete Beach	coastal barrier island	5	Pinellas County, but managed by City of St. Pete Beach	Audubon Florida steward working with local volunteer group
Sand Key	coastal barrier island	10	Pinellas County, but managed by the City of Clearwater Beach	Audubon Florida steward working with local volunteer group

[a] Prior predation management at our sites included using conditioned taste aversion to deter Fish Crows and decrease predation of shorebird and seabird eggs at all locations in March–July 2016.
[b] All of the monitoring of decoy nests was conducted by Beth Forys and Jo Campo, the technician hired to do the work. Most of monitoring of the real nests was also done by Beth Forys and Jo Campo, but they were assisted by Audubon Florida and local volunteer bird stewards.

II. Species Introduction (BP 1)
The species targeted to benefit from conditioned stimulus aversion were breeding Snowy Plovers, Black Skimmers, Wilson's Plovers, and American Oystercatchers. Each of these species was present at one or more of our sites, with all species present at Ft. De Soto. These species have been identified as focal (high conservation priority) species under Florida's Beach-nesting Bird Plan (Schulte 2016). Fish Crows had been previously identified as a major source of predation through annual monitoring of nests at these sites. Predation was determined by direct observation of predation as well as tracks around nests.

III. Triggers or Thresholds (BP 2)
We did not use a trigger or threshold, but Fish Crows had caused the abandonment of a Black Skimmer Colony near Sand Key (Forys et al. 2015) and were implicated in extremely low productivity on Siesta Key and Anna Maria Island.

IV. Management Activities (BPs 3–4)
Since 2014, we have been exploring methods of non-lethal Fish Crow control because our sites are very visible to the public. Additionally, because Fish Crows are nesting and likely maintaining territories during the shorebird and seabird nesting season (McNair 1984), it is possible that removal of resident crows would be offset by crows moving into the treatment area from adjacent territories. For example, Ryan et al. (2013) demonstrated that American Crow (*Corvus brachyrhynchos*) culling did not result in a decrease in crow predation of seabird eggs in California.

During the 2016 breeding season we experimentally used the emetic Carbachol injected into quail eggs to deter Fish Crow predation of shorebird and seabird eggs through Conditioned Taste Aversion (CTA). This technique was successful with Fish Crows in the lab (Avery and Decker 1994) and American Crows in the field

(Dimmick and Nicolaus 1990). In our study CTA was effective at most locations but was determined to be impractical for the following reasons: 1) there is no existing permit for the use of Carbachol for CTA in Florida; 2) in several instances, Fish Crows took Carbachol-laced eggs and buried them in the sand where non-target species could be exposed to the chemical; and, 3) we also experienced problems with the Carbachol-laced eggs degrading in the hot Florida sun during the 4-hour period of the experiment.

During the 2017 season, we explored a relatively new method of non-lethal control that substituted a mild electric stimulus to crows taking an egg instead of the emetic. This method was first developed by Velasco (2015) to deter American Crow predation on Least Terns. In her study it was moderately successful, but she had difficulty attracting crows to the electrified eggs. Based on knowledge gained during our 2016 research, we added wood decoys of shorebirds and seabirds adjacent to the electrified eggs to attract crows.

Before the onset of breeding, at each field site we walked a 1 km of beach and recorded the number of individual crows seen. As the beach width was highly variant, the total area searched differed. At the onset of breeding (February-June, 2017), we created 10 experimental nests at each site in the general area of plover/seabird nesting. Each experimental nest contained decoys of one of the focal species and an electrified egg. Symbolic fencing (stakes and twine) was placed around the experiment nests similar to the way that real nests are posted at the site. The electrified egg was a quail's egg that was similar in size and color to the species nesting in the area. The egg was hollowed out and filled with conductive paint and then wired to a battery. The electrified egg was placed in a hole on a metal plate that was attached to a shocking device and was covered in sand. When Fish Crows landed on the plate and made contact by pecking the electrified egg, they received a shock (Figure 1).
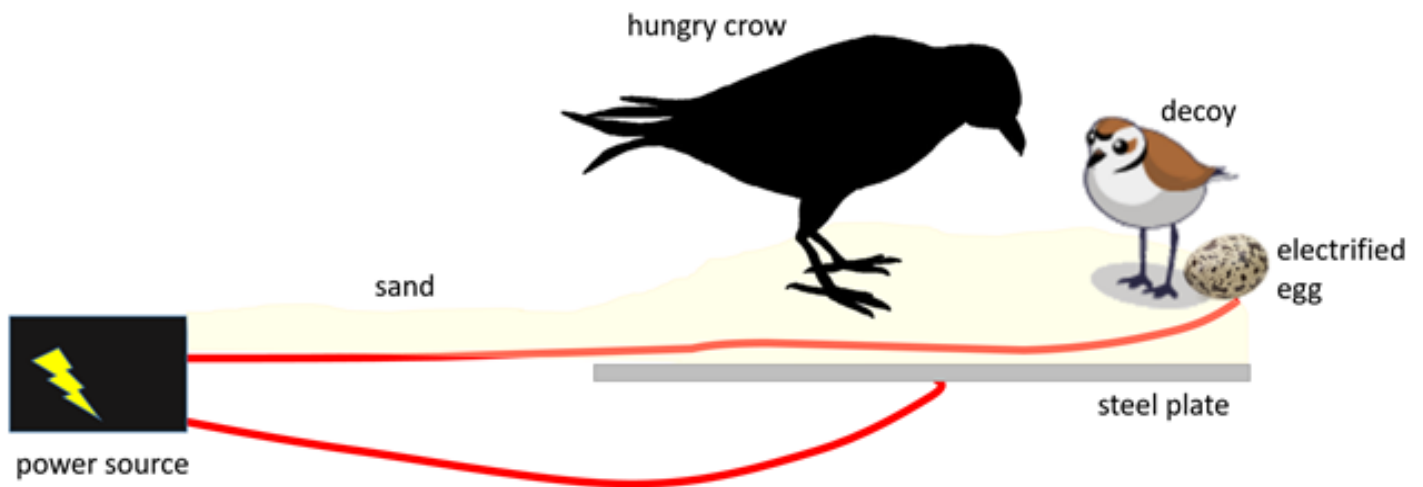
Figure 1. Experimental set-up

The 10 experimental nests were set-up each morning at 0800 and monitored until 1200 each day for 10 days. The highest number of crows observed at any one time in the 1 km linear transect was recorded each day to gauge flock size. During the 4-hour monitoring window we recorded each time crows pecked at the experiment egg and how many crows saw a crow receiving the electric stimulus. After the end of the 10-day experiment, we repeated the experimental set-up once/week with 10 decoys and eggs, but without electricity, to see how long the aversion lasted as measured by the number of decoy eggs taken by crows. In addition, we monitored real nests at least 3 times/week from the onset of egg laying after the experiment to measure egg loss to Fish Crows. Predation was attributed to Fish Crows if tracks were observed leading up to the nest. Tracks have been used to determine predation by corvids on seabird eggs in several other studies (Angelstam 1986, Avery et al. 1995). Every time we observed Fish Crows depredating real and fake eggs during our research they approached the nest by walking and took the egg while standing (Figures 2and3). This follow-up occurred for the duration of nesting (10-13 weeks).

Figure 2. Fish Crows approach an electrified egg near a wood Snowy Plover decoy.

Figure 3. Fish Crow tracks around an egg and decoy (the crow was scared away by a pedestrian but returned later to grab the egg).

Below are the results regarding the effectiveness of conditioned stimulus aversion at our sites.

1. _Siesta Key (Snowy Plover)_. INCONCLUSIVE. Five crows received the electro-stimulus during the 10-day treatment. We do not feel the management activity was very effective at Siesta Key, although our results are inconclusive. We suspect at least one real Snowy Plover nest was depredated by Fish Crows after our experiment and 10 of our decoy eggs were depredated during our 13-week follow up (Appendix 1). Local stakeholders had concerns that Fish Crows would be attracted to the existing Snowy Plover nests if we placed our decoys and electrified eggs within ~50m of the nests. Thus, all treatment was done 50-100m from an actual nest. In addition, eggs were quickly eaten by a variety of predators so it was difficult to determine if the Fish Crow management was effective.

2. _Lido Key (Black Skimmer, Least Terns)_. EFFECTIVE. Four crows received the electro-stimulus during the 10-day experiment. Prior to our management activity, the Audubon Florida bird monitor reported 3-4 Fish Crows repeatedly harassing and taking Black Skimmer eggs at the colony. After the treatment, Fish Crows remained in the area but were not observed taking eggs. None of our decoy eggs were taken during the 10-week follow-up (Appendix 1). While the Least Terns nests were over-washed during a storm, the Black Skimmers were highly productive.

3. _Anna Maria (Snowy Plover)_. EFFECTIVE. Seven Fish Crows received the electro-stimulus during the 10-day treatment. Prior to our experiment, we observed Fish Crows harassing Snowy Plovers that were attempting to nest. After the experiment, a pair of Snowy Plovers nested successfully twice, each time producing 3 chicks. However, the chicks were observed on the beach for only 2 days after hatching and we suspect they were depredated. We do not know if Fish Crows or another predator took the chicks. None of our decoy nests were depredated during the 14 weeks of post-experiment monitoring (Appendix 1).

4. _Ft. De Soto (Wilson's Plover, American Oystercatcher, Black Skimmer, Least Tern)_. SOMEWHAT EFFECTIVE. Fifteen Fish Crows received the electro-stimulus during the 10-day treatment. Prior to our experiment we observed Fish Crows harassing Wilson's Plovers, an American Oystercatcher pair, and taking eggs of Black Skimmers and Least Terns. After our experiment, Fish Crows were still seen occasionally harassing the shorebirds and seabirds, and only 3 real Black Skimmer eggs were taken by Fish Crows. Seven of our decoy eggs were taken during the 10 weeks following our monitoring (Appendix 1). The Wilson's plover nest hatched and fledged 1 chick. Unfortunately, at the end of the incubation period for the American Oystercatcher and many of the Black Skimmer nests, a coyote depredated on many of the eggs and after several nights of coyote predation, all of the birds abandoned their nesting.

5. _St. Pete Beach (Black Skimmer)_. EFFECTIVE. Ten Fish Crows received the electro-stimulus during the 10-day treatment. Prior to our experiment Fish Crows were observed taking almost every egg laid by the Black

Skimmers. After our experiment only a few real eggs were taken of Black Skimmers and only 5 decoy eggs were taken (all on the same day) during the 12 weeks of follow up. This colony was highly productive.

6. _**Sand Key (Black Skimmer).**_ **EFFECTIVE.** Eight Fish Crows received the electro-stimulus during the 10-day treatment. Prior to our experiment Fish Crows were seen taking several Black Skimmer eggs. After our experiment, few skimmer eggs were taken and only 4 decoy eggs were taken during the follow-up experiment. Productivity for the site was good, but a single Laughing Gull predated >50 small chicks, lowering the overall productivity.

V. Secondary Effects and Unintended Consequences (BP 5)
Through our field observations, we did not observe any negative secondary effects or unintended consequences. However, we did have a few Laughing Gulls receive electro-stimuli when trying to take electrified skimmer eggs. In each case the gull left the colony.

VI. Timing of Management Activities (BP 5)
We began management within two weeks of the onset of egg laying at each site. For the Snowy Plovers, we began in late March/early April. The Wilson's Plover and American Oystercatcher initiated nesting in late April/early May. The Least Terns and Black Skimmers began nesting in late May/early June. Monitoring continued for the duration of the nesting season. We chose the onset of nesting in terms of both shorebird and predator ecology, as it's hard to attract Fish Crows to decoys and eggs before actual nesting commences.

VII. Outreach and Communications (BP 6)
We educated volunteers at each site prior to the beginning of the management activity through emails, posts on Florida beach-nesting bird Facebook pages, and face-to-face meetings. We did not attempt to announce our activities to the public. Some of the volunteers were initially concerned about the electricity hurting the Fish Crows and other species. Most volunteers were satisfied when we explained this was a shock similar to that from electric fences used with chickens and that small birds would not be shocked because their gape size was too small to grab the egg.

Our activities were implemented on beaches frequented by thousands of local residents and tourists. This was a small-scale pilot study using non-injurious methods, which limited the need for broad stakeholder outreach. Also, our activities were on beaches frequented by thousands of local residents and tourists, which limited the feasibility of broad outreach. If approached by stakeholders, project personnel explained that the study was examining predation on shorebird and seabird eggs.

VIII. Permitting and Regulations (BP 7)
We contacted City, County, State, and Federal biologists/officials several months prior to our work. Fish Crows are technically protected by the Migratory Bird Treaty Act. However, USFWS 50 CFR 21.43 (Depredation order for blackbirds, cowbirds, grackles, crows and magpies) states that a Federal permit is not required to control these birds "when found committing or about to commit depredations upon ornamental or shade trees, agricultural crops, livestock, or wildlife, or when concentrated in such numbers and manner as to constitute a health hazard or other nuisance." In addition, we were using a very low amount of electricity and a commercially available "small animal and poultry" electric fence energizer that did not produce enough voltage to kill a Fish Crow. Only animals standing on the metal plate making contact with an open (wet) bill could receive a shock. The gape of the bill had to be larger than the width of the egg. We applied for, and received a permit to do research at Ft. De Soto which is a Pinellas County Park. None of the other municipalities required any permits. We also received an animal use permit from Eckerd College. We worked with the following biologists to discuss permitting:

Florida Fish and Wildlife Conservation Commission: Nancy Douglass (Sub-section Leader Conservation Planning Section) and Craig Faulhaber (Avian Conservation Coordinator).

United States Fish and Wildlife Service: Cindy Fury (Supervisory Wildlife Biologist, Florida Migratory Bird Field Office)

IX. Standardized Data Collection (BP 8)

It makes sense to collect data in a standardized manner. The State of Florida has a well-organized system for monitoring nesting shore and seabird species as described in BP 8 of this document. However, it was relatively easy to enter the data into the State database and re-enter it into the BP focused database.

X. Coordination (BP 9)

This was a stand-alone experiment, but we attempted to keep interested parties abreast of progress. This project was funded through a grant from NFWF to the USFWS.

XI. Lessons Learned

Conditioned stimulus aversion has the potential to change Fish Crow behavior when appropriately implemented. The electro-stimulus management strategy has the potential to deter Fish Crow Predation on the eggs of Black Skimmers, Least Terns, American Oystercatchers, and Snowy and Wilson's Plover. However, it needs to be employed relatively close to the actual eggs and it may not deter Fish Crows from eating plover chicks. For birds that produce chicks that are generally too large for Fish Crows to take (American Oystercatchers and Black Skimmers), electro-stimulus appears to be an effective method of deterring egg predation.

A google site has been created to help others interested in attempting CSA for Fish Crows: https://sites.google.com/a/eckerd.edu/csa-for-fish-crows/.

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Appendix 1. Number of Fish Crows taking wax-filled quail eggs after the end of the experiment at 6 field sites. Ten wax filled quail eggs were placed with decoys at each field site each week after the end of the experiment until the end of that site's breeding season.

Week	Siesta Key (SNPL)	Lido (BLSK)	Anna Maria (SNPL)	Ft. De Soto (WIPL, AMOY, BLSK, LETE)[b]	St. Pete Beach (BLSK)	Sand Key (BLSK)
1	3	0	0	1	0	0
2	1	0	0	2	5	0
3	1	0	0	3	0	0
4	1	0	0	0	0	0
5	2	0	0	1	0	0
6	2	0	0	0	0	0
7	0	0	0	0	0	0
8	0	0	0	0[a]	0	0[a]
9	0	0	0	0	0	4
10	0	0	0	0	0	0
11	0		0		0	
12	0		0		0	
13	0		0			
14			0			
Total number taken after experiment	10	0	0	7	5	4
[a] Zero eggs were taken by Fish Crows, however, Laughing Gulls took two eggs.						

B. GEORGIA: NEST EXCLOSURES AND WILSON'S PLOVERS
Author (s): Lauren Gingerella (lauren.gingerella25@uga.edu)
Site(s): Little St. Simons Island

I. Site Introduction (BP 1)
Little St. Simons Island (LSSI) is a coastal barrier island located at the mouth of the Altamaha River on the Georgia coast. The island is approximately 11,000 acres in size with 7 miles of undeveloped shoreline. LSSI is only accessible by boat, and as a result, it is minimally disturbed by human activities. The island is privately owned by Hank and Wendy Paulson, who protected the island in perpetuity from development in 2015 when a conservation easement was placed on the entire property. A small eco-lodge is operated on LSSI, in which a maximum of 32 guests can stay overnight and partake in naturalist-led activities. A two to three-member ecological department monitors and manages LSSI's ecological resources. LSSI collaborates with many partners, including The Nature Conservancy, Georgia Department of Natural Resources, University of Georgia, and St. Simons Land Trust, to successfully implement and achieve management goals. LSSI is a site within the Georgia Barrier Islands, which is a Western Hemisphere Shorebird Reserve Network (WHSRN) site designated as a "Landscape of Hemispheric Importance" for shorebirds. LSSI is unique as a demonstration site since we experimented with predator exclosures to test if the management technique is effective for increasing Wilson's Plover nest success. An intensive research study regarding their efficacy with this species has never been conducted before.

Predation management has been implemented on LSSI for several years prior to the 2017 breeding season. The primary objective of LSSI's predation management is to minimize predation on shorebird, seabird, and

sea turtle nests. The ecological management staff will trap and shoot raccoons during the breeding season, however, the level of effort varies by year. Often, LSSI staff need to focus efforts on "problem" animals, and areas with high shorebird nesting concentrations due to limited resources and beach accessibility. Problem animals are predators that repeatedly depredate shorebird and sea turtle nests in a certain area. For shorebird management, they are targeted around areas of depredated oystercatcher nests with the goal of removing the predator prior to the next renest attempt. In 2013 and 2014, LSSI worked with a GA DNR contractor to remove raccoons as part of a predator study. LSSI hired USDA Wildlife Services in 2014 to trap and shoot coyotes with the goal of removing all individuals from the island. Six coyotes were removed over the following three years, and the final seventh known individual was shot during an aerial hunt in January 2017. In addition to coyote removal, USDA is focused on thinning the European fallow deer herd, removing feral pigs, and trapping raccoons. European fallow deer are considered invasive on LSSI as they have drastically changed the island's vegetative communities. They are known to alter dune habitat through foraging on coastal vegetation and trampling, which could have negative effects on beach-nesting birds. Electric fencing had been used several years ago on a Least Tern colony, but concerns about sea turtle and alligator interactions with the fencing has halted any later application.

II. Species Introduction (BP 1)
Wilson's Plovers are listed as a "Species of High Concern" on the U.S. Shorebird Conservation Plan (Brown et al. 2001), and are listed as "Threatened" in Georgia (GA DNR 2010). Historically, Wilson's Plovers were found as far north as New Jersey, but in the past 100 years their Atlantic Coast breeding range has contracted, and they are no longer found nesting north of Virginia (Zdravkovic 2013). Like many other beach-nesting bird species, Wilson's Plovers are facing numerous threats at their breeding sites, such as human disturbance, habitat degradation and change, and increased predator abundance.

Predator exclosures were deployed at Wilson's Plover nests during the 2016 and 2017 breeding season as part of a graduate research study. Predator exclosures are an alternative to lethal predation management, and have been shown to increase hatch success among Piping Plovers and Snowy Plovers. This management technique has been used minimally with Wilson's Plovers, so we decided to study the effectiveness of predator exclosures for increasing Wilson's Plover nest success. We used the same predator exclosure design and methodology recommended for Piping Plover nest protection (USFWS 1996) since Wilson's Plovers are similar in size.

Since this management approach only focuses on one species we did not have to prioritize management actions for multiple species. Predators were identified through incidental track sightings, predator signs at nests, prey carcasses, and trail cameras at predator exclosures. Nest monitoring data from previous Wilson's Plover and American Oystercatcher breeding seasons also help identify which predator species are present and absent on LSSI.

III. Triggers or Thresholds (BP 2)
Lethal predation management occurs every breeding season on LSSI. Typically, it starts after the first American Oystercatcher nest is depredated. The decision to remove coyotes was made in 2014 upon discovery of the island's first coyote-depredated oystercatcher nest. Coyotes were first present on LSSI in 2010, but did not immediately learn to key-in on shorebird nests. Regarding Wilson's Plovers, three years of nest monitoring (2012, 2013, and 2015) on LSSI indicating high predation rates helped trigger the predator exclosure study.

IV. Management Activities (BPs 3–4)
We decided to use the non-lethal management technique of predator exclosures to better understand how they influenced Wilson's Plover nest success. The standardized exclosure design and methods described in "Guidelines for the Use of Predator Exclosures to Protect Piping Plover Nests" listed in the Atlantic Coast Piping Plover Revised Recovery Plan was utilized for this study (USFWS 1996). Predator exclosures were a 10-foot in diameter circular 2x4-inch welded wire fence supported by 5 wooden posts. Exclosures were buried 8 inches deep and were at least 3 feet above ground. The nest was directly in the center of the exclosure, so there was always 5 feet from nest to fencing. A mesh net with holes less than 3/4 inches in size was attached to the top of the exclosure with zip-ties. Predator exclosures were installed around the nest site in the cooler morning and late evening hours to avoid the eggs' overheating. A trail camera was placed nearby to monitor

for predators that may target exclosures and attempt to depredate adults. The entire installation process was completed in under 20 minutes to minimize the amount of time the parents were off the nest. Once the exclosure was set-up, we distanced ourselves from the nest, waited, and watched for the parents to return. An adult was required to return to incubate the nest within an hour of completing the exclosure installation. If neither parent returned to incubate within the timeframe, it was determined that they had rejected the exclosure and the exclosure was immediately removed. Eleven pairs rejected an exclosure in 2017, and in every case an adult returned immediately to incubate the nest once the exclosure was removed. Wilson's Plovers may become wary of exclosures as only one pair rejected an exclosure (n=18) in 2016.

When a nest was located it was judged if it was suitable for a predator exclosure. Nests located in thick vegetation or on uneven ground were not included in the study, but still monitored. In 2017, predator exclosures were deployed at every other suitable nest with a full clutch of eggs within different beach units. Unexclosed nests capable of being exclosed were designated as control nests. All nests were checked every one to three days until hatching, and all chicks were color-banded. Chicks were relocated twice a week during resighting surveys.

Though we did not quantify raccoon abundance, it is evident that they were very abundant and a leading cause of nest failure in 2017. Trail camera images showed an increase in raccoon activity at predator exclosures between 2016 and 2017. In 2017, raccoons learned there was a food source within the fencing, and attempted to dig under several exclosures. Fish Crows were observed perching on and circling several exclosures as well. Neither predator managed to get inside any exclosures nor depredate any exclosed nests. However, during that time adult Wilson's Plovers did not incubate the nest, so eggs were exposed to weather. Three exclosures were visited by predators, either raccoon or Fish Crow, while nests hatched. No adult or chick mortality was captured on the trail cameras; however, I suspect at least three plover chicks were depredated while attempting to exit exclosures. Predator tracks and scat at exclosures, and minimal time between nest checks for chicks to move far away leads me to believe two chicks were lost by Fish Crows at a single exclosure, and one chick by raccoon at a different exclosure. I am unable to confidently confirm these or other possible depredations as Wilson's Plover chicks excel at concealing themselves, and mortality was not captured on trail cameras. In the instance of the possible Fish Crow depredation, the third chick survived until fledgling. The only predator of exclosed nests were ghost crabs. Overall, the daily survivorship rate of exclosed nests (n=23, 0.993, SE=0.500) was significantly higher (p < 0.0001) than unexclosed control nests (n=27, 0.931, SE=0.219) in 2017. Preliminary results indicate that predator exclosures are effective at increasing Wilson's Plover nest success.

The cost of predator exclosure supplies for two years of research was approximately $1200, which includes the 2x4-inch welded wire fencing, wooden posts, netting, zip-ties, wire cutters, and shovels. Each exclosure cost roughly $50. Most of the supplies were reusable, such as fencing and netting, and were installed at nests multiple times throughout the study. Trail cameras were $125, and 15 were purchased for a total cost of $1875. A bike carrier, which was $125, was purchased to transport exclosure equipment up and down the beach. LSSI provided a research bike for free. The total cost of predator exclosure related supplies was $3200 for the entire study.

The primary focus of this demonstration project was the Wilson's Plover predator exclosure study, however, lethal predation management is a top priority for LSSI. The level of effort varies on the year, and in 2017, LSSI staff conducted only a handful of trap nights. This involved baiting two to five tomahawk traps in the early evening, and checking traps the following morning. Traps were placed in areas with high shorebird nesting concentrations nearby documented oystercatcher nest failures. The goal of this trapping approach was to focus efforts on "problem" predators that repetitively depredate nests. Any raccoons captured were shot. Since the level of trapping effort by LSSI staff was low this year, we do not feel this was an effective management activity. USDA was more effective with their predator removal, however there was more time and money spent on the activity. In addition to predator removal, USDA was contracted to remove European fallow deer. During the breeding season, USDA trapped and hunted raccoons on the beach and inland, and about 95% of the 118 raccoons removed were in high marsh about 0.5 miles from the beach. USDA used foothold traps for raccoons, and hunting involved driving around in an ORV or truck and spotlighting for predators. Spotlighting in the high marsh was very effective for hunting raccoons since they often went in the marsh to feed on fiddler crabs and

there was high visibility for spotlighting. The coyote removed in January was shot during an aerial hunt of the island, and we suspected coyotes were absent on LSSI during most of the breeding season. No coyote signs were observed until the end of June when a single coyote track was documented on the beach. We suspect the coyote was naïve about shorebird nests as it did not depredate the few that were still active, and walked within 1 meter of an active nest. Another goal of the aerial hunt was to reduce the island's European fallow deer herd population.

V. Secondary Effects and Unintended Consequences (BP 5)
The absence of coyotes for the 2017 breeding season coincided with an increase in raccoon abundance on the beach. Predator abundance was not quantified, but trends were estimated from anecdotal track sightings and nest monitoring data. When coyotes were present on LSSI prior to 2014, American Oystercatchers (number of nesting pairs 16 +/- 2) had a few successful breeding seasons. The number of oystercatcher fledglings in 2011 was 8, and 7 in 2012 and 2013. This is possibly a result of coyotes keeping raccoon abundance low and they had not learned to key-in on shorebird nests yet. American Oystercatcher productivity suffered once coyotes began depredating shorebird nests in 2014. Only two oystercatcher chicks survived to fledge in 2014 and 2015, and over 30 nests were lost to coyote predation in both years combined. Wilson's Plover nest monitoring did not occur in 2014.

VI. Timing of Management Activities (BP 5)
Predator exclosures were only deployed during the breeding season. Exclosures were deployed at Wilson's Plover nest sites once the pair laid a full clutch, typically three eggs. The pair is more likely to return to incubate the nest if exclosures are deployed at full clutches. Exclosures remained erected around the nest until the nest hatched, and the adults moved the chicks away from the nest site. Trail cameras monitored predator activity at exclosures.

Lethal predation management typically only occurs during the breeding season as well. Management efforts are focused on the individual predators that are depredating nests on the beach. The exception is coyote management, since the goal was complete removal and not reduction in population size as with raccoons. USDA trapped and hunted in one-week intervals three to five times a year on LSSI, including during the non-breeding season. Food resources are limited during the winter months, so coyotes are likely to approach bait.

VII. Outreach and Communications (BP 6)
Many of the guests that visit the eco-lodge on LSSI do so to be immersed in nature and learn about Southeastern ecosystems and biota. During the breeding season, I presented my graduate research once a week to island guests. This was a half hour PowerPoint presentation discussing broad-scale shorebird conservation and threats, Wilson's Plover natural history, study methods, predator exclosures, and preliminary results. I avoided initiating conversations about lethal predation management since it is a controversial topic. Lodge management did not want to lose business if guests were strongly opposed to trapping and/or hunting. However, if a guest asked me about lethal predation management I was honest and provided information regarding it. Every guest I talked with appeared to be interested and supportive of the predator exclosure study.

In addition, I wrote a blog article (naturelssi.com) about the Wilson's Plover predator exclosure study during the first field season. LSSI's blog has a broader reach than on-island visitors, and was shared on the island's social media accounts as well. Unfortunately, I do not feel LSSI's blog is effective since my article, which was published on June 1, 2016, is the most recent article published on the blog. More articles need to be published to drive traffic to the blog and my article. Signs asking guests to stay below the mean high tide line for nesting shorebirds were posted at the lodge, beach entrance, and marina. An additional sign asking guests to stay away from predator exclosures was posted at the lodge. Guests usually stayed on the wet sand, and away from the dunes. I feel the signs were rarely viewed, but the island naturalists were the best tool for communicating the importance of staying away from nesting habitat. Only one occurrence of a guest approaching an exclosure was captured on a trail camera.

VIII. Permitting and Regulations (BP 7)

Permitting and regulations was discussed with Tim Keyes, GA DNR Coastal Bird Biologist. I banded Wilson's Plovers under U.S. Department of Interior permit #06689 sub-permittee D. Tim Keyes is the permittee holder for sub-permittee D. The research study was approved by LSSI's Ecological Advisory Council and owners to be conducted on the property. LSSI staff operate under a GA DNR Scientific Collecting Special Purpose Permit CN: 27067 sub-permittee for lethal predator control. Under this permit, LSSI staff can conduct research and management activities related to sea turtles, which includes the removal of up to 15 raccoons and/or 15 armadillos. The removal of predators around shorebird nests assists with sea turtle management too as both taxa share breeding habitat and are challenged with the same predators. In addition, I was listed on LSSI's sea turtle permit with if there was a circumstance where I need to come into contact with sea turtles. USDA operates under a Memorandum of Agreement with GA DNR, which grants them permission to conduct wildlife management, including nuisance control, of non-endangered species for protection of property, agriculture, natural resources, and human health and safety.

IX. Standardized Data Collection (BP 8)

The standardized procedure is similar to the data collection format that I had used in previous years. I had no issues entering my data, and thought the operating procedure sheet was informative. On LSSI, several nests were partially depredated by ghost crabs, so an additional data field regarding this would be helpful. Regarding my graduate study, not every unexclosed nest is included as a control nest. Many Wilson's Plover nests were located in thick vegetation or on a steep dune, and not suitable for a predator exclosure. Only unexclosed nests capable of being exclosed were designated as control nests in analysis though I monitored every nest I found. For the BP data, I included all Wilson's Plover nests that I monitored on LSSI in 2017. I can provide more information regarding which nests were control if needed. Finally, USDA provided the total number of predators trapped and shot throughout their visit on LSSI, not the number of individuals trapped and shot per night. To reflect this, I added an "End Date" on the trapping and shooting spreadsheets.

X. Coordination (BP 9)

This University of Georgia graduate project was coordinated with GA DNR and Little St. Simons Island. I coordinated band combinations through the Wilson's Plover Working Group listserv. Funding was provided by National Fish and Wildlife Foundation (NFWF), with cash match from GA DNR and LSSI. While conducting field work on LSSI, I did not receive a graduate assistantship stipend, but was paid by LSSI and worked as their shorebird technician. In addition to the responsibilities required of my study, I monitored nesting American Oystercatchers and Least Terns, assisted with lethal predation management, and helped train new staff on various island monitoring and surveys.

XI. Lessons Learned

Predator exclosures are a management technique that is successful at increasing nest success, but should be used with caution as predators may become attracted to fencing. It might be beneficial to use exclosures every other year, or in years where predation is predicted to be high. This would allow for "problem" animals to die off, and limit exposure to predators that could associate exclosures with food. In addition, a lot of effort and time goes into setting up exclosures, so staggering deployment years would help breeding sites with limited resources or staff. Alternating deployment years may help with pairs that become cautious of exclosures as well. Previously, lethal predation management for raccoons began once the breeding season was underway. Lethal predation management would have more of a positive impact on nesting shorebirds and sea turtles if it began prior to the breeding season, or occurred year-round.

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C. SOUTH CAROLINA: CHRONOLOGY OF EFFORTS TO BENEFIT BIRDS AND TURTLES
Author(s): Janet Thibault (thibaultj@dnr.sc.gov)
Site(s): Botany Bay

I. Site Introduction (BP 1)
Botany Bay Plantation Wildlife Management Area (Botany Bay) is a coastal Heritage Preserve managed by South Carolina Department of Natural Resources (SCDNR). Located on Edisto Island, South Carolina, the 4,630 acre property contains extensive *Spartina* saltmarsh, maritime forest, and approximately 3 miles of barrier beach interspersed by two tidal inlets. SCDNR acquired this property and opened it to the public in 2008. Beforehand, it was privately owned. Botany Bay has the second highest nesting density of Endangered Loggerhead sea turtles (*Caretta caretta*) and 526 nests were laid on the property in 2015. Because of the importance of this site to nesting Loggerheads, control specific to sea turtle predators has been conducted since 2010. Coastal shorebirds also nest at Botany Bay's beaches, however, monitoring of beach nesting birds had not been conducted prior to 2015. For this project, we attempted to examine the chronology of predator control in order to determine the best benefit to beach nesting birds as well as sea turtles.

II. Species Introduction (BP 1)
American oystercatcher, (*Haematopus palliattus*) a "Species of High Concern" as well as two State Threatened species, the Wilson's plover (*Charadrius wilsonia*) and least tern (*Sternula antillarum*) nest on Botany Bay's beaches and are the only beach nesting birds at this site. South Carolina supports over 400 pairs of breeding American oystercatchers and approximately 375 pairs of nesting Wilson's plovers statewide. Nest monitoring of these species at Botany Bay began in 2015 in an attempt determine productivity estimates and identify causes of nest loss. SCDNR documented nesting success (or failure) of these species during the spring and summer of 2015 and 2016 and determined the number of pairs nesting, hatching success (number of eggs hatched per nest), and causes of nest failure. When chicks hatched, fledging success was determined for each brood. SCDNR managers wanted to determine if nests were lost to overwash or other causes. Mammalian predation was determined to be the primary cause of nest loss in 2015 and 2016 and occurred during the egg laying stage of nesting. Raccoon tracks, scat and digging were frequently found during nest monitoring activities and raccoons were also determined to have predated Loggerhead turtle nests.

Prior to this project, predator control began when sea turtles started nesting, in late May and June. This year (2017) trapping was focused just after shorebird nest initiation in late April through early May. These dates were based on when shorebird nests were being targeted by raccoons determined from 2015 and 2016 shorebird nest monitoring data.

III. Triggers or Thresholds (BP 2)
Because Botany Bay is a priority nesting site for Loggerhead sea turtles, predator control has been a significant management tool used by the SCDNR Sea Turtle Program. By altering the timing of predator control in 2017 we hoped to provide the most benefit to nesting shorebirds as well as nesting sea turtles at Botany Bay. Approximately 10 pairs of Wilson's plovers and 4 pairs of American oystercatchers nest on the property which is approximately 3% of the plovers and 1% of the oystercatchers nesting in the state. Although this is not a large portion of shorebird nesting in South Carolina, we hoped predator control activities would mutually benefit all species nesting on Botany Bay's beaches.

IV. Management Activities (BPs 3–4)
Predator control at Botany Bay was coordinated through the SCDNR Coastal Bird Program and SCDNR Sea Turtle Program. In the past, the Sea Turtle Program had paid for predator control at Botany Bay. In 2017 the SCDNR Coastal Bird Program obtained a National Fish and Wildlife Foundation (NFWF) grant to pay for

predator control activities. Managers were supportive of continuing predator control to benefit sea turtles as well as nesting birds at the property. The SCDNR Sea Turtle Program has conducted lethal predator control at other Loggerhead sea turtle nesting sites in the state and already held a depredation permit for the property, therefore, protocols for lethal control per the Sea Turtle Program were utilized this year at Botany Bay. Predator control was conducted by a private contractor who had worked on the property in the past and had conducted trapping activities for the Sea Turtle Program at other properties. The trapper targeted mammalian predators (raccoon, opossum) with encapsulated (dog proof) foot hold traps on trails leading to the beach and access points from the marsh. He pre-baited traps with cat food and/or marshmallows and shot trapped animals with a pistol. All carcasses were removed and taken off site or buried.

In October 2016, a foot bridge connecting beach access to the property was damaged by Hurricane Matthew. The property was closed to the public from October 2016 to August 2017 while the bridge was out of use. SCDNR staff and the trapper were only able to access the beach during a short window of time during low-tide (~2-3 hours) when staff were able to scramble down the bank and cross a tidal creek. The trapper removed 25 raccoons and 2 opossums this year. In the past he has been able to remove more. I feel that he would have been more successful if the foot bridge was not damaged and he was able to spend more time deploying traps. During nest checks, it appeared that shorebird nests were being predated as soon as they were laid with several nests being eaten before a full clutch was laid. However, of the 2 nests that hatched this season, both were able to fledge chicks suggesting that the most vulnerable time for beach nesting birds is the nest initiation and incubation stage.

V. Secondary Effects and Unintended Consequences (BP 5)
There were no secondary effects from predator control in 2017. However, due to the access issues the trapper had limited time on the property and did not remove as many predators as in years past.

VI. Timing of Management Activities (BP5)
In year's past, predator control in South Carolina occurred in May and June to benefit sea turtle nesting. Determining appropriate timing of predator control to benefit both sea turtles and beach nesting birds has been a management priority for the past few years at Botany Bay. In 2016, the SCDNR Coastal Bird Program recommended predator control occur in March prior to shorebird nesting to reduce early clutch loss, however, this did not appear to be affective for beach nesting birds. The trapper reported that there was no raccoon sign on the beaches in March so he concentrated trapping efforts on high marsh and high ground adjacent to the beaches where he was successful. The trapper removed 70 raccoons and 40 opossums from both Botany Bay Plantation and adjacent land from March 6th to March 19th, 2016. Raccoons may not be active on the property's beaches until there is a reliable food source such as shorebird and turtle nests. Predation was again a major cause of nest loss in 2016 despite the removal of animals prior to the start of shorebird nesting.

Timing for predator control was re-evaluated and conducted more in sync with the ecology of these mammals in 2017. Shorebird nesting begins mid-April at Botany Bay, therefore, this is the timeframe when predator control was conducted in 2017. Trapping began April 23 through May 6th, approximately 2 weeks after the first few oystercatcher and plover nests were initiated. This was the time period when predation began to occur in 2016 and 2015 based on nest monitoring data. However, minimal animals were removed in 2017 (25 raccoon, 2 opossum) due to limited time spent on the property because of access issues from the damaged bridge and short amounts of time when the tide was low enough to cross onto the beach.

VII. Outreach and Communications (BP 6)
Botany Bay is typically open to the public just prior to sunrise and just after sunset. Predator control is not usually announced to the public at this site and the trapper typically deploys traps out of view of public trails and removes all animals prior to the property opening each day. Trapping usually occurs over 14 consecutive days at this site. In 2017, the beach was closed to the public from October 2016 until late August 2017.

VIII. Permitting and Regulations (BP 7)
Predator control was conducted under a South Carolina Depredation Permit operated under the SCDNR Sea

Turtle Program rules. The state Sea Turtle Coordinator worked with our program on permitting regulations.

IX. Standardized Data Collection (BP 8)

Beach bird nest monitoring was conducted by SCDNR staff and data were collected on nest success, productivity, fledging rates as well as causes of nest loss and nesting phenology. Nests were monitored at least every 3 days and most causes of nest loss were identified. Predator control was conducted by private contractor and although we asked that number of animals removed each night be recorded, those data were not collected. In the future we will communicate protocols in a more precise and direct manner and will follow up with the trapper during the season.

In addition, 2017 was the first year of a 2-year study at Botany Bay on diamondback terrapin *(Malaclemys terrapin)* nesting ecology. Researchers are investigating terrapin nest temperatures on non-disturbed beaches. Anecdotally, many terrapin nests were predated by raccoons as well this season. We will inquire with the terrapin project leader if they can share any of their findings for this BP effort.

X. Coordination (BP 9)

Coordination for this effort was conducted within our state organization (SCDNR) Sea Turtle Program and Coastal Bird Program. The cost of predator control was low enough we did not have to put the contract out for bid, so we paid the trapper directly from our NFWF funds. All other activities were done with staff time and equipment.

XI. Lessons Learned

At Botany Bay, raccoons appear to shift from using the high grounds/maritime forest in March to utilizing the beach in the spring and summer (late April-May) when reliable food sources are more abundant (i.e. bird and turtle eggs). The bridge access was an issue in 2017 limiting the time to set and check traps this year. Almost all bird nests were depredated because not all of the raccoons accessing the beach were removed. Nest laying and incubation appear to be the most vulnerable time for shorebirds nesting at Botany Bay. However, of the 2 nests that hatched this season, both were able to fledge chicks suggesting that the most vulnerable time for beach nesting birds is a few weeks into the incubation stage. After several years of nest monitoring and conducting predator control at different times of the beach nesting bird season, we have identified this window as the most important to remove nest predators and will continue to trap after shorebird nest initiation to target these predators.

D. NORTH CAROLINA: MONITORING EFFICACY USING NEST CAMERAS
Author(s): Hope Sutton, Curtis Smalling, and Sara Schweitzer (suttonh@uncw.edu)
Site(s): Masonboro Island

I. Site Introduction (BP 1)

Masonboro Island is a 13.5-km long coastal barrier island on the North Carolina coast between Wrightsville Beach and Carolina Beach in New Hanover County. The 2,288-ha undeveloped barrier island complex is protected and managed as a component of the North Carolina National Estuarine Research Reserve and a State Dedicated Nature Preserve as part of the N.C. Coastal Reserve program under the N.C. Department of Environmental Quality, Division of Coastal Management. The site has complex logistical considerations, with access limited to a small number of boat landing sites, most of which are further limited by inadequate water depths during much of the tidal cycle. Limited predation management activities were conducted at the site in 2012–2014, 2016, and 2017. Initial efforts focused on removal of red fox due to depredation of sea turtle nests, with complete removal attempted; later efforts included raccoons, with removal designed to decrease predator populations to reach shorebird nesting success targets.

Masonboro Island was selected as a demonstration site because it hosts a significant number of North Carolina's American oystercatcher *(Haematopus palliatus)* and Wilson's plover *(Charadrius wilsonia)* nesting pairs; there are years of monitoring data on beach-nesting species to use in effect analyses; prior trapping efforts were followed by increased productivity of beach-nesting species; and monitoring of beach-nesting species, targeted trapping efforts, and support exists to allow research studies and long-term evaluation to be

accomplished. Further, Masonboro Island is one of only two undeveloped barrier islands along the southern North Carolina coast, and its proximity to the University of North Carolina at Wilmington makes it an ideal long-term study site.

II. Species Introduction (BP 1)

The island is an important nesting site for many shorebird species including the Wilson's plover, willet (*Tringa semipalmata*), and approximately 10% of the state's nesting American oystercatcher pairs. Since 2010, several small, loose nesting colonies of least terns (*Sternula antillarum*) and one pair of black skimmers (*Rynchops niger*) have also been present on the island. In addition, loggerhead (*Caretta caretta*) and green (*Chelonia mydas*) sea turtles use the ocean beach for nesting. Historically, predation management activities have been implemented to benefit loggerhead sea turtles due to high levels of nest predation, averaging nearly 60% of nests between 2005 and 2011, as documented through regular monitoring of the ocean beach throughout the nesting season. Based on predator sign at and near nests, red fox (*Vulpes vulpes*) was the original target species for predation management efforts.

Following predation management between 2012 and 2014, predation of sea turtle nests decreased to less than 10%; however, depredation of shorebird nests continued to be near 100%, as documented by shorebird nest monitoring efforts 2-3 times weekly from 2013-2015. Increased effort to document causes of shorebird nest failure resulted in a decision to expand predation management to include raccoon (*Procyon lotor*) in 2016, based on predator sign in nesting areas indicating they were preying on oystercatcher eggs. This multi-species approach continued in 2017 for the demonstration site effort. Opossum were present but were not a target species and were released when trapped. In all cases, management activity has been targeted to best utilize limited funding given the complex logistics involved with the site. Management efforts were focused and based on surveys of predator sign conducted by volunteer researchers and students in the weeks prior to management and observations by professional trappers at the start of management activities. Additionally, although not included as part of the original project activities, wildlife camera traps were used on a limited basis in an attempt to document predator presence in the month prior to initiation of management.

III. Triggers or Thresholds (BP 2)

American oystercatchers have been the primary focus of shorebird monitoring activities at Masonboro Island since 2010 due to the high number of nesting pairs present. Species of interest reproductive success levels suggested in the American oystercatcher conservation business plan and in recommendations from the American oystercatcher Working Group have driven the decision to undertake predation management action. Initially, the goal for predation management on Masonboro Island was to reduce sea turtle nest predation levels to below 10% of nests. In more recent years, the goal has been to achieve a productivity rate for American oystercatchers of at least 0.50 fledglings per pair.

IV. Management Activities (BPs 3–4)

Lethal management was identified as the most effective option to achieve the stated goals. Literature and experts consulted suggested that non-lethal methods, such as electric or other fencing, egg aversion conditioning, or restrain-trapping and relocation were not likely to result in an immediate reduction in predation levels given the lifespans of the target species, conflicts with recreationists, difficult logistics, and immediate need to stop loss of eggs and chicks. As a result, we were not able to identify a non-lethal technique as a potential effective method for this scenario.

Trapping was the primary management activity for both red fox and raccoon. A private wildlife management firm was selected to conduct the management operation. The firm's lead trapper has extensive profession experience, including previous experience conducting predation management activities at the site as part of a USDA Wildlife Services team and an established relationship with the site's management agency. All activities were conducted in accordance with appropriate permits as required by the N.C. Wildlife Resources Commission (NCWRC).

Foothold traps and cable snare restraints were used. Bridger 1.65 padded jaw traps were used for red fox and K.O. 1.5 double jaw traps were used for raccoon. Trap locations were distributed to capture both target predator species and selected by the trapper based on available tracks and sign, in areas with a history of predation based on monitoring data from previous nesting seasons, and with the intention of minimizing the possibility of human or domestic animal interaction. Traps were checked daily shortly after sunrise during the management activity periods of February 20-24, 2017 and June 16-18, 2017. Target animals trapped were dispatched on site according to American Veterinary Medical Association guidelines and using USFWS and NCWRC approved methods. Raccoon carcasses were disposed of on site; red fox carcasses were transported off site and delivered to a UNCW researcher. Non-target animal trapped were released.

The management period for 2017 was selected to occur prior to the start of the nesting season and during a low visitor use period. The plan for the management effort called for continuous trapping for up to 5 days or until no fresh sign was observed. Due to complex logistics at the site, the trapper camps on site during the management operation, limiting the duration of effort. During this initial management period, 6 raccoons and 2 red foxes were taken. Although this effectively reduced the total predator population, on the final day of the operation, based on fresh sign, the trapper believed one red fox to still be present on the island. Following the loss of several early nests to a spring storm, the level of predation of American oystercatcher nests was high through the early portion of the nesting season. The shorebird monitoring technician documented red fox tracks in nesting areas and camera traps documented depredation by red fox and opossum. A follow-up predation management effort was conducted focused on the single red fox known to be present. One individual, with markings and physical characteristics similar to those of the animal documented on camera was taken during this operation. No further red fox depredation was documented during the remainder of the season. Most oystercatcher renesting activity had ceased by mid-June, but four nests were initiated after the second trapping period. Of these, one fledged a chick, one was lost to opossum depredation, and two were lost to unknown causes. Fecundity for American oystercatcher nests identified following the second predator removal operation was 0.25 fledglings per pair as compared to 0.11 for nests prior to this effort.

Wildlife cameras were utilized to document and establish causes of nest failure. Due to logistical complications and limited camera availability, approximately 30% of nests were monitored with cameras. Equipment issues resulted in no images for 18% of deployments. Depredation was documented as the cause of nest failure for 27% of failed nests. Use of cameras also provided conclusive evidence regarding predator species, which can be difficult to determine from tracks in sandy, windblown environments. Geography of predation events based on camera data was used to focus follow-up predation management efforts. Although outside the scope of this project, camera data also revealed some interesting findings regarding behavior of adult birds following the loss of a nest and could be an area of future study.

Based on predation management efforts on Masonboro Island, it is clear that the timing of predation management is critical to its effectiveness for meeting reproductive success goals. Reducing the level of predator activity to a near zero level just prior to the beginning of the nesting season appears to have the potential to provide a predation free window for nesting to take place. The presence of a single red fox between February 25 and June 16 resulted in 8 known and 18 possible red fox nest depredations. Following up the initial management effort more quickly would likely have resulted in greatly reduced predation, but was not possible due to the availability of the trapper. Limited funding and administrative hurdles did not allow for contracting a secondary firm to conduct the follow-up effort. In addition to timing, having sufficient resources available to continue management activity until signs of predators have been reduced to the intended level is very important. Fortunately, some funds remained following the initial management effort that allowed follow-up management to occur.

V. Secondary Effects and Unintended Consequences (BP 5)
No data were collected related secondary effects of management activities. No changes to ghost crab populations were documented or noticed through general field observation or anecdotal reports from seasonal staff, interns, or visitors. Although opossum predation was documented with camera traps and tracks were noted in nesting areas, it is not known whether there is a relationship between opossum population and red fox or raccoon populations.

VI. Timing of Management Activities (BP5)

Management activity was scheduled to take place just prior to the anticipated arrival of nesting American oystercatcher pairs. At this site, the target trapping period is late January to early March. In 2017, predation management activities took place from February 20-24. A five day period on site allows the trapper to conduct intensive, targeted effort to utilize resources most efficiently. The duration of the trapping period was based on logistical and scheduling considerations and was similar to previous years' trapping periods. A follow-up management effort was undertaken in June 2017 based on evidence that at least one red fox was still present and depredating shorebird nests. Late winter was also targeted for management to avoid interaction with human visitors and to avoid orphaning kits.

VII. Outreach and Communications (BP 6)

Management activities were not widely publicized to the public through media outlets. Because the site is open to the public but visitation during the predation management period is typically low, it is believed that the most critical communication is with members of the public who are physically present at the site. To accomplish this, signs were installed on site at key access points for several days prior to and throughout management activities. Broader communication with the public may unnecessarily alarm some members of the community and the effort required to fully explain and contextualize the need for and rationale behind this type of predation management activity would be prohibitively expensive. A talking point document was developed by the site management agency and the partner organizations involved with sea turtle monitoring, shorebird monitoring, and predation management and is available to all partner agencies and organizations for use in communicating with the public or the media should the need arise. In addition, local law enforcement is made aware of these efforts so that they will be prepared if they receive calls from the public. (Talking points document and sign text attached.)

VIII. Permitting and Regulations (BP 7)

As discussed above, a depredation permit was obtained from the N.C. WRC. State regulations regarding hunting and trapping seasons and methods were followed. Although all partners on the grant are familiar with these regulations, the wildlife management contractor is also expected to maintain current knowledge and adhere to all applicable regulations and required to do so as a condition of the contract. The site management agency holds the depredation permit which allows removal of specific predator species from the site. The site manager typically communicates about predation management permitting and regulations with Daron Barnes, Colleen Olfenbuttel, and David Jordan, all staff of the NCWRC.

IX. Standardized Data Collection (BP 8)

Predation management data collection requirements were reasonable and fairly closely mirrored data that would have been collected for any predation management activities conducted at this site. Some suggestions include: clarifying whether the date reflects the date a trap was set or an animal was taken; adding geospatial data either for animals taken or all traps to add the possibility of doing geospatial analyses; and adding sex for animals taken.

Oystercatcher productivity data were collected using standard methods used throughout the state. These involved 2-3 visits weekly to the site, during which nesting territories were checked for active nests or chicks. Nests locations were obtained with a handheld GPS unit and nests were monitored through success or failure. Chicks were also monitored and, whenever possible, banded prior to fledging.

Additional data from this site were collected from camera traps prior to and following predation management. Red fox carcasses from these activities will have additional data, including morphometric and genetic data, collected from them by Dr. David Webster and his associates at the University of N.C. Wilmington.

X. Coordination (BP 9)

Activities at this site were coordinated among the partners on the project – North Carolina Wildlife Resources Commission, North Carolina Audubon, and North Carolina National Estuarine Research Reserve. Activities were not coordinated with other demonstration sites or other groups regionally. Funding was received and managed by North Carolina Audubon, including contracting with the predation management service and employing the seasonal shorebird technician.

XI. Lessons Learned

- Predation management is a long-term activity that requires ongoing funds, agency commitment, and a good relationship with knowledgeable professional wildlife management specialists familiar with the site in question.
- Timing is critical and timing of follow-up activity is even more critical.
- The impact of a single fox over 13 weeks of prime nesting season resulted in a productivity rate well below target.
- Camera traps can effectively be used to document sources of nest failure and confirm presence of predators; however, in the more linear habitat of the narrow barrier island at this site, individual red foxes have been documented to travel further than typically expected on a regular basis, limiting the usefulness of camera trap data for narrowing down the geographic area in which a predation management effort is implemented.
- Camera traps used in conjunction with surveys for other predator sign (e.g., tracks) appear to be helpful in identifying high activity areas and informing trapping locations.

E. RHODE ISLAND: ASSESSING VALUE OF LETHAL CONTROL IN ADDITION TO NONLETHAL MANAGEMENT
Author(s): Nick Ernst (Nick_Ernst@fws.gov)
Site(s): Ninigret Conservation Area, Quonochontaug Beach, Napatree Point, Sandy Point Island

I. Site Introduction (BP 1)

Name of Site*	Geographic Location	Approximate Length (mi)[b]	Landowner
Ninigret Conservation Area (NCA)	coastal barrier beach	2.25	State of Rhode Island, Division of Parks and Recreation
Quonochontaug Beach (Quonny)	coastal barrier beach	1.5	Weekapaug Fire District, Nopes Island Conservancy, Shelter Harbor Association, State of Rhode Island
Napatree Point	coastal peninsula	1.3	Watch Hill Conservancy/Watch Hill Fire District
Sandy Point Island	coastal barrier island	1.3	Avalonia Land Conservancy

[a] Rhode Island Division of Fish and Wildlife has conducted management at all four sites in the past. On Napatree Point there was one season of foot hold trapping in 2009 and non-lethal management -lethal has occurred since 2009. On Sandy Point Island there was one instance of gull removal 2011, which consisted of shooting adults and nest destruction.
[b] NCA is a narrow strip of beach between Ninigret Pond and the Atlantic Ocean that is approx. 0.1–0.25mi wide. Quonny is a narrow land barrier between Quonochontaug Pond and the Atlantic Ocean that is between 0.1– 0.2 mi wide. Napatree point is a narrow peninsula, between 0.07–0.2 miles wide. Sandy Point Island is approx. 0.1 mi wide at its widest point.

II. Species Introduction (BP 1)

Our management targeted Piping Plover and Least Tern at all four sites and American Oystercatcher at all sites except NCA. These species were selected because they are the only identified target species that occur at those sites. Given the small overall size of sites and close proximity of nesting between species, all species benefited from management actions. We used camera traps, track sightings, predator sign at nests, and direct observations to identify and prioritize predators for management actions.

III. Triggers or Thresholds (BP 2)

Lethal Predator Control
The observation of predator tracks and scat near shorebird nests was one threshold used to determine the use of lethal control measures; i.e., multiple tracks of one predator or several species observed on subsequent monitoring visits. Also, if multiple nests or chicks were depredated over a short period of time, we requested that USDA-APHIS conduct a trapping session.

Non-lethal Predator Control
Nest exclosures were the primary type of non-lethal control used to protect plover nests. When mammalian predators were detected at sites, exclosures were put around nests as soon as possible after the clutch

was complete. The number of crows at a site served as a threshold for avoiding use of exclosures. Crow numbers appear to be increasing at many of our sites and have caused abandonment issues when they perch on exclosures. Exclosures were not used if crows were frequently observed at a nesting site on multiple monitoring visits throughout the nesting season. Crow harassment was conducted at all sites. Whenever monitors observed crows in nesting areas, they were flushed from the area. Perches also were removed from sites whenever possible.

IV. Management Activities (BPs 3–4)
Lethal Predator Control
The decision to use lethal predator control was largely dependent upon predator presence, landowner permission, public safety, and the number of beach nesting birds that would benefit from management. Once landowner consent was obtained, we attempted to remove as many avian and mammalian predators as possible from nesting sites from March until early June. The goal with trapping during these specific windows was to begin after these beaches were closed to all use by pets/dogs, while maintaining predation management benefits during the preseason (April), incubation (May), and hatching (June) periods within the nesting season. Due to the increase in beach visitation as summer progressed, lethal control was ended by early June for public safety.

Non-lethal Predator Control
Factors that determine whether to exclose nests included: slope around the nest, density of vegetation, types of predators present (tracts, scat, photos), and whether there was history of adult abandonment or predation as a result of exclosure use. On sites with evidence of mammalian predators, nests were exclosed as close to the completion of the clutch as possible. On sites where crows were observed frequently and in high numbers, nests were not exclosed to reduce the risk of nest abandonment resulting from crows perching on exclosures. Crows were flushed opportunistically by plover monitors whenever they were encountered in nesting areas for all sites. Perches were also removed whenever possible.

Site Specific Management Activities
1. NCA: Landowners were supportive of lethal predator control, so it was combined with other non lethal methods. A combination of both lethal and non-lethal management was employed here. USDA APHIS was contracted to use soft catch foot hold traps as well as box traps during specified trap windows (3–7 April, 8–12 May, and 12–16 June, 2017). Foot hold traps targeted mammalian predators while box traps targeted both mammalian predators, as well as avian, with considerable success in trapping American and Fish Crows. Additionally, nesting areas were roped off, predator exclosure fencing was installed around nests when possible, motion cameras were installed, and shorebird monitors flushed crows when observed in nesting areas.

2. Quonny: Landowners were supportive of lethal predator control, so it was combined with other non-lethal methods. A combination of both lethal and non-lethal management was employed here. USDA-APHIS was contracted to use soft catch foot hold traps as well as box traps during specified trap windows (3–7 April, 8–12 May, and 12–16 June, 2017). Foot hold traps targeted mammalian predators while box traps targeted both mammalian predators, as well as avian, with considerable success in trapping American and Fish Crows. Additionally, nesting areas were roped off, predator exclosure fencing was installed around nests when possible, motion cameras were installed, and shorebird monitors flushed crows when observed in nesting areas.

3. Napatree Point: The landowners were not supportive of lethal predator control, so other non-lethal methods were employed. This site received non-lethal monitoring/management only. Here, we placed motion cameras, monitored for any predator tracks/sign, we roped off nesting areas and installed predator exclosure fencing surrounding nests when possible, and shorebird monitors flushed crows when observed in nesting areas.

4. Sandy Point: The landowners were not supportive of lethal predator control, so other non-lethal methods were employed. This site received non-lethal monitoring/management only. Motion cameras

were installed, nesting areas were roped, any predator tracks/sign were monitored and other non lethal deterrent methods were used when possible (hazing crows, etc). Predator exclosures were not installed here this year due to the absence of mammalian predators on the island, and the prevalence of Fish Crow which have been observed harassing plovers in exclosures during past years. All invasive tree of heaven (*Ailanthus altissima*), which provided perches for crows and other avian predators, was also cut down.

Results

In the 2017 season, the overall productivity for Piping Plover across all managed sites was 0.68 chicks fledged per pair. Predation and a wet spring were the main factors contributing to the low hatch and fledge success observed this year. Despite generally poor productivity this season, we believe the combined use of lethal and non-lethal predator control contributed to higher reproductive success at two of our sites. Piping Plover productivity was higher at NCA and Quonny where both lethal and non-lethal management were conducted, compared to Sandy Point and Napatree, which received only non-lethal control. On NCA, there was final productivity for plovers of 2.29 chicks fledged/pair, following initially poor nest success early in the season. Prior to trapping, Fish Crows were consistently present at this site and nests were depredated. Following removal of 17 crows and one raccoon at NCA, nest and chick success immediately improved. Plover productivity also appeared to benefit from lethal predation management at Quonny this season, as well. After the removal of one coyote and two opossums, seven chicks fledged for a productivity of 0.70 chicks fledged/pair. Only three out of the 19 nests observed at Napatree and Sandy Point hatched this season, and none of the chicks survived to fledging age.

Least Tern productivity was generally poor overall; however, more chicks fledged at demonstration sites with lethal predator control. At NCA 39 pairs fledged 8 chicks for a productivity of 0.21 chicks/pair. At Quonny, 27 pairs of Least Terns fledged four chicks for a productivity of 0.15 chicks/pair. Eight pairs of Least Terns attempted to nest at Napatree and one pair at Sandy Point, but no chicks fledged this season. Lethal predator control in conjunction with non-lethal control efforts seemed more effective than non-lethal control alone at increasing productivity for plovers and Least Terns.

Unlike plovers and terns, American Oystercatcher had higher productivity at sites receiving only non-lethal control. At Sandy Point, nine pairs fledged 16 chicks for a productivity of 1.78 chicks fledge/pair. One pair attempted to nest at Napatree and Quonny, however, these pairs did not fledged any chicks.

V. Secondary Effects and Unintended Consequences (BP 5)

No secondary effects were observed on any managed sites. We used field observations of scat and tracks during nest monitoring visits and game camera photos to assess potential effects.

VI. Timing of Management Activities (BP5)

The timing of our predation management related to shorebird ecology more than predator-specific ecology. In addition, high public use at our sites dictated the timing of lethal control, such that it ended by mid-June.

Lethal predation management

Lethal management occurred 3–7 April, 8–12 May, and 12–16 June, 2017. The goal with trapping during these specific windows was to begin after these beaches were closed to all use by pets/dogs, but still catch the preseason (April), incubation (May), and hatching (June) periods within the nesting season.

Non-lethal predation management

Non-lethal management occurred throughout the season from April–August.

VII. Outreach and Communications (BP 6)

We did not publicly announce predation management; however, all sites that received trapping were well posted with signage at entrances and along trails/travel routes to make sure the public knew traps were present. It should be noted that no attempt has ever been made to hide the fact that predation management takes place, and we are open about it when any inquiries are made. We chose not to make a public

announcement because any traps that were set were in places that were either closed to the public, or in areas that were not traveled by or easily accessible to the public (i.e., within roped areas, deeper within dune, densely vegetated areas, etc). In addition, it was likely that there would be a large degree of negative public perception.

VIII. Permitting and Regulations (BP 7)
State of Rhode Island scientific collection permits were obtained for any site that received lethal management, as well as separate state permits allowing the use of leg-hold style traps. A federal migratory bird collection permit was also obtained in the event we saw the need to remove any gulls. We consulted with the Division of Migratory Birds as well as biologists with the state of Rhode Island about compliance with regulations.

IX. Standardized Data Collection (BP 8)
In general, data collection for the predator BP study went well and all fields were applicable and assimilated well into the data we already collect. Some additional guidance might be useful in monitoring for predation post hatching. Generally, chicks are either present, or missing, and while predation can be assumed in the event chicks disappear, it is seldom able to be confirmed (finding a chick carcass/remains, etc.) and the specific predator cannot always be positively identified. As a result, the majority of our responses under the "Chicks Depredated" column within the database were unknown, because we could not confidently attribute missing chicks to a predator. In nearly all of those cases, however, we can assume these missing chicks were predated. No additional data in regards to predation management was collected beyond what is covered within the scope of this project.

X. Coordination (BP 9)
Management was coordinated with landowners; however, this generally consisted of keeping them informed of our activities on their properties. We did contract with USDA-APHIS to conduct all trapping and lethal predation management as well as monitoring with motion cameras. Other predation management (additional cameras, hazing, exclosures, roped areas, etc.) were carried out by our personnel. We also coordinated with The Nature Conservancy to share methods/experience in order to assist with some predator issues they had on their managed sites. Funding was placed into an inter-agency agreement between USFWS and USDA-APHIS to conduct predator monitoring and lethal control.

XI. Lessons Learned
The main factors influencing the reproductive success of shorebirds and terns at the Rhode Island demonstration sites during the 2017 nesting season included predation pressure, weather, and human disturbance. A combination of lethal and non-lethal predator control appeared to be a more effective strategy to reduce predation pressure on Piping Plovers and Least Terns than implementing non-lethal control only. American Oystercatchers, however, had higher productivity at Sandy Point, where only non-lethal control efforts were implemented.

Nest exclosures were effective at increasing hatching success for plovers at sites where mammalian predators were the main concern. However, when crows were present at sites it was difficult to use exclosures without first reducing the number of crows through lethal control. Early in the nesting season it was difficult to exclose a number of nests immediately after their clutch completion due to inclement weather. Many of these nests were then depredated before we could exclose them. In the future under similar circumstances, it might be worthwhile considering exclosing a 2–3 egg nest (before completion) if predation pressure is high. It would be important to document any negative impacts of this action (e.g., nest abandonment).

Crow harassment seemed to temporarily reduce predation pressure, but it is unclear how quickly crows returned to areas once monitors left the site. Removing perches was an easy way to try and make sites less attractive to crows, although it is difficult to determine if this activity positively impacted productivity.

When lethal predator control is possible we recommend using it in conjunction with nest exclosures and crow harassment if applicable. It is critical to accurately assess the predators present at each site prior to, and during, management activities. When crows are present, the benefits of using exclosures and the risk of adult

nest abandonment should be carefully considered. At sites with high crow abundance where lethal control is not feasible, it would be worthwhile considering only exclosing a subset of nests and monitoring them closely to ensure crows are not targeting the exclosures. Experimenting with taste aversion treatments might also help decrease nest predation by crows.

Development of standardized monitoring protocols to track changes in predator populations at nesting would be helpful to determine the effectiveness of control efforts especially at different times of the year (e.g., late winter vs spring/summer). Given that predator populations and pressure can vary considerably from year it year, it is important to continually assess predation management activities and adapt when necessary.

F. MASSACHUSETTS: ASSESSING INTERACTIONS OF HUMAN DISTURBANCE AND PREDATION
Author(s): Luanne Johnson (LuanneJ@biodiversityworksmv.org)
Site(s): Edgartown Great Pond

I. Site Introduction (BP 1)
Martha's Vineyard is a 100-square mile island situated 10 km south of Woods Hole/Falmouth, Massachusetts. Edgartown Great Pond (EGP) is a 2-km stretch of barrier beach on the south shore of Martha's Vineyard that fronts a 540–889 acre freshwater pond. The size of the pond varies, depending on whether or not it is open to the ocean. When the pond is open in the spring and late summer, mudflat habitat is exposed. After the pond closes, water levels rise and cover the mudflat areas within a few days to a couple of weeks. The outer beach at EGP is a high-energy beach with strong wave action and light wrack accumulation.

This barrier beach offers 12km^2 of nesting habitat for Piping Plovers (PIPL), American Oystercatchers (AMOY), and Least Terns (LETE), with the majority free from vegetation after hurricane Irene in fall of 2012 and subsequent storms. Four families and a large homeowners association own the two km of beach we monitor (Figure 1). At the eastern edge of the pond opening area, a small portion of the beach is open to the public. It is owned and managed by the Martha's Vineyard Land Bank and is accessible only by boat.
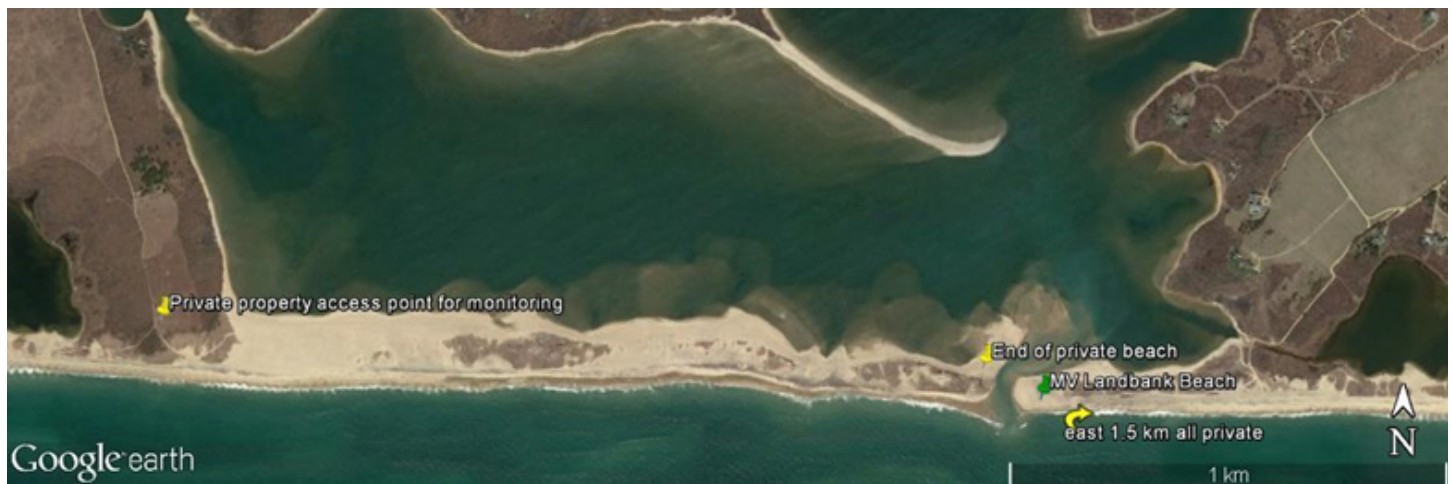
Figure 1. Edgartown Great Pond demonstration site and property ownership map.

II. Species Introduction (BP 1)
Our management targeted egg and chick predators of PIPL with grant funding from the U.S. Fish and Wildlife Service through the Buzzard's Bay Restoration Fund designated for predation management and public outreach to benefit PIPL impacted by a Buzzard's Bay oil spill. We hoped that this predation management also would reduce egg and chick predators of AMOY and LETE nesting at EGP.

BiodiversityWorks has protected beach-nesting birds at EGP since 2011 and our biologists monitored the site in years prior for other organizations. We had long-term nest monitoring data that identified Striped Skunks and American Crows as primary egg predators and American Crows as a primary PIPL chick predator at the site. We determined these predators from tracks at depredated nests, transect surveys of predator tracks, and field observations of these predators harassing nesting birds by our staff over the years. While we did not observe

crows eating PIPL chicks, we suspected crow predation on chicks when we observed crow tracks around predator exclosures at PIPL nests after nest hatch, high densities of crow tracks in areas where plover families fed, as well as from PIPL responses to crows (intensity of calls and distraction displays). We also observed high intensity alarm calls by PIPL when Northern Harrier hawks were hunting on the beach. There are no fox, coyote or opossum on the Island and raccoon have not predated nests at EGP.

III. Triggers or Thresholds (BP 2)
We engage in lethal predation management at a site when non-lethal methods fail. This occurs when we document significant (>50%) PIPL chick or nest loss from predation, when tern colonies fail from egg predation annually, or AMOY fail to hatch chicks due to egg predation Table 1 (Appendix)

IV. Management Activities (BPs 3–4)
We use non-lethal predation management at all sites annually. Non-lethal management includes perch removal for raptors and crows, posts and signs designed to prevent perching by avian predators, predator exclosures around PIPL nests (when no cats or raptors are active at the site), removal or burial of carcasses washed ashore, and communication with landowners about potential predator subsidies (food left on the beach, compost piles or trash near the beach, etc..). Lastly, we monitor from a distance to avoid leading predators to nests.

We refrain from use of exclosures at EGP in the spring due to annual migratory raptor and Northern Harrier hawk activity. The EGP beach abuts coastal heathlands and sandplain grasslands at each end where Northern Harrier Hawks nest (a Threatened species in Massachusetts). These hawks sometimes hunt beach-nesting birds and their chicks. Over two decades of monitoring and protection, a few (2–3) PIPL adult mortalities have occurred at predator exclosures at EGP from raptors (either harriers or migratory raptors). Harrier hunting activity on the beach varies annually, and we believe they hunt on the beach more when vole populations in the heathlands are low, as in drought years. The risk of adult PIPL loss at exclosures seems to decrease by mid-season after migratory raptors move through and when harriers are perching and resting closer to their nest sites. Without predator exclosures around PIPL nests early in the season, we often lose the first one or two PIPL nests to skunk or crow predation. These losses triggered lethal predation management for these egg predators.

To deter skunks from LETE eggs, we pre-fenced a large area (100m x 100m or larger) with low predator fencing (2x2 inch wire mesh, 24-inch tall, buried 2–4 inches in the sand). We placed decoys within the fencing prior to tern arrival in early May, but we have variable success with this type of fencing. In 2013, a large colony of over 250 pairs of LETE nested within the pre-fenced area we created for them, and they were successful at keeping avian predators away. A pair of PIPL and AMOY hatched chicks within the colony, but the terns abandoned after a severe thunderstorm. We repeated the fencing in 2014, and attracted a colony of 32 pairs of LETE, but a skunk with kits that we were unable to trap in box traps, dug under the fencing and decimated the colony. AT EGP, we cannot electrify the fencing because it is remote, private, and the beach goers include many families with children. Low predator fencing requires tremendous effort and volunteer coordination, so pre-fencing depends on how much time we can invest in it and when volunteers are available.

Lethal management is primarily box trapping of Striped Skunks and American Crows that we dispatch via CO_2 chamber, which veterinarians advising the U.S. Fish and Wildlife Service recommended as the most humane method of field euthanasia. However, crows can become trap shy to box traps. In 2015, we maintained our box trapping effort early in the season and contracted USDA-APHIS for crow removal. They used mock PIPL predator exclosures baited with chicken eggs containing a small dose of DRC-1339, a blackbird-specific avicide. PIPL productivity increased to 1.13 chicks fledged per pair in 2015, from 0 and 0.43 in 2013 and 2014, respectively (Table 1). We believed that the USDA DRC-1339 application in 2015 eradicated any trap savvy crows, so we did not contract USDA for crow removal in 2016. In addition, USDA used DRC-1339 to remove crows at a site 1.5 miles east, and we suspected EGP would benefit from that crow removal. Our box trapping removed four crows in 2016, and three pairs of PIPL hatched 10 chicks. However, no PIPL chicks fledged. The chick loss was attributed to possibly 1–2 crows and Northern Harriers that regularly hunted the beach in that summer of severe drought.

In 2017, we experimented with an Australian drop-in crow trap with hopes of capturing multiple crows in this large trap away from the beach (Figure 2) that may not be willing to enter box traps. If successful, this method of crow capture would be less expensive than box trapping or DRC-1339. The drop-in crow trap was baited with two crow decoys, compost, chicken heads, and bright orange crackers. Our camera at the trap showed crows perched on top of the trap on different occasions, but they never entered nor took bait. As described below, we captured five crows in box traps. We used two of the live crows captured in box traps as live decoys in the drop-in trap to increase the likelihood of a crow entering the drop-in trap. Much to our surprise, the crows escaped the drop-in trap within two minutes. Observing them showed us that the space between the rungs on top of the trap needed to be narrower to prevent crows from flying out. We plan to deploy the trap in March 2018, when food is scarce for crows. Despite the drop-in trap failure, PIPL productivity was 2.0 chicks per pair for three pairs in 2017 (Table 1).

Drop-in crow trap: NOT EFFECTIVE. No crows were captured with this method at EGP. However, modifications to reduce the rung spacing on the trap may prove more effective for capturing crows and keeping them in the trap.

Also, we set more box traps in an effort to increase Striped Skunk capture rates on this large expanse of beach; however, skunks remained difficult to trap and depredated a LETE colony, as well as several AMOY and PIPL nest attempts. We used 18–19 box traps on the beach (Figure 2), and created a line of traps from the pond to ocean side to intercept any skunks walking onto the beach from the west end, but our most problematic skunk would not enter the traps. We tried changing bait to sweets from sardines and trapping in the dunes along deer trails, but were still unsuccessful. We captured five crows in box traps on the beach

Additional box trap transect: SOMEWHAT EFFECTIVE. The skunk targeted for trapping did not enter any traps, but five crows were captured in box traps.

In the future, we will try to pre-fence a large area for LETE and AMOY, with chicken wire buried underground to prevent skunks from tunneling under the fencing. We have been more successful with fewer trap nights and traps in other years. The first two weeks of May are a prime time to capture skunks and crows, and after that window, captures decrease until mid-June, when we tend to have better success.

V. Secondary Effects and Unintended Consequences (BP 5)
Box trapping often occurs when AMOY have nests on the beach, and sometimes when we have unexcluded PIPL nests. Because box traps attract crows, gulls, raccoon, and skunk, and not all of these species or individuals are trappable, we make every effort to keep traps away from active nesting areas where AMOY or PIPL nests are vulnerable to predators. Traps should always have covers so that crows and gulls cannot access the bait from outside the trap.

VI. Timing of Management Activities (BP5)
Predation management at EGP occurs annually from late April through the end of May and sometimes into June, depending on when the property owners that allow access at the West end arrive and begin using the beach. They do not like to have trapping active when they are in residence. We do not box trap earlier in the spring because skunks are relatively inactive along the south shore until later in April.

VII. Outreach and Communications (BP 6)
EGP is a privately-owned beach, and some of the property owners prefer to keep themselves out of the media. Thus, we do not advertise our lethal predator control activities in the newspaper. We share predation management results and data in our reports to grantors for beach nesting bird monitoring as well as in posters at donor events or in presentations.

We ask landowners for permission to use lethal predation management and have copies of our requests that were successful in obtaining permission for box trapping and euthanasia, as well as for DRC-1339 application to reduce crow densities. Permission for lethal skunk control is easier to acquire than permission for lethal crow control, primarily due to local lore that Striped Skunks are an invasive and introduced species. Landowners and

seasonal residents on the Vineyard tend to view crow predation as 'natural,' which we counter with data on high densities of generalist species that receive subsidies from humans.

VIII. Permitting and Regulations (BP 7)

We apply to the Massachusetts Natural Heritage and Endangered Species Program for a permit to trap and dispatch up to 60 striped skunks, 10 raccoon, and 60 American or Fish Crows annually. We mark each trap with a tag identifying our organization and our permit number. We report our trapping data to MassWildlife annually to renew our permit.

IX. Standardized Data Collection (BP 8)

Data collection in the requested standardized manner (for the 2017 BP demonstration site study) was similar to our typical data collection and was easy for us to accomplish. In addition, we set time-lapse cameras and maintained them as part of the MA demonstration sites assessment of human disturbance impacts on nest and/or chick predation.

X. Coordination (BP 9)

We met regularly by phone with our partners at demonstration sites to coordinate standardized data collection and entry as well as a camera study to assess human disturbance.

XI. Lessons Learned

Predation management is not simple and it is very expensive. You must commit to the effort for a number of years in order to understand annual variation in predator activity and responses to your management. It may be more successful at sites where the group or agency conducting the management owns the site and has control over when, where, and how predator removal can happen. When implementing predation management on private sites, success can vary, sometimes due to limitations imposed by the landowners. For example, they may not want any trapping after they arrive for the summer or they may allow trapping and removal of skunks but not crows. They may agree initially, and then change their mind when they read the permission letter from USDA-APHIS and decide not to sign.

Table 1. Piping plover nest losses, predator species, productivity, and predation management at EGP 2011–2017, with notes on American Oystercatcher and Least Tern predation and predators

Year	# of Pairs	# Nests depredated and predator species	# Nests exclosed	# Nests hatched	# Chicks fledged	Productivity (chicks/pair)	# Days box traps set	# Trap nights	Predators captured	AMOY and LETE notes
2011	4	**0–1** (unknown)	3	3	8 (of 9)	2.0	0	0	NA	3 AMOY, 13 LETE nests depredated by skunk
2012	7	**2** (1 skunk, 1 crow)	8	6	7(of 21)	1.0	0	0	NA	5 AMOY, 35 LETE nests depredated by skunk
2013	7	**6** (1 skunk, I crow, 6 unknown)	3	5	3 (of13)	0.43	12	72	3 skunk, 3 crow	1 AMOY nest depredated by skunk, AMOY chicks depredated by harrier (suspected)
2014	6	**18** (7 skunk, 7 crow, 4 unknown)	1	0	0 (of 0)	0	13	118	3 skunks	2 AMOY nests depredated by skunk and crow, 32 LETE nests depredated by skunk
2015	8	**6** (2 skunk, 4 unknown)	1	4	9 (of 14)	1.13	7	70	5 crows trapped, 6–10 removed by DRC-1339	2 AMOY nests depredated by skunk, AMOY chicks depredated by crow, no LETE nested
2016	5	**4** (2 skunk, 2 unknown)	1	3	0 (of 10)	0.0	8	78	1 skunk, 4 crow	1 AMOY nest depredated by skunk, No LETE nested
2017	3	**5** (3 skunk, 2 unknown)	3	2	6 (of 7)	2.0	23	316	1 skunk, 5 crow (2 released)	5 AMOY nests depredated by skunk and crow, 28 LETE nests depredated by crow.

Figure 2. Locations of Piping Plover (PIPL), American oystercatcher (AMOY) and Least Tern (LETE) nests at Edgartown Great Pond in relationship to box trap sites and Australian drop-in crow trap in 2017.

Author(s): Jeffrey Denoncour (jdenoncour@thetrustees.org)
Site(s): Crane Beach, MA

I. Site Introduction (BP 1)

Crane Beach is a 1,100-acre, 4.5-mile-long barrier beach, located in Ipswich, Massachusetts, owned and managed by the Trustees, a state-wide, non-profit land conservation organization. The shorebird research and management program at Crane Beach began in 1986, and has focused on limiting predation and human disturbance of protected birds and their nests. This is achieved by closing off large sections of beach habitat, informing visitors of beach regulations and applying predation management. Non-lethal predation management began in 1987, when wire exclosures were used to protect Piping Plover nests. Later, in the 1990's, electric fencing was incorporated to protect both plover and tern nests from mammal predation. Not until 2008 was selective lethal predator control implemented in response to declines in annual productivity caused by "smart" predators keying in on shorebird nests, chicks and nest exclosures. Since 2008, lethal control for American Crows has been conducted annually. Control for Great Horned Owl was added in 2015 and coyote in 2017.

II. Species Introduction (BP 1)

Over the past 20 years, an average of 32 Piping Plover (PIPL) and 145 Least Tern (LETE) pairs nest on Crane Beach annually. During the 2017 breeding season 39 PIPL and 172 LETE pairs nested. These two species are the focus for management activities and predator control because of their listing under State and Federal Endangered Species Acts. Due to shared nesting habitat and similar predation impacts, both species benefit from predation management.

To determine which predator species to target, we use a variety of methods during daily monitoring activities including checking camera traps, recording predator sign at predated nests and exclosures, and observing predator tracks and direct observation of predators in the habitat. It is important to note that lethal control is only implemented when a high degree of confidence is achieved. While assumptions can help paint an overall picture, they do not provide the level of accuracy needed. Our goal is to remove individuals conducting the predation and not entire populations.

III. Triggers or Thresholds (BP 2)

Some depredation is expected and a single predation event, or a predator's mere presence, does not trigger selective predator control. The decision to implement is one we do not take lightly and involves analyzing consistent trends and targeted behavior by a predator species over multiple years. Additionally, annual trends in productivity rates will factor into the decision. If the goal of roughly 1.25 plover chicks per pair (as estimated by Massachusetts to increase the Piping Plover population; Melvin and Gibbs 1996) is not met for multiple years due to predation, we may initiate lethal predator control. By relying on predation trends over singular predation events, the Trustees avoid over reaction to current predator threats and preserve trophic-level function.

IV. Management Activities (BPs 3–4)

After increasing from five to 44 nesting plover pairs between 1986 and 1999, with an average productivity rate of 2.04 chicks per pair, the Crane Beach population plummeted to an average of 30 nesting pairs, producing .92 chicks per pair between 2000–2007. This decrease in pairs and productivity was a combination of changing beach morphology and a rise in "smart" predators (American Crows, Great Horned Owls and coyote) becoming adept at preying on nests, chicks, and keying onto exclosures resulting in nest abandonment, and adult mortality. Ultimately the effectiveness of non-lethal control had deteriorated, leading to its limited use, and making nests more susceptible to predation. This led to the exploration of alternative means to prevent predation in the form of selective lethal control. Following implementation of lethal control for American Crows, average plover pairs remained stable at 31, but productivity rose to 1.31 chicks per pair between 2008–2017, suggesting an increase in productivity due to predator control.

Two methods of predation management (lethal and non-lethal) were utilized in 2017. A comprehensive lethal predation management program was implemented by contracting with APHIS Wildlife Services (USDA).

Methods under this contract included lethal control for American Crows, Great Horned Owls, and coyotes. We targeted these species for predator control because they displayed targeted behavior, and they were identified as the most pervasive predator threat in previous years. In addition, electric fencing was used to protect roughly 11 acres of habitat where both LETE and PIPL were concentrated (28/72 were PIPL nests).

Crow management lasted between April 19th and June 5th and involved the construction of mock bait stations, pre-baiting, and services provided by USDA to deploy Avicide DRC-1339. Bait stations included three open-topped 2X2 inch wire-mesh exclosures designed to replicate non-lethal nest exclosures. Hard-boiled chicken eggs were placed inside exclosures to mimic a shorebird nest. An ongoing log recorded the uptake of pre-bait and toxicant-laced eggs. Game cameras placed at all three of the bait stations recorded predators taking bait.

American Crow Consuming DRC-1339 Laced Chicken Egg. The Trustees of Reservations

Of the three bait stations, two received uptake of pre-bait and a third was removed after receiving no uptake. Once uptake of pre-bait by crows became consistent, USDA was notified, and they deployed DRC-1339 toxicant laced eggs. Twelve toxicant eggs were deployed this season and six of 12 were taken by American Crows. Pre-baiting continued after the last round of toxicant, but no uptake occurred and baiting ceased.

Additional efforts to remove crows with firearms occurred this season in response to two crows displaying targeted behavior that resulted in the depredation of five plover nests over a few days. These crows were seen at similar times of day, consistently foraging along the eastern end of the beach and were witnessed predating a plover nest. Due to the animal's disregard for a nearby bait station, control with firearms was conducted by USDA to prevent further nest loss. On 12 May the eastern portion of Crane Beach was closed to the public, control was implemented, and one crow was removed with a shotgun. On 13 May new toxicant deployed on the previous day (12 May) was taken by American Crow and crow predation ceased for the remainder of the season. This was a good example of the importance of monitoring predator behavior, and the effectiveness of a quick reaction to predators through lethal control.

The most conspicuous predator was at least one Great Horned Owl that had learned predatory behavior. The owl(s) were present on the beach for a fourth year in a row. Frequently, we found LETE nests that had been predated, and we found three plover nests that were predated by an owl during this season (2017). Because a Great Horned Owl had targeted circular exclosures in both 2014 and 2015, we did not use circular exclosures in 2016, which is our only non-lethal means to prevent avian predation. We did not use circular exclosure in 2017, but two owls were removed by USDA using firearms and call backs on 23–24 May. In addition to firearms, bal-chatri traps also were deployed to increase the chance of owl removal, especially if the owls were not responding to call backs. Control for owls began in March and ended 10 July. In response to the removal of these owls, one circular exclosure was placed

Owl Caught on Camera Trap at Exclosure. The Trustees of Reservations

around a plover nest for the first time since 2015. However, within a few days an adult plover was killed at the exclosure. Plover feathers were discovered and an owl was caught on camera trap at the exclosure. As a result,

the exclosure was removed and the remaining adult abandoned the nest. We assume that the owl with the learned predatory behavior was not one of the two removed or that multiple owls are displaying this predatory behavior.

Coyotes, which first arrived at Crane Beach in the late 90's, are the other most-active predator. Trends in recent years show coyotes are particularly active when LETE arrive, begin nesting, and especially during hatching. Often, we find coyote tracks that lead directly to newly hatched tern nests. Coyotes also have been active predators of PIPL nests and chicks. For the first time in the program's history, we implemented efforts to lethally remove coyotes as part of USDA's predation management plan. Control for coyote began in March and ended on 10 July. One coyote was removed during the 2017 season using call backs and firearms on 10 July. We believe that coyotes are an important component of maintaining mesopredator populations, for this reason our goal is not to eliminate coyotes at Crane Beach, but rather reduce resident animals that key into shorebirds.

Predated Least Tern Nest. The Trustees of Reservations

In 2017, plover pairs produced 72 nests, 96 chicks, and 33 fledglings, or .85 fledglings per pair. Productivity did not surpass the state goal of 1.25, and fell below the average productivity from 1998–2017 (1.23 fledglings per breeding pair) for a third year in a row. Least terns also produced very few chicks even with the number of nesting pairs at their highest since 2003. Low productivity was a result of increased storm events and predation. In recent years, changes in beach morphology have compounded these factors due to the creation of large swaths of prime nesting habitat and loss of

Coyote on Camera Trap Within Most Densely Nested Habitat. The Trustees of Reservations

habitat in other areas. This has led to an increasing risk of nest overwash, as birds concentrate in accreting areas that are often just above the high tide line. Additionally, a narrow beach profile in eroding areas increases the proximity of nests to the ocean. In addition to increased nest overwash, changes in morphology also reduce space for effective electric fence use. The high density of nests in newly created prime habitat attracts predators to the wealth of prey and few non-lethal management actions are feasible in these areas. As a result, nest and chick loss is high in prime areas, and in many cases, chicks in these areas are predated immediately after hatching. A majority of fledglings now come from remote pairs, in irregular nesting habitat. Considering environmental stressors, changing beach morphology, and deteriorating effectiveness of non-lethal control, selective predation management has become a key method of reducing predator impacts. Had predator control not been implemented, productivity may have been much lower.

V. Secondary Effects and Unintended Consequences (BP 5)
We did not witness an increase in mesopredator populations as a result of removing a coyote or two Great Horned Owls.

VI. Timing of Management Activities (BP5)

Management activities began in March of 2017 to get a head start on predators prior to nesting and lasted throughout nesting, ending in July. Specifically, crow management using DRC-1339 lasted between April 19th and June 5th. After we observed consistent hunting behaviors and crow depredation of a Piping Plover nest, the eastern portion of Crane Beach was closed to the public on 12 May, and lethal control was implemented, and one crow was removed with a shotgun. Control for both coyote and owls began in March and ended 10 July.

VII. Outreach and Communications (BP 6)

Over the years the Trustees have remained transparent about our predator control efforts through communication with the public, visitors, local law enforcement, state biologists, and internally within our organization.

VIII. Permitting and Regulations (BP 7)

USDA obtained the required permits needed to carry out predator control.

IX. Standardized Data Collection (BP 8)

We feel data collected this season through the BP process was not overly burdensome and hope it aids understandings. We feel having accurate biological data to support decisions is an important part of predator control, and used to support and communicate predation management decisions.

X. Coordination (BP 9)

Efforts were paid for using both internal operating funds and mitigation funds granted to the Trustees by Massachusetts Fish and Wildlife under the Piping Plover Habitat Conservation Plan.

XI. Lessons Learned

Selective predation management continues to be a topic of debate and more data is needed to shed light on its effectiveness. Rarely is anything static in shorebird management. Beaches are constantly shifting, shorebird and predator populations fluctuate, and new threats evolve. This is an important philosophy of shorebird management at the Trustees, and our adaptive approach to predation management.

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Author(s): Lauren Miller-Donnelly (laurenmiller@massaudubon.org)
Site(s): Little Beach, MA

I. Site Introduction (BP 1)

Little Beach is a coastal mainland site consisting of 19.4 acres of nesting habitat? (5.3 MAS 14.1 C.R.). Little Beach is a Massachusetts Audubon Society property. We have previously conducted management activities on this site, including both non-lethal and lethal methods.

II. Species Introduction (BP 1)

Management activities focused on American Oystercatcher, Piping Plover, Least Tern, Common Tern, and Diamondback Terrapin. We focused on ground-nesting coastal waterbirds as well Diamondback Terrapin, which is a threatened species in Massachusetts. Federally-listed species were given top priority for management action. Predator species at the site were identified and targeted using a variety of methods, including game cameras, point counts, track surveys, dusk and dawn surveys, daily observations, and recording of scat, predations at nests, and investigation of carcasses.

III. Triggers or Thresholds (BP 2)

Multiple years of >50% of egg and chick losses attributed to predation, and relative ineffectiveness of non-lethal predation management practices resulted in program of targeted predator removal. Increasing effects of predators in recent years also contributed to this decision.

IV. Management Activities (BPs 3–4)

Non-lethal management tactics are used in all years. We employ lethal control when non-lethal activates do not work. Non-lethal control methods included posts/rods that preclude perching, removal of trash from nesting areas, remote monitoring of birds to reduce human scent in vicinity of nests, and removal of marine animal carcasses from the beach.

Mock exclosures were set up by April 1 to conduct early baiting (pre-shorebird nesting) for crows because we have had evidence of American Crow predation. The mock exclosures have game cameras on them and other game cameras are set towards the exclosures and set on time-lapse to view diurnal predators near the mock exclosures or near nests on the beach. Once crows are actively taking untreated chicken eggs they are replaced with toxic eggs (avicide DRC 1339). Because we know that coyote have predated nests we have asked for USDA to come at night and remove a coyote. In the past the time-lapse camera work has identified American Crows and Herring Gulls as removal targets. We have removed American Crows (2015 and 2016) using the poison technique and have removed 1 Herring Gull (2015) using suppressed firearms in previous seasons.

Our management program is based on 1) multiple years of nesting and predator impacts data, 2) recommendations from professional wildlife damage managers, 3) ability to obtain permits to conduct predation management activities, and 4) available capacity (including funds and personnel expertise) to implement the plan. Mass Audubon Coastal Waterbird Program created a document with guidelines for how we decide upon our predator control activities. We only decide to control a particular predator if there is enough direct evidence that this particular predator is having an impact on the birds.

In 2017 the management activities were not effective because we had hoped that coyote removal would be easier than it turned out to be. The other obstacle was that fox and striped skunk were not included on the list of predators approved for removal. Using this year's evidence we plan to update our predator document to include both species. In addition, with a standardized methodology, the four MA demonstration sites tested the hypothesis that greater human disturbance of nesting birds contributed to increased predator impacts. We used trap cameras in areas of low, moderate, and heavy human disturbance of nesting habitat to examine the relationship between disturbance and predation events.

V. Secondary Effects and Unintended Consequences (BP 5)

Through track observations, we noticed that a predator came out to the mock exclosure for investigation. Eventually we noticed that a skunk dug at the mock exclosure and then it even dug under one of them and ate the old rotten eggs.

VI. Timing of Management Activities (BP5)

We contracted with USDA to remove coyote throughout the breeding season from mid-April to mid-July. During the mid-peak of the nest-laying season for plovers we started to have nest predation issues. Once the Least Terns arrived and we had hundreds of birds on the beach, the night-time predator visits by fox and skunk increased. Coyote were already visiting regularly.

VII. Outreach and Communications (BP 6)

Non-lethal activities are reported to the public via seasonal reports posted online. Lethal predation management was not announced, although documentation of this is available through permitting processes, and subject to FOIA requests. As an environmental organization, we do not proactively report predator removal activities to the public to avoid controversy. We feel that this approach has been effective. If questioned, we would disclose our activities and have prepared talking points and FAQs to meet this challenge. Our management of the island includes a communications plan to handle press issues.

VIII. Permitting and Regulations (BP 7)

We comply with the state and federal guidelines under endangered species laws regarding use of exclosures, electric fencing, placement of cameras in nesting habitat, and reporting. Predator removal activities are conducted by contracted professional wildlife damage managers (USDA-APHIS). Applicable permits are obtained by USDA-APHIS. We discussed permitting with USDA-APHIS and MADFW Natural Heritage Program.

IX. Standardized Data Collection (BP 8)

The data requested by the predator BP study overlapped entirely with data collected by MA shorebird cooperators who report monitoring results to MADFW, which made data entry and reporting easy. One suggestion for improvement is that there could be a column for age of chicks when lost or date of chick loss; or for the nests, date of nest completion so you can compare nests laid early vs nests laid at the end of the summer. Also with this information, you could look at how many days a nest is on the ground before it is predated, which may vary at different stages of the nesting season.

X. Coordination (BP 9)

We coordinated with other sites within Massachusetts conducting predator control as well as with the demonstration sites in Rhode Island. Funding for management activities depended on the type of management conducted. Non-lethal management activities are part of operations; predator removal was a line item.

XI. Lessons Learned

There is a need to better understand the behaviors and movements of American Crows in our landscape, a better understanding of the effect of avicide on crows (how many individuals, what they do with the eggs, what could happen if other birds consume egg shells, whether or not they are learning, etc.) Our analysis of camera data is incomplete, but we look forward to sharing results of our project as soon as possible.

Author(s): Katharine Parsons (kparsons@massaudubon.org)
Site(s): Dead Neck Sampsons, MA

I. Site Introduction (BP 1)

Dead Neck Sampsons Island is a 3.38km long coastal barrier island. The island is owned by Mass Audubon and Three Bays Preservation, Inc. Non-lethal and lethal predation management has occurred at this site in the past.

II. Species Introduction (BP 1)

Our focal species for management were Piping Plover, Least Tern, Common Tern, and American Oystercatcher. We selected these species because they repeatedly experience poor reproductive success due to predation and were likely to benefit from predator removal. We identified predators at our site from many years' data from camera traps, track transect surveys, incidental track sightings, predator sign at nests, direct observations of predation, prey carcasses, and anecdotal evidence.

III. Triggers or Thresholds (BP 2)

Multiple years of >50% of egg and chick losses attributed to predation, and relative ineffectiveness of non-lethal predation management practices resulted in program of targeted predator removal. Increasing effects of predators in recent years also contributed to this decision.

IV. Management Activities (BPs 3–4)

Our management program is based on 1) multiple years of nesting and predator impacts data, 2) recommendations from professional wildlife damage managers, 3) ability to obtain permits to conduct predation management activities, and 4) available capacity (including funds and personnel expertise) to implement the plan.

Non-lethal management practices included the following: removing perches from vicinity of nesting, using posts/rods that precluded perching, removal of trash from nesting areas, installation of "dog line" (i.e., lower line of twine added to symbolic fencing), dog/people outreach and exclusion from restricted areas of island,

remote monitoring of birds to reduce human scent in vicinity of nests, and removal of marine animal carcasses from the beach. Non-lethal control measures were used in all years. Lethal management practices included mock exclosures with toxic eggs (avicide DRC 1339) deployed during late Apr–May.

With a standardized methodology, the four MA demonstration sites tested the hypothesis that greater human disturbance of nesting birds contributed to increased predator impacts. We used camera traps in areas of low, moderate, and heavy human disturbance of nesting habitat to examine the relationship between disturbance and predation events. We believe the program followed this year, which targeted avian egg predators, was successful in that no plover or tern eggs are known to have been predated by crows or grackles. Unfortunately, most beaches in the state experienced high rates of nest overwash due to the timing of lunar high tides in the nesting season coupled with wind.

V. Secondary Effects and Unintended Consequences (BP 5)
We did not observe any secondary effects or unintended consequences related to management activities.

VI. Timing of Management Activities (BP5)
Non-lethal management took place Apr–Aug. Predator removal activities took place from mid-Apr–May. All management activities occurred during the shorebird nesting season.

VII. Outreach and Communications (BP 6)
Non-lethal activities are reported to the public via seasonal reports posted online. Lethal predation management was not announced, although documentation of this is available through permitting processes, and subject to FOIA requests. As an environmental organization, we do not proactively report predator removal activities to the public to avoid controversy. We feel that this approach has been effective. If questioned, we would disclose our activities and have prepared talking points and FAQs to meet this challenge. Our management of the island includes a communications plan to handle press issues.

VIII. Permitting and Regulations (BP 7)
We comply with the state and federal guidelines under endangered species laws regarding use of exclosures, electric fencing, placement of cameras in nesting habitat, and reporting. Predator removal activities are conducted by contracted professional wildlife damage managers (USDA-APHIS). Applicable permits are obtained by USDA-APHIS. We discussed permitting with USDA-APHIS and the MADFW Natural Heritage Program.

IX. Standardized Data Collection (BP 8)
The data requested overlap entirely with data collected by MA shorebird cooperators who report monitoring results to MADFW. In addition to the demonstration site data, we collect environmental data (weather, tide), focal nesting species behavior, distance of nest from high tide line and toe of dune, presence of vegetative cover in vicinity of nest, other nest microhabitat variables, predator species point counts, pedestrian and boat presence, and dog presence.

X. Coordination (BP 9)
We coordinated management at the sites within Massachusetts as well as with sites in Rhode Island and elsewhere along the coast. Funding depended on management method. Non-lethal management activities are part of operations; predator removal was a line item.

XI. Lessons Learned
Our analysis of trap camera data is incomplete, but we look forward to sharing results of our project as soon as possible.

SUPPLEMENTAL MATERIAL: INTERVIEW CONSENT AND QUESTIONS

A. INTERVIEW CONSENT FORM

We would like to contact you to ask you more detailed questions about your predation management activities. We will first contact you to schedule an approximately 1-hr phone discussion. Once it is scheduled, we will send you our list of questions that we would like to discuss so that you may be prepared. You also have the option of a self-guided, web-based survey. This will contain the same questions as the interview, so it will be extensive, but you can take this at any time between now and March 15, 2017.

The information we collect from our discussion with you will not be personally-identifiable. You will be assigned a number under which your responses will be coded. The results from this work will be used in a predation management best management practices document and database of activities that will be available to managers across the Atlantic Coast flyway. The BP document will be publicly available but the database of detailed activities will only be provided by request and with approval of the US Fish and Wildlife Service.

The following questions seek your consent to move forward in this process and address several details in this process. Our work has received approval from Virginia Tech's Institutional Review Board, Approval #17-003.

1. Are you willing to be contacted for an approximately 1-2-hr phone interview or self-guided, web-based survey (Yes/No)? Questions for the interview/survey will be sent to you at least one-week in advance of your interview.

2. Are you willing to have the phone call recorded for data coding purposes only (Yes/No)? The voice recordings will not be made publicly available but just used to code your responses.

3. Your name will not be identified with your responses. However, may we use the name of the ma agement area/job site where predation management activities are/were conducted or does the site need to remain anonymous?

4. Your name will be numerically coded and we will not associate your name with your responses in any written document or database. However, may we list your name in the BMP document as a person with whom we discussed this questionnaire (Yes/No)?

B. PHONE AND WEB-BASED INTERVIEW QUESTIONS

Predator BP Interview Questionnaire – These questions were developed using the nine best management practices from our BP objectives outline as well as from the working plan of Kat Miles, a graduate student at Virginia Tech studying red fox ecology on Fire Island, New York. Ideally, we would like interviews to be no more than one-hour long, but if managers have experience with all predation management methods, we expect that interviews may be longer than one hour.

Please note that the wording of questions below may not exactly reflect the wording of interview questions, but the information requested is the same. Some questions will be phrased as multiple-choice rather than open-ended questions to save time during the interview process. If you are interested in a PDF containing the exact questions used for the phone and web-based interviews, please contact Kelsi Hunt (hunt0382@ vt.edu) or Sarah Karpanty (karpanty@vt.edu).

Numerical ID: (note names and links to IDs in separate file)
Interview date:
Interview start time:
Interview end time:

Phase 2: Interview Questions.

BEST PRACTICE 1: IDENTIFYING TARGET SHOREBIRD SPECIES AND PREDATOR GUILDS
In what geographic setting did management take place (coastal, non-island; coastal, barrier island; coastal, other island; or non-coastal)?

What prey species did/does your predation management target and how did you determine what species to target?

Is your past/present/future management targeted at any of our four AFSI focal species (breeding American Oystercatcher, Piping Plover, Snowy Plover, Wilson's Plover)?

How do you prioritize management actions in relation to prey species?

What predator species has/does/will your management target and how did you determine what species to target?

Do you have something in place to consider unintended consequences of predation management on other species of concern? How do you report or mitigate possible secondary effects? For example, if you removed raccoons and ghost crab populations increased, how would you mitigate that secondary effect?

BEST PRACTICE 2: IDENTIFYING THRESHOLDS OR TRIGGERS
At your site, is there a trigger or threshold that would lead to lethal predation management (e.g., number or percentage of nests/chicks depredated or number, number of predator tracks on transects, direct observation(s) of predation?)

     If so, what is this trigger or threshold?

At your site, is there a trigger or threshold that would lead to non-lethal predation management (e.g., number or percentage of nests/chicks depredated or number, number of predator tracks on transects, direct observation(s) of predation?)

     If so, what is this trigger or threshold?

If you manage multiple sites, how do you prioritize which site(s) are managed for predators?

BEST PRACTICE 3: METHODOLOGICAL CONSIDERATIONS FOR DIRECT PREDATION MANAGEMENT TECHNIQUES

Have/are you using direct (lethal) predation management techniques such as:

1. Trapping
2. Shooting
3. Nest Destruction
4. Poisoning
5. Other methods not listed (e.g., fumigants, etc.)

If so, what techniques have you used and what predator species were targeted with each?

Who or what agency has performed/will perform the trapping? For example, USDA, yourselves, another contractor, etc.

What was the duration and timing of each specific management activity? Were activities repeated over multiple breeding seasons or years?

How much effort was involved with each activity? For example, number of trap nights, applications, etc.

What was the total cost associated with each management activity?

How was the effectiveness of these management activities measured?

Did you collect any data on predator abundance or occupancy before/and or after each management activity?

If so, what methods were used to collect this data?

Did you observe any of the following during the same breeding season that predation management activities were conducted compare to the prior breeding season?
Increased hatching?
Increased fledging?
Increased adult survival?
Increased estimated population size?
Change in predator abundance or occupancy?

Did you observed any of the following in the subsequent breeding season after management activities were conducted in comparison to previous breeding seasons?
Increased hatching?
Increased fledging?
Increased adult survival?
Increased estimated population size?
Change in predator abundance or occupancy?

If there were changes in shorebird productivity and/or predator abundance, are there any factors aside from predation management that may have contributed to these changes?

BEST PRACTICE 4: METHODOLOGICAL CONSIDERATIONS FOR INDIRECT PREDATION MANAGEMENT TECHNIQUES

Have/are you using indirect (non-lethal) predation management techniques such as:

1. Exclusion
2. Harassment
3. Chemical aversion
4. Trap and relocate
5. Other techniques (e.g., shock aversion, anti-perching, etc.)

If so, what techniques have you used and what predator species were targeted with each?

What was the duration and timing of each specific management activity? Were activities repeated over multiple breeding seasons or years?

How much effort was involved with each activity?

What was the total cost associated with each management activity?

How was the effectiveness of these management activities measured?

Did you collect any data on predator abundance or occupancy before/and or after each management activity?

If so, what methods were used to collect this data?

Did you observe any of the following during the same breeding season that predation management activities were conducted compare to the prior breeding season?
Increased hatching?
Increased fledging?
Increased adult survival?
Increased estimated population size?
Change in predator abundance or occupancy?

Did you observed any of the following in the subsequent breeding season after management activities were conducted in comparison to previous breeding seasons?
Increased hatching?
Increased fledging?
Increased adult survival?
Increased estimated population size?
Change in predator abundance or occupancy?

If there were changes in shorebird productivity and/or predator abundance, are there any factors aside from predation management that may have contributed to these changes?

Given the methods you've utilized (both lethal and non-lethal) how effective do you think each of the management actions are/were, in general, for increasing shorebird productivity and/or overall population size? (responses on a Likert scale of 1–5, with 1 meaning highly ineffective and 5 meaning highly effective)?

BEST PRACTICE 5: TIMING OF METHODS IN RELATION TO SHOREBIRD AND PREDATOR ANNUAL CYCLES

When planning and utilizing predation management how did/do you take into account the ecology and annual cycle of the prey species?

When planning and utilizing predation management how did/do you take into account the ecology and annual cycle of the predator species?

How do you incorporate risk management actions to nesting shorebirds? For example, what happens when management activities overlap with the active breeding season?

BEST PRACTICE 6: COMMUNITY ENGAGEMENT, OUTREACH, COMMUNICATIONS

Did you publicly announce predation management activities beforehand? If so, how would you describe the overall public response?

If you did not publicly announce predation management activities beforehand, what factors influenced your decision not to do so?

If you did publicly announce predation management activities beforehand, what communication and outreach tools/techniques did you utilize to inform and engage the public and/or stakeholders?

> Were these tools/techniques effective?

Did you seek input or assistance from the public for any management activities? For example, input and/or assistance from veterinarians or cat adoption groups?

> If so, was this effective?

Based on your experience working with the general public, how acceptable to the general public were the management activities used (responses on a Likert scale of 1–5, with 1 meaning highly unacceptable and 5 meaning highly acceptable)?

BEST PRACTICE 7: REGULATORY CONSTRAINTS

What is/was your experience working with the NEPA process?

What is/was your experience working with other state and federal regulations and permitting?

What is/was your experience working with landowners to gain permission for management activities?

BEST PRACTICE 8: MONITORING AND REPORTING

Have your findings been published in a peer-reviewed journal or a report? If so, could you provide the citation information, so we can make sure it's included in a comprehensive literature review?

Would you be willing to adopt a standardized method of data collection on shorebird metrics related to predation management? If so, do you have any suggestions?

Would you be willing to adopt a standardized method of data collection on predation management metrics? If so, do you have any suggestions?

BEST PRACTICE 9: COORDINATION OF MANAGEMENT ACTIONS AND FUNDING RESOURCES

What level of communication do you have with other groups performing predation management in your state for target shorebird species?

What level of communication do you have with other groups performing predation management in your state for other taxa?

Do you have suggestions for facilitating communication between groups?

Do you have suggestions for linking 'short term' funding models between groups into 'longer term' funding?

SUPPLEMENTAL MATERIAL BP2: TOOLS FOR PRIORITIZING PREDATION MANAGEMENT

A. FLORIDA PANHANDLE PREDATOR MATRIX

The following predation management matrix is used in the Florida panhandle to prioritize predation management tasks across many different sites in the region. This summary was adapted from an email discussion with Raya Pruner of Florida Fish and Wildlife Conservation Commission.

The matrix was developed as a product of a NRDA project for shorebird predation management across the Florida panhandle. All sites with documented shorebird nesting were included in the matrix initially; however, privately managed beaches and sites with internal trapping were removed over time to allow for those resources to be used at sites without the funding to hire their own predation management personnel.

Matrix Point Assignments

For each site, the 5-year average number of breeding adults for each of Florida's five focal beach nesting species is calculated separately:
* Snowy Plover
* Wilson's Plover
* American Oystercatcher
* Least Tern
* Black Skimmer

The averages are then used to assign points to rank each breeding population as follows (see Table 1 below):
☐ For state-threatened solitary nesters (SNPL and AMOY)
  ο Top site (highest 5-yr average of breeding adults) = 40 points
  ο Top 1/3 = 20 points
  ο Middle 1/3 = 10 points
  ο Bottom 1/3 = 5 points
☐ For state-threated colonial nesters (LETE and BLSK)
  ο Top site = 30 points
  ο Top 1/3 = 15 points
  ο Mid 1/3 = 7.5 points
  ο Bottom 1/3 = 3.75 points
☐ Not listed (WIPL)
  ο Top site = 10 points
  ο Top 1/3 = 5 points
  ο Middle 1/3 = 2.5 points
  ο Bottom 1/3 = 1.25 points
☐ USDA-APHIS adds additional points for:
  ο Likelihood of predator recolonization (i.e., island sites likely would have a lower predator recolonization rate following removal) = 1, 5, or 10 points with sites having higher rates of recolonization receiving lower point values
Logistical constraints = 1, 5, or 10 points with difficult to access sites receiving lower point values

How to use the Matrix

With the matrix, predation management is prioritized based on the calculated relative influence of each site on the overall shorebird breeding population (as described above in 'Matrix Point Assignment'). Thus, sites with a higher breeding populations and greater species diversity/presence of listed species receive higher priority (Table 1). These sites are visited first by USDA at the start of the breeding season to reduce predation pressure prior to nest initiation, but not early enough that recolonization by predators is a concern. For example, the earliest known Snowy Plover nest in Florida is February 14, hence the top priority site begins predation management on February 1.

USDA personnel visit each site initially in matrix priority order (with a few caveats discussed below). After each site has been visited once, after May 4, USDA can either take calls or start over on the matrix. If they take calls, the matrix is again used to prioritize those sites. For example, if four different sites continue to experience predation issues after the initial visit by USDA, the USDA uses the matrix to prioritize which of the four will be first and determine site-visit order for the second round of predation management activities. After they visit those sites, they will continue with the matrix order, so that they continue going to sites, as long as there is funding available to do so.

Considerations and Caveats

Florida uses breeding adults rather than productivity to represent breeding potential in the predation management matrix. This was decided because all sites included in the matrix did not have consistent productivity data. In addition, the matrix is updated annually to include the most recent year's population estimate. For some sites that may not have been covered well in the past, they are allowed to move up in priority because better data are available for the size of the breeding population.

In Florida, many of the sites included in the matrix are managed by the same agency (e.g., state parks). Because of this, they added flexibility by the site manager(s) to the protocol. For example, one site may be listed highest priority by the matrix, but managers may prefer to trap a lower-ranking site based on current nesting and observed predator pressures. USDA will swap those sites on the matrix, but otherwise visit other sites as planned.

Communication between site managers is necessary when deviation from the matrix-assigned order is needed. For example, managers will need to communicate between groups and with USDA when there are no signs of predators or trapping is not needed (e.g., nesting complete for site). In these cases, USDA can skip the site(s) and move to the next site. Additionally, weather or unforeseen circumstances may delay trapping at a site, and in this case, USDA can go to the next site on the matrix and go back to the skipped site as needed.

Despite having a standardized approach for prioritizing predation management at sites, Florida has experienced some issues with the predation management matrix. There are often too few USDA personnel available to cover sites adequately, and therefore sites are not trapped often enough. Although the matrix offers an organized method for prioritizing sites, if the USDA is not successful trapping a site, the site goes back into the rotation and will have to wait ~4 months to be visited a second time. This has become an issue with animals that become 'trap-wise' because USDA are unable to spend enough time at these sites to target these individuals with different methods.

We welcome managers to use the Florida panhandle predator matrix as a starting point that you can tailor to fit your needs. You may have long-term productivity data or data on predator abundance and predation rates that you may consider including in the matrix if you choose to use this method to prioritize predation management activities between sites.

Table 1. Example predation management matrix from Raya Pruner at Florida Fish and Wildlife Commission. Sites were assigned points based on the 5-yr average of breeding adults of each of the five focal nesting species (SNPL, AMOY, WIPL, LETE, and BLSK) at each site. See details provided above in the next on how point values are assigned. In general, points are assigned based on the listing status of the species, the probability of predator recolonization following removal and the logistics of trapping at each site. The sum of these scores is reported as 'Total Score' and reflects the 'Rank #' assigned to each site with higher total scores receiving priority.

Rank #	Site	Trapper	Point ranking of 2011-2015 average # breeding adults of SNPL (ST)	Point ranking of 2011-2015 average # breeding adults of AMOY (SSC)	Point ranking of 2011-2015 average # breeding adults of WIPL (not listed)	Point ranking of 2011-2015 average # breeding adults of LETE (ST)	Point ranking of 2011-2015 average # breeding adults of BLSK (SSC)	Point ranking of immigration of predators back to site (determined by USDA)	Point ranking of logistics of trapping/access to site (determined by USDA)	Total Score
1	A	A	20	40	5	7.5	2.5	5	10	90
2	B	A	40	0	10	7.5	5	1	10	73.5
4	C	A	10	20	2.5	15	10	5	1	63.5
6	D	A	20	10	2.5	7.5	2.5	5	10	57.5
9	E	A	10	10	5	3.75	0	1	10	39.75
10	F	A	5	20	2.5	3.75	0	5	1	37.25
13	G	A	5	5	1.25	3.75	0	10	1	26
3	H	B	20	0	0	15	20	5	10	70
5	I	B	10	0	5	30	10	5	5	65
7	J	B	10	0	0	15	5	1	10	41
8	K	B	20	0	1.25	3.75	0	5	10	40
11	L	B	5	0	1.25	7.5	2.5	5	10	31.25
12	M	B	10	0	0	15	0	1	5	31
14	N	B	5	0	0	7.5	0	1	5	18.5
15	O	B	5	0	0	3.75	0	1	5	14.75

B. PREDATION MANAGEMENT DECISION TREE

This predation management decision tree was anonymously volunteered for use in this document. All references to the aforementioned volunteer have been removed for the sake of discretion.

Decision Tree Model: (example of most definitive case of lethal control use for illustration purposes only)
Note: Native predators can be considered "invasive" in the context of rare beach nesting bird species; control of native predators may be appropriate where human alterations of the landscape are allowing native predator populations to thrive in situations where they would not have been historically.

Predator is affecting a significant percentage of the AFSI-species breeding population at a site.

Predator = native

Predator ID'd late in the season and most eggs/chicks are already lost

Predator = invasive/exotic

No action this year; possible action following season if predator is identified

Predator ID'd early in the season

Multiple individuals acting as predators

This predator species has not been active at the site in past years; try non-lethal in first year

Single individual identified

Non-lethal deterrent methods have not been tried; try in first year

Problems with this predator have occurred in past years

Other methods of non-lethal deterrent have been tried and failed

Implement species-appropriated lethal control after necessary approvals

Predation Management Decision Tree and Triggers

1. Predator determined to have a negative impact on the productivity of AFSI species at one or more sites over the course of an entire field season or longer. Describe the following:
   a. Hatching success, productivity, and total number of pairs over the past 5 years or more at the site and adjacent sites, if applicable.
   b. Current predator suite through evidence of ALL predators present at the site (tracks, sign, visual confirmations, photographs) and adjacent sites, if applicable.
   c. Evidence of predation events on eggs, chicks, or adults that were caused by predator under consideration for management (tracks, sign, feathers, pellets, photographs, etc.).
   d. All non-lethal predation management techniques used at the site over past 5 years, and adjacent sites, if applicable. If these techniques were ineffective, state reasons for lack of effectiveness and why this is unlikely to improve.
   e. Go to Step 2.
2. Is predator State or Federally listed?
   a. Yes-no action will be taken.
   b. No, go to Step 3.
3. Define negative impact (at discretion of managers): For example, what has hatching success been and over how many years? Was productivity low (use your own threshold here, e.g., <1.5 chicks/pair)? Were any dead adults located? Did colonies fail to produce any/or very few fledglings?
   a. Yes, go to Step 4.
   b. No, no action taken.
4. Are the predation rates of other predators such that removal of any predator may increase the rates of predation by other species? Or, would the removal of one predator result in an influx of other animals of the same species such that predation rates may actually increase or predation management effort would have to increase substantially?
   a. Yes, no action taken.
   b. No, go to Step 5.
5. Is there any evidence that predator under consideration may be limiting the populations of other predators in the area? **This should be determined by working with professional wildlife biologists and through relevant literature, as data are not likely to be available from the site itself.
   a. Yes, no action taken.
   b. Unknown, no action taken.
   c. No, go to Step 6.
6. Were past strategies of non-lethal predation management effective at certain times and not others; if so, can these techniques be adjusted to be better maintained and more efficient?
   a. Yes, no action taken (adapt non-lethal methods).
   b. No go to step 7.
7. Are there alternative non-lethal methods that may be available to deter this predator that have not been tried (but may have worked at other similar sites)?
   a. Yes, no action taken (adapt non-lethal methods).
   b. No, go to step 8.
8. Are there lethal removal strategies available to manage this predator?
   a. Yes, go to step 9.
   b. No, no action taken.
9. Have lethal removal methods been shown to be effective at other sites? How were those sites similar in nature to the site targeted for management?
   a. Yes, go to step 10.
   b. No, no action taken.
10. Managers consult and make decision to put forward a request for lethal predation management strategy.
11. Management strategy carried out and evaluated for a single season, including: point counts and/or systematic searches for pellets/sign/tracks for avian predators, infrared cameras used to document predator presence and activity, and transects established for monitoring of all predator tracks. Efficacy of management strategy evaluated: inter-season improvement in hatching success of AFSI species and decrease in losses due to target predator.

Example Predation Management Scenario Using the Decision Tree Model

Populations of Least Terns, Common Terns, and Piping Plovers at a particular site have been experiencing poor productivity levels for four years (2006-2009). What predation management options should be considered for 2010?

1. Predator determined to have a negative impact on the hatching success of Piping Plovers at one site over the course of an entire field season or longer. Describe the following:

Hatching success, productivity and total numbers of pairs of Piping Plover have been decreasing since 2006. In 2005, Piping Plover, Least Tern, and Common Tern productivity at this site peaked at their highest in 20 years of monitoring. However, in 2006, the numbers of pairs and productivity declined, and that trend continued into 2009, with some of the lowest documented hatching success and productivity ever documented on this site. Predators identified at the site through sign, photographs or visual confirmation over the past five years include eastern coyote, Virginia opossum, American Crow, Great Horned Owl, domestic dog, Common Grackle, Red-tailed Hawk, ants (likely associated with Great Horned Owl and nocturnal abandonment) and human vandalism. Definitive evidence of predation by eastern coyote (eggs, chicks) documented in 2006-08, Great Horned Owl (eggs, chicks, adults) during 2006-09, ants (eggs, chicks—associated with Great-horned Owl presence) 2007-09, American Crow (eggs) 2006-09. No confirmation of predation by Virginia opossum, Common Grackle, domestic dog, or Red-tailed Hawk has been confirmed. In 2009, predation by eastern coyote was much reduced; an opossum breached fencing at least once but we did not document any mammalian predation in the Least Tern colony. For prevention of avian predation on Piping Plover only, we used predator exclosures on a limited basis due to the habitat structure; because of the narrowness of the backshore available to plovers to nest and density of vegetation, it is unlikely we will be able to use this technique for more than one to two plover nests. In 2008 and 2009, predation by American Crow was determined to be the leading cause of nest failure (excluding tidal washover) for Piping Plover and Common Tern. Therefore, we would like to consider lethal removal of American Crow.

   a. Go to Step 2.
2. Is predator currently state or federally listed?
   a. No, go to Step 3.
3. Define negative impact: What was hatching success? Over how many years? What was productivity? Were any dead adults located?
   a. Hatching success was 34% in 2009 (n = 32/93 eggs) nest success was 0.32 (9/28 nest attempts hatched). Of the 28 nests that failed, 12 were suspected to be predated by American Crow, 7 to tidal overwash, 9 others lost to unknown causes of predation or suspected other predators). Piping Plover productivity was the lowest it has been in 20 years of monitoring at 0.46 chicks/pair between both sites. Least Tern and Common Tern productivity was estimated to be 0 at both sites. No dead adults located, American Crows not typically expected to predate adults. Go to Step 4.
4. Are the predation rates of other predators such that removal of any predator may increase the rates of predation by other species? Or, would the removal of one predator result in an influx of other animals of the same species such that predation rates may actually increase or predation management effort would have to increase substantially?
   a. We do not have evidence to believe so, go to Step 5
5. Is there any evidence that predator under consideration may be limiting the populations over other predators in the area? **This should be determined by working with professional wildlife biologists and the literature, as data are not likely available from the site itself.
   a. No, go to Step 6
6. Were past strategies of non-lethal predation management effective at certain times for this species and not others; if so, can these techniques be adjusted to be better maintained and more efficient?
   a. Although exclosures can be effective against crow predation in some cases, we are unable to use exclosures in many cases due to the structure of the beach. In addition, there is no technique available to prevent predation on Least Tern and Common Tern nests. Go to step 7.
7. Are alternative non-lethal methods that may be available to deter this predator that have not been tried?
   a. None of which we are aware, go to step 8.

8.   Are there lethal removal strategies available to manage this predator?
     a.   Yes, go to step 9
9.   Have lethal removal methods been shown to be effective at other sites? How were those sites similar in nature to the site targeted for management?
     a.   Yes, crow removal was shown to be strongly correlated with an increase of hatching success at a nearby site in both 2008 and 2009. Go to step 10.
10. anagers consult on lethal predation management strategies, public relations issues and communication plan. The decision to put forward a request for lethal predation management will be based on the outcome of these discussions.

Guidelines for Lethal Management

☐ Whenever possible, lethal management should be directed at individual specialist predators con firmed to have taken listed species at the site where removal is initiated.

     o   For example, individual gulls become accustomed to preying on eggs or chicks of shorebirds (e.g., specialists) and can be identified repeatedly (can use dye on roost sites to mark individuals if necessary).
     o   Certain lethal methods target individual specialists by using attractants (e.g., crows that target exclosures are targeted using open-top exclosures and fake eggs).
     o   Direct observation and cameras (including infrared at night) can be used to confirm predator identification at sites were predation is occurring.

☐   Controls should be timed to reduce predation when coastal species are most vulnerable, but also to remove predators at the time where the least amount of effort and best results can be achieved (e.g., Great Horned Owl prior to their chick rearing season).

☐   Lethal management of any state/federally listed species will not be undertaken.

☐   For denning mammals close to active nesting sites, dens can be filled in before they become active (pre-nesting season) if predation has been determined to occur at those sites (though not always effective).

☐   Methods should be selected that are most humane and have minimal chance of secondary mortality.

☐   All trapping and lethal control will be undertaken only with state and federal permits and in consultation with state and federal wildlife agencies.

☐   All methods of non-lethal and lethal management must be carefully evaluated for efficacy and must be approved annually for all sites where implemented. The evaluation process is detailed below.

☐   For any lethal management option, consider ecological consequences (short- and long-term) of removal and/or release into new environment.

     o   E.g., coyotes – removal of dominant pair can result in replacement by transient coyotes searching for a territory, ultimately leading to both an increase in predation levels because there is no dominant pair in an area limiting small mammal numbers, as well as a never-ending need to remove animals lethally during the breeding season.

☐   Consider the long-term strategy; e.g., intense targeted removal for one year, followed by no or limited removal in subsequent years, mimicking natural cycles if deemed appropriate upon evaluation of efficacy.

Consider the long-term strategy; e.g., intense targeted removal for one year, followed by no or limited removal in subsequent years, mimicking natural cycles if deemed appropriate upon evaluation of efficacy.

C. MAINE DRAFT PIPING PLOVER PROTECTION MANAGEMENT POLICY

Issue: Maine has a relatively small population of piping plovers, which makes them especially vulnerable to increases in human disturbance, habitat loss, and predation. Piping plovers are state endangered and federally threatened. Piping plovers recently underwent a precipitous decline from 66 pairs (2002) to 24 pairs (2008), which was caused primarily by an increase in nest and chick predation by gulls, crows, skunks, fox, coyote, and raccoons. Predation is a major factor limiting piping plover reproductive success at many Atlantic Coast sites. As with other limiting factors, the nature and severity of predation is highly site specific. Federal and state

agencies remove predators where warranted and feasible to recover the piping plover.

Beginning in 2007, the Maine Department of Inland Fisheries and Wildlife (MDIFW), Rachel Carson National Wildlife Refuge (RCNWR), and the U. S. Fish and Wildlife Service (USFWS) contracted with U.S. Department of Agriculture APHIS Wildlife Services (USDA WS), to conduct a predation management program at Maine piping plover nesting beaches to reverse this downward trend. Annual implementation of the predation management program coupled with increased efforts in monitoring, outreach, and law enforcement have increased number of nesting pairs from 24 pairs recorded in 2008 to 64 pairs in 2017. Productivity rates have increased from 1.06 fledglings per nesting pair in 2007 to a high of 1.95 fledglings per nesting pair in 2015.

Prior to the piping plover decline, predator removal was used sparingly on a case-by-case basis to resolve problems with individual animals. MDIFW and USFWS ability to address predation was largely dictated by funding that limited the amount of effort, location, and duration of predation management activities. Predation management activities are often controversial and cannot be implemented without landowner permission. Increasing plover populations, public scrutiny of predator removal methods, and limited funding available for predation management efforts prompted MDIFW and USFWS to develop this predation management policy to guide decisions on the extent to which future predation management is warranted.

The following policy addresses criteria for piping plovers, additionally, predation management at some sites may also benefit the state endangered Least Tern.
In 2001, the MDIFW used a public working group to establish goals and objectives for piping plovers:

State Goal: Increase the abundance of piping plovers and the number and quality of nesting sites in Maine.

State Population Objective: Increase the number of nesting pairs of Piping Plover to at least 80 distributed at all available breeding sites in at least 3 of the prior 5 years by 2015.

State Productivity Objective: Increase the statewide average annual productivity of piping plovers to 2.0 fledged chicks per nesting female in at least 3 of the prior 5 years through 2015.
In 2017, Piping Plover managers from MDIFW, USFWS, RCNWR, USDA WS and Maine Audubon reviewed the objectives developed in 2001. Partners agreed MDIFW needs to move forward with the state planning process that will provide an approach that reflects current habitat capacity, social concerns, and available resources. Through this process new objectives will be developed that are realistic and achievable.
In the interim, partners agreed that a range of 50-70 nesting pairs and state productivity of 1.6 fledglings per pair is reasonable and sustainable.

Decision Criteria for Piping Plover Predation Management: The following criteria will be used to guide decisions concerning predation management activities for nonlethal and lethal predator removal. Use of stake and twine to identify nesting areas is an effective means of preventing disturbance by humans and their pets. Nest exclosures are effective means of discouraging predation of plover eggs and incubating adults. These recovery plan methods are routinely used throughout eastern Canada and U. S. beaches, all Maine plover beaches, and will continue to be implemented with landowner permission for all nesting pairs. These methods are therefore outside the criteria identified in this policy.

It should be noted that exclosures sometimes attract "smart predators" that key in on them and depredate eggs and or exploit the exclosures to kill adults. If a predator is keying in on exclosures, we may be unable to use them until that predator is removed.

Intensive predation management is defined as predation management activities conducted using all available methods (lethal and non-lethal) for the entire nesting season.

Threshold for intensive predation management: When the statewide nesting population is approaching <50 pairs, state productivity is <1.6 fledglings per pair, and predation is a primary cause of population decline or reduced productivity, intensive predation management may occur on one or more nesting beaches.

Site Criteria for implementation of intensive predator management when predation is identified as a limiting factor:
- Sites with productivity < than 1.6 chicks fledged/pair for at least 2 of the most recent 3 years; or
- Sites where immediate removal is required due to adults being depredated, there is a sudden sharp increase in predator numbers, or a "smart predator" is depredating the site; or
- Sites that have had 4 or more nesting pairs documented at least once since 1981; or
- Sites that have functional habitat that can support 4 or more pairs.

Limited predation management is defined as predation management activities conducted only on a case-by-case basis primarily using non-lethal methods.

Threshold for limited predation management: When the statewide nesting population is > to 60 pairs *and* annual productivity is > than 1.6 chicks fledged/pair for at least 2 of the most recent 3 years.

Predator Removal Methods
Predator management will occur only with landowner permission.
Implementation of predator removal will occur only when preventative, avoidance/deterrents, and public education efforts have proven insufficiently ineffective. Public outreach and volunteer beach monitors can be effective in deterring (consistent human presence near the nesting areas) and identifying predation events. Tactics that deter or repel predators include effigies, lasers, and predator-resistant fences.
Non-lethal techniques for predator removal: Nonlethal techniques will be the preferred choice for removal of nontarget predators affecting nesting piping plovers. Live/decoy traps, cage or box traps, raptor traps and net traps may be implemented under certain scenarios.
Lethal predator removal will be conducted in the following circumstances:
- Coyote, fox, raccoon, and skunks are rabies vectors; therefore, since translocation of such species pose an imminent public health or safety threat, these species will be euthanized.
- Other target species include mink, short-tailed weasel, long-tailed weasel, opossum, and chipmunks; mink in particular are extremely voracious and efficient predators; a single individual can easily consume an entire clutch of plover eggs or chicks in a single night. Fencing least tern colonies does not prevent predation by mustelids.
- Gulls, crows, and ravens are highly intelligent birds, and predator deterrents are only effective when combined with lethal removal reinforcement. Therefore, crows observed nesting in close proximity to plover or tern nesting areas or individuals observed preying on plovers or terns will be removed using lethal methods. Methods employed will be determined during consultation between MDIFW and Landowner/Manager.
- Other species (including those that are typically non-targets) have the potential to prey upon least terns and piping plovers. Lethal removal of these predators will only occur on a case by case bases, following consultation between MDIFW and Landowner/Manager

Predation Management Evaluation
USFWS, MDIFW, RCNWR, Maine Audubon, and USDA WS will meet annually to determine the effectiveness of predation management activities. The following actions will be taken annually prior to continuing predator removal:
1. Review of detailed records of predator removal.
2. Assess plover productivity after predator removal.
3. Identify problems or conflicts with the public and adjust management activities to minimize or eliminate conflicts.
4. Determine whether to continue predation management on plover nesting beaches in Maine.

Public Input
The MDIFW, USFWS, and USDA WS are interested in hearing public concerns and input concerning predation management and other management activities used to help recover Maine's piping plover population. The public is encouraged to contact MDIFW, USFWS, and USDA WS with their concerns. Biologists from state or federal agencies are available to meet with beach landowners and beach associations to explain the need for

predation management and discuss concerns and issues the public may have regarding such efforts.
MDIFW, Research and Assessment Section, Lindsay Tudor, phone # 207 941-4479.
USFWS, Maine Field Office, Mark McCollough, phone # 207 866-3344 x115.
USDA Wildlife Services, Adam Vashon, phone # 207 629-5181.

See flow chart below for decision guidelines for implementation of predation management for piping plovers.

MDIFW implements Predator Deterrence Measures	State abundance and productivity below threshold and site meets criteria for implementaion of intensive Predator managment

Management Actions
1. Consult between Landowner/Manager, MDIFW Wildlife Biologist and MDIFW contractor.
2. Nest exclosures erected around nests by MDIFW contractor.
3. Erect stake and twine fencing with signage.

Consult between Landowner/Manager, MDIFW wildlife biologist and MDIFW contractor to discuss predator monitoring, predator management options, duration and timing of efforts. Landowner/Manager will receive notification of predator surveys or predator management activites in written (email) form before implementation.

Implement Predator Removal

MAMMALIAN

AVIAN

free ranging dog, feral/free ranging cat

non-target species: Woodchuck, Squirrels, Porcupine, Fisher, Otter

target species: Fox, Coyote, Skunk, Weasel Mink, Raccoon, Opossum, Chipmunk

Hawks, Falcons, Owls

Crows, Ravens

Gulls

Management Actions

1. Contact Landowner/ Manager and MDIFW wildlife biologist immediately.

2. Return captured dogs/cats to owner if identified or transport to the local animal care facility

Management Actions

1. Implement use of non-lethal traps to capture and release nontargets.

2. If a non-target species is causing predation, consult between Parks Regional Manager, park manager, MDIFW wildlife biologist, MDIFW contractor regarding implementation of lethal control methods.

Management Actions

1. Implementation of lethal removal according to MDIFW policy on rabies vectors and MDIFW recommendations regarding target predators.

Management Actions

1. Implement deterrent methods and/or non-lethal traps to capture and relocate individuals.

2. Discuss with MDIFW if predator should be euthanized. This action requires a depredation permit from USFWS.

Management Actions

1. If feasible, implement crow live trap.

2. If predator cannot be trapped, implement lethal removal in conjunction with non-lethal deterents such as effigies around nesting areas.

Management Actions

1. Discuss with MDIFW if predator should be euthanized. This action requires a depredation permit from USFWS.

2. Implement lethal removal in conjunction with non-lethal deterents such as effigies around nesting areas.

Public notification using signage regarding predator control efforts.

Implement project evaluation.

D. Summary and lessons learned from the Maine-Massachusetts structured decision making workshop on predation management

Structured Decision Making for Predator Removal to Benefit Piping Plovers and Other Beach Nesting Birds

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TABLE OF CONTENTS

Abstract

Decisions regarding endangered species recovery often face sparse data and multiple sources of uncertainty about the effects of management. Structured decision making (SDM) provides a systematic process for organizing information about management actions in the face of uncertainty, focusing on the value of different actions for one or more biological, economic, and social/political. Selective predator removal has been employed as a management action to increase productivity of Atlantic coast Piping Plover (*Charadrius melodus*) and Least Tern (*Sternula antillarum*). However, given the resources being devoted to selective predator removal, there is a continuing need for both a quantitative approach to assuring the efficacy of predator removal and a decision-making process for when to initiate (or discontinue) a predator removal program. We held a 4.5-day SDM workshop including two states, Maine and Massachusetts, at Parker River National Wildlife Refuge in Newburyport, MA from October 2-6, 2017 to rapidly prototype predator removal decisions for beach nesting shorebirds. We developed a framework for using expert opinion to guide wildlife managers through the decision-making process. We recommend further evaluation of the hypothesis that management to benefit a data-rich focal species will also benefit data-poor sympatric species.

Introduction

Lethal predator removal to benefit species of conservation concern is a common yet controversial management action (Smith et al. 2010). The decision to remove one species from an ecosystem to benefit another represents a tradeoff among different ways that wildlife species and their habitat are valued. The role of science is to ensure that decision makers have the best available information on the consequences of alternative actions for biological populations and the key uncertainties. Structured decision making (SDM) provides an approach for a careful, organized, and transparent analysis of natural resource management decisions, including predator removal, by breaking decisions into component parts and separating the values of stakeholders from the scientific evaluation of management actions and uncertainty (Ralls and Starfield 1995, Gregory and Keeney 2002, Martin et al. 2009).

The SDM process includes five steps (**PrOACT**): 1) define the **Pr**oblem, 2) identify **O**bjectives, 3) develop **A**lternatives, 4) predict **C**onsequences, and 5) evaluate **T**rades-offs (Hammond et al. 1999, Gregory and Long 2009). Once the SDM process is triggered (i.e. it has been identified that a decision needs to be made), the first step, defining the **problem** (bold terms, see glossary for further details), includes characterizing the right problem because it drives everything else in the decision making process (Gregory and Long 2009). Framing the problem includes identifying the decision makers responsible, classifying the scope and scale of the problem, and understanding what other decisions may be linked to the current decision. Once the problem is adequately defined, a foundation for identifying measurable objectives and creating a wide range of alternatives to consider is established (Gregory and Long 2009). In the case of predator removal, the decisions may include whether to implement lethal predator management, where to implement it, which predator species to target, and what methods to use.

Once the problem has been defined, fundamental **objectives** are identified, representing the broadest objectives the decision-makers want to achieve through the decision-making process (Gregory and Keeney 2002). For predator management, fundamental objectives may include population parameter targets, such as growth rate, reproductive output, distribution or abundance for the focal management beneficiary species. Objectives can be organized hierarchically to clarify what is important to decision makers and form the foundation for identifying and evaluating alternatives. Each objective is characterized by a **measurable attribute** that can be used to estimate the success of different management alternatives with respect to the objectives (Keeney and Gregory 2005). The objectives should encompass explicit statements that allow focused discussions and evaluation of the problem. The objectives and alternatives create the foundation for developing quantitative models to help guide the decision-making process (Gregory and Keeney 2002).

Alternatives represent the range of potential options for satisfying the identified objectives (Gregory and Keeney 2002). The process of identifying alternatives uses the fundamental objectives to help to generate possible alternative actions by challenging constraints and developing creative alternatives without considering their feasibility. **Constraints** restrict the range of possible alternatives and often reflect policy or practical

considerations that bound the range of possibilities, but it can also be useful to assume that a constraint does not exist and then create alternatives that reflect its absence to broaden the range of possible alternatives (Gregory and Keeney 2002). In the case of predator management, a regional decision may be one of resource allocation to a range of potential sites, with a potential goal of increasing the total value of the removal program while remaining within the constraints of the program's budget. This resource allocation process is known as a "**0/1 knapsack problem**", in which different sites represent items (in this case, sites) that can be placed into a knapsack (in this case, a regional predator control program) and the total size of the knapsack is determined by the budget (Hajkowicz et al. 2007). The optimal decision is one that selects a combination of sites that maximizes the value of the program (defined by the fundamental objectives) given the budgetary constraint.

Identifying the **consequences** of a decision is a forward-looking process that attempts to predict what the future will look like after taking action. Apart from the intended direct benefits of predator removal for the management beneficiary species, unintended consequences may be ecological, such as mesopredator release (Courchamp et al. 1999) or social, such as stakeholder resistance (Messmer et al. 1999). Unintended consequences can be included in the objectives-setting step of the process as outcomes to avoid. Influence diagrams, consequence tables, and quantitative models can all be used to link alternative actions to objective outcomes (Gregory et al. 2012). An influence diagram can be used to visually demonstrate the decision problem representing the decisions, objectives, and uncertainties as nodes and the direction and magnitude of influence as arrows. In wildlife conservation problems, influence diagrams are commonly used to depict relationships among population parameters and the ecological factors that affect them, including anthropogenic influences (Marcot 2006). Such diagrams may be useful in making hypotheses about the consequences of predator removal explicit. A consequence table can help to summarize the performance of each alternative on each objective (Ewen et al. 2015) and represents a straightforward way to enumerate biological objectives, such as population size, and social objectives, such as cost and stakeholder attitudes. Once consequences are laid out in the form of hypotheses, quantitative models can be used to reduce uncertainty in the decision among each of the alternatives evaluated (Marcot 2006). For many endangered species, empirical, precise data are often lacking for population parameters and habitat relationships, yet decisions must proceed. In these cases, expert opinion can be used as initial estimates until more knowledge is gained (Martin et al. 2005).

Because objectives often conflict with one another (i.e., management benefit and cost), evaluating **tradeoffs** is an important part of the SDM process and guides the decisions of which objectives to sacrifice in order to gain something from another objective. Dealing with tradeoffs is therefore a challenging task, requiring knowledge of the impacts of a selected alternative over the relevant period of time (Gregory and Keeney 2002). It is often useful to first eliminate alternatives that are clearly less. By reducing the number of alternatives, tradeoffs may become more evident (Gregory and Keeney 2002). If difficult trade-offs remain, optimization procedures can be used to select the best alternative using the difference in preferences among objectives (Larson et al. 2003). Ultimately, the goal of the SDM process is to improve the quality of our decisions and provide decision processes that are transparent and replicable. Specifically, using the PrOACT decision making model can provide a framework for guiding important decisions. By defining the problem, identifying objectives, forming alternatives and addressing tradeoffs, wildlife managers can work towards making smarter and more transparent choices (Gregory and Keeney 2002). Given the potential for strong public backlash when lethally controlling one wildlife species to benefit another, defensible and transparent decision-making process for predator removal is crucial for the long-term success and support of predator management programs.
We held a 4.5-day structured decision-making (SDM) workshop at Parker River National Wildlife Refuge in Newburyport, MA from October 2-6, 2017 to **rapidly prototype** predator removal decisions for plovers and terns in Maine and Massachusetts. Selective predator removal has been implemented throughout the last 15-20 years across a variety of management agencies along the Atlantic Coast to increase productivity of the federally threatened Atlantic coast Piping Plover (*Charadrius melodus*) and state-listed Least Tern (*Sternula antillarum;* ME endangered, MA special concern). Comparisons of productivity of Piping Plovers between sites with and without predator removal show promise for the effectiveness of this conservation strategy (Vashon et al. 2012). Given the large number of resources being devoted to selective predator removal, there is a

continuing need for assuring the efficacy of predator removal as well as a transparent decision-making process for when to initiate (or discontinue) a predator removal program.

An SDM Case Study: Piping Plovers and Least Terns
Defining the Problem

Two states were involved in the rapid prototyping process, and each state had their own triggers for initiating the decision-making process and their own objectives for predator removal decisions. The **trigger** to examine predator removal decisions in the state of Maine was a desire to strengthen the predator removal policy, growing concerns over optimizing benefits to nesting plovers and terns, and the continuing need for public outreach regarding the justification of predator removal efforts. Selective predator removal was conducted at a subset of Piping Plover nesting sites from 2007-2016 and has been identified as a major factor in the recovery of the population from a steep decline that followed several years of low productivity (24 pairs in 2008; 66 pairs in 2016; (USFWS 2017). Abundance of Least Terns has remained stable in recent years; however, the population is restricted to nesting at between 3 to 6 sites throughout the entire state. In 2013, Maine partners drafted a policy that outlines criteria to guide decisions concerning predator removal. Historically, funding and landowner permission have driven many predator removal decisions; however, partners are concerned that these sites may not be the most optimal sites for maximizing conservation outcomes for the two focal species.

The **trigger** to examine predator removal decisions in Massachusetts was a desire to ensure actions do, in fact, benefit the productivity of Piping Plovers. A statewide Habitat Conservation Plan (HCP), which is being implemented under a 26-year permit issued to the Massachusetts Division of Fisheries and Wildlife (MassWildlife) by the U.S. Fish and Wildlife Service (USFWS), requires predator removal to offset take due to authorized recreational beach use. One of the broad program goals for the HCP is to maintain a viable and robust Piping Plover population (i.e., able to persist near current population size for the long term). MassWildlife has considerable discretion regarding selection of sites where the predator removal is conducted and (as a permit requirement) must also develop methods for monitoring and demonstrating the efficacy of the predator removal. Therefore, the trigger to re-examine predator removal decisions in Massachusetts included a need to measure efficacy per requirements set forth by the HCP. While abundance and distribution of Least Terns has remained stable in Massachusetts, predator removal decisions for plovers that also benefitted terns were considered desirable.

The **primary decision makers** with respect to selecting sites for predator removal are a coalition of conservation partners in each state (Maine: Maine Audubon, Maine Department of Inland Fisheries and Wildlife, and Rachel Carson National Wildlife Refuge; Massachusetts: Mass Wildlife, Mass Audubon, Trustees of Reservations, USFWS, and many other organizations not represented at the workshop). USDA APHIS Wildlife Services (WS) carry out selective predator removal in both states and make recommendations for how to conduct predator removal (trap locations, trap types, duration of trapping, etc.) at each site. There are many stakeholders beyond the listed decision makers and organizations that are affected by and that can affect predator removal decisions. For example, negative opinions of predator removal by landowners and the public can constrain the implementation of predator removal at a given site.

In both states, the decision involves the allocation of resources (staff time and money) toward selective predator removal at a subset of sites on an annual basis. For the purposes of this workshop, we assumed that the amount of money dedicated to predator removal was fixed every year. For managers in Maine and Massachusetts, two scales of decision-making problems were identified: local (within sites) and regional (among sites).

Local Scale (within sites)

Local decisions included when (what month in a particular year) and how (which predators to target) to conduct predator removal. These decisions are most frequently a rapid response to predators observed near or within nesting areas, and/or observations of predators actively depredating nests. To effectively implement rapid responses, a selective predator removal plan and agreements must be in place prior to the response initiation at a site. Both Massachusetts and Maine engage in rapid response; however, agencies prefer proactive decisions focused on implementing predator removal prior to the start of the nesting season to reduce the likelihood of predators depredating nests. Because the capacity to do rapid response is conditional on having a proactive strategy that identifies all potential sites that predator removal could occur, for this workshop, we focused on the regional scale decision (among sites).

Regional Scale (among sites)

Regional decisions included where (which sites) and when (between years) predator removal should begin or be terminated. Regional predator removal decisions are made October through December for implementation in the upcoming field season and are, in part, based on information and observations from previous years, including productivity (chicks fledged/pair), numbers of nesting pairs, nesting distribution and predator activity (tracks, nest predation events, chick loss, or adult mortality).

Objectives

Several shared and unique objectives and constraints were identified for Maine and Massachusetts (Table 1). Shared objectives included maximizing population growth of Piping Plovers, maximizing the number of sites benefitting from Piping Plover productivity gains at predator removal sites, maximizing the learning opportunity to evaluate the effectiveness of predator removal, and minimizing the cost (per year) of predator removal programs. Piping Plover population growth was represented by a proxy measure of the number of fledglings gained by implementing predator control. The number of other sites benefiting from productivity gains at predator removal sites was represented by a constructed measure of "opportunity" to benefit from fledgling dispersal. A metric for learning was not quantified in the prototype but may be represented by the power to detect an effect of predator control, and cost was represented by the true cost of predator control implementation in dollars.

For both states, benefits of predator control to Least Tern population growth, abundance, and productivity were also fundamental objectives. For this prototype, both states selected proxy measures for this metric. Maine selected the number of sites with Least Tern pairs benefiting from predator removal, as the species has a very limited distribution in the state. Massachusetts selected the number of Least Tern pairs potentially benefitting from predator removal, as the species is not in as precarious a situation in Massachusetts as compared to Maine, and so is less of a direct conservation focus.

A constraint shared between both states included the hesitancy to conduct predator removal at sites with low public acceptability or support for predator removal. Although state agencies could implement actions aimed at lifting this constraint over time (maximizing public support), we assumed these constraints could not be lifted for the purposes of this prototype (i.e., cannot implement predator removal at sites with low public support). Actions related to increasing support could be added in a subsequent prototype to ensure all sites are considered for predator removal.

The key constraint for Massachusetts was the requirement of the Massachusetts HCP which states that for each pair of plovers affected by a take, a site or sites with at least 2.5 pairs of breeding Piping Plovers must benefit (i.e., increased productivity) from predator removal. In addition, sites where predator removal is implemented by MassWildlife shall be selected based on the following criteria to ensure that the mitigation will offset the anticipated take (Table 4-3 in the HCP; MADFW and ICF International 2016):
- high predation rates resulting in low productivity (<1 fledgling/pair);
- landowners willing to implement predator management;
- relatively high abundance densities (i.e., >5 plover pairs); and
- identifiable predators that are feasible to manage ("implementable").

These requirements restrict the set of sites that can be selected in any given year, and we assume this information will be available from previous years when making the decision to implement predator removal for some set of possible sites. The requirement of 2.5 pairs benefited per pair exposed to take sets a floor on the amount of effort that must be expended.

Alternatives

A large number of possible alternatives are available to decision makers. At each site, managers coordinate with WS to identify which species to target (e.g. crows, mammals, raptors) as well as the methods (e.g. shooting, box trap, toxicants) and intensity (e.g. number of traps, toxicant baits). The types of human activity at and around a site constrain the methods that can be used.

As a simplification, we assumed WS always implements the best possible predator removal strategy for a site and that the total cost was a fixed constraint. Each decision-maker begins with a comprehensive list of sites where it is possible to carry out predator removal (e.g. permission of landowner, public exposure, meets HCP requirements, etc.). Each site has some level of required effort determined by the best possible predator removal actions planned by WS. Each site can either be managed or not, subject to the constraint of available resources across all sites. This is an example of the 0/1 knapsack problem, where each site is an object that takes up a particular amount of space (the cost of management) in the knapsack (total budget) and has a weight related to its value (benefit to the birds/public support). The goal is to manage at a set of sites ('objects') that has the greatest value possible ('weight') within the constraint of the budget ('amount of space in the knapsack'). While participants of the workshop had prior reason for believing that management outcomes at some sets of sites were interrelated, for the purposes of this prototype a predator removal plan for a site was treated as an independent decision that was not affected by predator management conducted at other sites other than by consuming part of the total budget available.

For this prototype, we assumed that the predator control decisions happen just once per year, but that the effort is sustained throughout the season, which is consistent with current practices. Previous experience with short term management efforts in Maine was considered less effective than sustained management effort through the season according to workshop participants. Nonetheless, if resources can be shifted in response to local conditions then the decision problem becomes more complex computationally. For example, a site could be selected for predator control at the beginning of the season based on data from previous years; however, as the nesting season progresses it could become apparent that a site with many pairs last year has few pairs this year, and a different site now has more pairs and higher risk of predation than expected. In this case, it is possible to solve the knapsack problem repeatedly (i.e., once per week) as new information becomes available, such as number of pairs nesting, the number of predators at a site, the expectation that predator removal will provide a boost, etc. If weekly decisions are desirable, a state-based decision-model that defines what "state" the sites must be in to trigger predator control and take resources away from other sites should be considered.

Consequences

Empirical Data Analysis

To evaluate which collection of sites should be selected each year, we estimated the consequences of including each site in the collection in terms of our objectives. Participants from each state independently developed an influence diagram representing hypotheses about how predator removal affects the distribution and population growth rates of Piping Plovers and Least Terns. A combined influence diagram across states included other actions that typically occur at sites such as nest exclosures and education and outreach (Fig 1). Participants agreed that the primary mechanisms by which predator removal influences population growth and distribution of Piping Plovers is through chick and adult survival, which are affected by predation (e.g. number of predators, predator community, and predator behavior; Fig 1). Participants agreed that the primary mechanisms by which predator removal influences population growth and distribution of Least Terns is through chick survival, adult survival and habitat quality, which are affected by predation (e.g. number of predators, predator community, and predator behavior; Fig 1). Participants also agreed that the primary scientific uncertainty was the effectiveness of predator removal for improving nest and chick survival, and hence the population growth rates of both species. We had access to Piping Plover site-level nest and brood data from Maine which allowed us to estimate nest and chick survival. Such data were not yet compiled for

Massachusetts. Thus, we proceeded with a modeling effort aimed at evaluating the effect of predator removal on annual productivity, daily nest survival, and daily chick survival with Piping Plover data from Maine only. Data for Least Terns in Maine and Massachusetts were not available at the time of the workshop.

We encountered a challenge with rigorously testing the effect of predator control that stemmed from the historical data because of how sites were selected as part of the predator management programs in both states. Predator removal programs had not pre-identified controls or reference sites, and predator removal was not applied according to a randomized design. Predator removal was applied based on results showing that productivity was low at a particular site relative to other sites or predation rates were increasing at a site relative to previous years. Predator removal programs were stopped at some sites for a variety of reasons, which might have included the need to shift focus to a higher priority site, lack of funding to continue at a site, decreased landowner support at a site, or increased productivity at a site (perception that the program was effective). Therefore, monitoring data for Maine contained virtually no instances where we could compare site-specific productivity before and after predator control with a reference site (with low starting productivity or otherwise) during the same time period. We were thus limited in our ability to separate the effects of predator control from natural temporal variation in nest and chick survival.

We compared Piping Plover nest and chick survival among sites with and without predator control in Maine from 2007-2016 (Fig. 2). We began by looking at raw productivity in Maine, similar to (Vashon et al. 2012) but correcting our estimates for the variance on productivity for the fact that we had repeated measurements from individual sites. We used a simple linear mixed effects model using the lmer function in program R v. 3.2.2 (R Core Team 2017) via the package lme4 that included fixed effects of predator removal (binary, 1 = removal, 0 = no removal), year (categorical), and an interaction between year and removal. Treating repeated observations of sites as independent ignores within-site features that affect productivity independent of the effects of predator removal, therefore we also incorporated a random effect of site. The response variable was a weighted average productivity for each site in a given year, with no indication of variance. We weighted the average by the number of pairs observed to give higher weight to averages of productivity calculated from a larger number of pairs. On average, sites with predator removal produced more fledglings than sites without (Table 2). However, there was a high variability among years (Fig. 3) and among sites (Table 2, $\tau 00$, BEACH). Such high variability and low numbers of pairs at each site makes it difficult to detect statistical differences between treatments. Many potential sources of variability were not controlled for in this analysis that may have contributed to the wide error bars and should be explored in future analyses.

The primary conclusion from the comparison of productivity at sites with and without predator removal programs is that, on average, sites with predator removal produce 0.5 fledglings more per pair than sites without predator removal. However, at a particular site in a particular year the expected gain is extremely uncertain. Moreover, predator removal was not applied according to a randomized design and the data were not collected in a way that permits a comparison of change over time in productivity between sites with and without predator removal, which would represent a true test of the method's effectiveness and could be implemented in the future to study effectiveness. For example, if two sites started with the same productivity, ideally in close spatial proximity so that non-predator related factors that limit productivity would affect both equally, and then predator removal were implemented at one of the two sites, we would predict productivity to increase at the treated site, but not the control. A power analysis using existing data can help to determine the design of such an approach.

One source of uncertainty inherent in comparing raw productivity estimates are the unknown biases that occur in the components that contribute to true productivity (i.e., nest survival, renest rate, chick survival). Raw nest survival is often biased high because some nests are destroyed by predators or weather and tides before they are found by monitors, and the magnitude of the bias is expected to increase with decreasing nest survival rates and decreasing monitoring intervals (Mayfield 1961). As a result, raw estimates of renesting rate are often biased low, and pair numbers are potentially underestimated (biased low). The bias in nest survival can be corrected by analyzing survival probabilities between nest check intervals, thereby estimating daily survival rates which should be applicable to nests that were never found (Shaffer and Burger 2004). The model requires data on the fate of each known nest (1 = active, 0 = lost) at regular intervals. Raw chick survival may be biased

low because plover chicks are free-ranging and may not always be detected by monitors; thus, some chicks that survive to fledge may be overlooked (Lukacs et al. 2004). Thus, fledgling counts are often also biased low. Bias in chick survival can be corrected using a binomial mixture model that estimates survival and detection probability of chicks simultaneously (Lukacs et al. 2004). The model requires data on the number of observed chicks in each brood collected at regular intervals.

Participants agreed that the primary scientific uncertainty that would impact the predator removal decision was the effectiveness of predator removal at improving productivity. Therefore, we analyzed the effect of predator removal on two components, nest survival and chick survival, using daily Piping Plover monitoring data from 2013 – 2017 in Maine to correct for biases in raw estimates. We also obtained annual information on predator removal (1 = used, 0 = not used) for each site, and nest exclosure data for each nest for each monitoring interval. For nest and chick survival, we developed a Bayesian mixed effects model that included a random site effect with posterior distributions for parameters of interest estimated using Markov Chain Monte Carlo (MCMC) simulation with Gibbs sampling as implemented in JAGS v. 3.4.0 (Plummer 2013) in program R v. 3.2.2 (R Core Team 2017) via the package jagsUI (Kellner 2017). We used non-informative priors for all parameters: a normal distribution with mean 0 and variance 1000 for all regression coefficients, and a uniform distribution between 0-50 for all variance parameters. We checked for convergence of 3 parallel MCMC chains per model by visually inspecting the trace plots and by using the Gelman-Rubin diagnostic ($\hat{R}$; (Gelman et al. 1996) and considered convergence to be achieved at $\hat{R} < 1.05$ for all parameters. We considered covariates (1 = predator removal used, 0 = not used) to be important predictors if the 95% credible intervals on the regression parameter did not overlap zero (Kuo and Mallick 1998, Link and Barker 2006).

Although we were able to generate unbiased nest and chick survival estimates for Piping Plovers for Maine from 2013-2017, the evidence for an effect of predator removal was inconclusive based on visual inspection of the 95% credible intervals, which overlapped by >25% (Cumming and Finch 2005). For the period where data were available from many sites and predator removal was performed in a relatively consistent manner by APHIS, some sites with predator removal had higher nest survival than those without, but that was not uniformly the case and we could not conduct before-after comparisons (Fig 4). The same pattern held for estimates of chick survival. Some sites where predator removal was not used had an increase in chick survival from 2013-2017, but others where it was used saw a decrease after it was implemented (Fig. 5).

Expert Opinion Analysis

During the workshop, it became clear that we could not estimate the effect of predator removal on productivity components (nest and chick survival) using our modeling approaches outlined above. Additionally, we did not have the ability to measure the effectiveness of predator removal for Least Terns in either state. Thus, we conducted a 4-point **expert elicitation** (Speirs-Bridge et al. 2010) to predict the consequences of implementing predator removal at a range of sites in Maine and Massachusetts. For Maine, the elicited objectives included stakeholder support (2 = decline, 3 = no change), opportunities for site colonization or population augmentation by Piping Plovers (constructed scale between 0 to 1), the number of Piping Plover fledglings gained (natural scale), number of sites with Least Tern pairs potentially benefiting from predator removal (natural scale), and cost (average $K per year; Table 3). In Massachusetts, the elicited objectives included stakeholder conflict (constructed scale from 1 to 5), the number of opportunities for colonization or dispersal by Piping Plovers (constructed scale from 0 to 3), the number of Piping Plover fledglings gained (natural scale), the number of Least Tern pairs potentially benefiting from predator removal (natural scale), and cost (constructed scale from 0 to 4; Table 4).

The alternatives included predator removal at different combinations of up 3 sites in Maine and 7 sites in Massachusetts, and no predator removal at any site (no action). Because many site combinations would involve more than one site manager, the decision to conduct predator control under many of the decisions would require agreements with managers across each state. The procedure involved each expert predicting outcomes for each objective. Specifically, experts consulted past data and used their collective best judgement to predict a realistic number of fledglings per pair at each site with and without predator removal, as well as the lowest and highest realistic numbers and their confidence in their estimates (i.e., 50-100%). We then

calculated the standard deviation and converted all estimated to 80% confidence intervals and used these predicted consequences to help determine the importance of each objective.

Trade Offs

A final step in the decision-making process is to clarify the relative importance of each objective, as objectives are rarely equally important in every context. We approached this step in the process by eliciting preferences from each expert for each objective. Cost was treated as a constraint, allowing decision-makers to consider and compare combinations of selected sites under a range of potential budget scenarios. Once experts determined the relative importance of each objective, we combined preferences with the predicted consequences to calculate an "**expected utility**" (i.e., total benefit) of each alternative (i.e., combination of sites). Then, we searched for the best combination of sites that returned the highest expected utility (or outcomes across all objectives while staying within a given budget).

We used swing weighting (Árvai et al. 2014)research and practice in international development has focused on improving the quality of life of people living in developing regions of the world. Recently, researchers, practitioners, and policy makers have recognized the need to blend insights from experts and community stakeholders in development decisions. Research in the decision sciences tells us that these kinds of multiparty and multiattribute decisions are extremely challenging. However, recent experience using structured decision-making (SDM to determine the relative importance of each objective to each decision maker within each state (Maine = 5, Massachusetts = 7). Each decision maker was presented with a hypothetical "worst case" scenario in which all objectives were at their least desired value. Each independently ranked the objectives in the order in which they would swing the worst value to the best possible value (rank 1 = most preferred), given that all other objectives remained at their worst value. Second, each independently assigned a score (1 to 100) to each objective that indicates how important the swing from worst to best was compared to the relative swing in all other objectives (score 100 = most preferred; 50 score = half as important as the most preferred). The weight for each objective was calculated by dividing each objective's score by the total sum of all scores across all objectives for each participant and represented the preferences for each participant (Table 5).

We calculated expected utility (EU) of each site if it were selected for predator removal, which represents the overall value gained across all objectives (i) as $EU^{alt} = \sum (w_i^{alt} \times outcome_i^{alt})$ for each decision maker. We used a simple greedy algorithm to first select the site with the highest EU, then select the site with the next highest EU, and so on until the budget was depleted, resulting in a rank order of preferred sites based on the cumulative expected utility as sites are added (Fig. 6). There was variability in cumulative utility among the participants. For example, two Massachusetts decision makers would have greater expected utility by selecting site C before site A as the first site and one decision maker would have greater expected utility by selecting sites A and B before adding site C (Fig. 6). For some individual objectives, such as the number of Piping Plover fledglings gained in Maine and the number of PIPL sites benefitting from predator removal in Massachusetts, the cumulative utility did not plateau with the maximum number of sites considered (Fig. 7). However, the latter objective bears refinement as the decision-making process continues because the number of sites benefitting from predator removal must eventually plateau (i.e. there are only so many potential sites to choose from).

A component that is ignored in our prototype is the fact that each site may have a different potential set of predator control options (i.e. combination of target predators, trapping vs. shooting). These options may not be fully known at the time a site is being considered for a predator removal program but are developed after a more detailed investigation of the site has been conducted. For this prototype, we assumed that the details of the predator control options at each site (e.g. number and types of traps, number of trap nights, target predators) would fit the needs of each site, but we could explore different combinations of site-specific alternatives in subsequent prototypes.

Discussion

Applying Results of the Prototyping Process

Structured decision-making can help managers reach a decision consistent with stated goals, while acknowledging uncertainty and tradeoffs in a transparent manner. At the end of the workshop, participants

expressed that stating the problem, objectives, alternatives, and tradeoffs explicitly was valuable and brought clarity to the decision-making process. Throughout this workshop, decision-makers were central to the SDM process, and policy constraints drove the process. Trade-offs were considered and included in the prototyping process, such as the inability to act at a site with low public support, rather than suggesting sites that realistically may not be considered for predator removal. We used the data available to explore the effectiveness of predator removal at various levels using several different quantitative modeling approaches. Decision-makers recognized that although several years of monitoring data have been collected, the data collection protocols were not designed to answer the question needed to support predator control decisions. Nonetheless, decisions on site selection need to be made and the process provided guidance on making a decision using expert opinion to rank the order of preferred sites to implement predator removal based on the cumulative expected utility as sites are added.

Through this prototyping process, decision-makers became aware of challenges of making a regional (among site) decision on an annual basis. Participants acknowledged that other decision-makers and stakeholders may have to be involved in the decision-making process. For example, private landowners or public sites may in fact have higher support for predator removal activities if they are involved in the process and can articulate their objectives and concerns. As a result, participants agreed it was important to determine the audience for selective predator removal decisions and a potential next step was to make a communication plan based on the workshop results to ensure that stakeholders are informed about the decision-making process. A matrix demonstrating the expected outcomes of different alternatives was suggested, which is currently summarized graphically (Fig. 6 and 7). Making a plan for sharing information among states was raised as a useful way to ensure that variation in experiences with selective predator removal was considered as the decisions were refined. Another future need was resolving how to scale up the prototyping process to all potential sites in both states and implementing the outcome, which would likely require a follow-up meeting.

Addressing Uncertainty for Data Rich Species

The take-home message from the workshop that garnered the most discussion was addressing uncertainty in predator removal efficacy. It was clear that both making decisions about selective predator removal and working with stakeholders would be easier if the scientific evidence for the effectiveness of predator removal were stronger. The primary limitation to our ability to make inferences about predator control was the lack of a rigorous study design in historical predator removal decisions. Although increases in Piping Plover productivity after predator removal is heartening, there has not been a way to separate the possible benefit of predator control from temporal change in productivity due to other causes, which can potentially be rectified with a before-after control-impact approach (Block et al. 2001). However, the complexity of the influence diagrams created by the participants made it clear that many factors could affect our ability to discern an effect of predator management, including site- and year-level variation in predator assemblages. Given this complexity, study designs may benefit from as many control-impact pairs as possible representing the range of potential variation in environmental conditions. However, decision-makers may not be willing to risk not conducting predator removal at a site with high numbers of pairs or previously high predation events.

Although there were substantial data on Piping Plovers (numerous sites, years, and nest-level data), workshop participants identified several ways data collection may have to change in order to inform the site selection (regional) decision. Information needs included: development of metrics for site-level response of predators to removal programs; standardized data on Piping Plover reproductive parameters (i.e., nest and chick survival); determination of covariates that may work across sites to predict effectiveness of selective predator removal; evaluating the utility of an experimental approaches to predator removal (such as a before-after control-impact design); and using population viability models that incorporate data on vital rates to predict responses to management. In Massachusetts, it is not possible under the HCP for the state to compel potential reference sites (those not requesting a take permit) to engage in predator removal as part of a statewide experiment. However, some land managers at the workshop expressed a potential willingness to cease predator removal for a short period as part of an experiment. The National Wildlife Refuge System was also suggested as a possible mechanism to examine variation in response to selective predator removal by Piping Plovers. As a requirement of the Massachusetts HCP, MassWildlife is responsible for providing a detailed analysis of the efficacy of predator removal in addition to developing methods for evaluating effectiveness. Following the

workshop, Massachusetts planned to use retrospective data from predator control and reference sites to examine responses of Piping Plover nest survival and chick survival to predator removal and to develop a method to adaptively manage predator removal to benefit Piping Plover reproductive success in the future. For a state like Maine, which has small numbers of pairs at each of its sites, reduction of biological uncertainty might take many years of an adaptive approach, depending on the strength of the effect of predator removal on the program's objectives (e.g., productivity). However, adaptive management over periods of time < 10 years has demonstrated the potential for learning gains regarding limiting factors even for critically small wildlife populations (Innes et al. 1999, Armstrong et al. 2007)New Zealand. An 8-year experiment to determine the cause of decline was undertaken by controlling introduced browsing and predatory mammal pests in two forest areas, then monitoring pest abundance, kokako chick output and adult density in the managed forests and an unmanaged non-treatment block. Treatments were switched between the unmanaged and one of the managed areas after 3–4 years. Reduction of pests, especially brushtail possums Trichosurus vulpecula and ship rats Rattus rattus, to very low levels resulted in significant increases in kokako chick output and adult density in all three study populations. This was due primarily to increased success of nesting attempts, which then increased the number of pairs attempting to breed, initially as newly recruited young females formed pairs with residual single males. The `adaptive management' approach of using routine large-scale pest control in a co-ordinated experiment to directly test the pest-limitation hypothesis enabled researchers and managers to investigate the cause of decline and to increase populations simultaneously. Predation is a more immediate cause of current kokako declines than competition. Management to recover vulnerable kokako populations should aim to reduce possums and ship rats to very low levels (<1% trap catch for possums; <1% tracking rate for ship rats, using particular indexing techniques.

For other beach-nesting bird species for which abundant monitoring data are available or are readily collected, a combination of expert opinion and experimentation or modeling similar to our proposed process will likely lead to robust decision-making on site selection for predator removal. (Martin et al. 2010) used a structured decision-making approach to determine the optimal strategy for removing raccoons (*Proycon lotor*) from the South Core Banks in North Carolina to benefit American Oystercatchers (*Haematopus palliatus*). The data included locally-collected mark-recapture data on raccoon demographics and 10 years of American oystercatcher nest monitoring data. Although the decision in that case was about local scale strategy for removing a specific predator, the fact that 10 years of available data were sufficient to find an optimal plan yields promise that site selection decisions for American Oystercatchers would be scientifically tractable, and expert opinion on stakeholder support at particular sites can enhance the decision-making process. Piping Plovers and American Oystercatchers breed sympatrically in many locations on the Atlantic coast, and therefore experimental approaches to site selection for predator removal could feasibly include objectives and monitoring data for both species, and thus achieve greater value. The Roseate Tern (*Sterna dougallii*) is a colonial ground-nesting seabird with a long-term population monitoring dataset across the species range and active predator control programs (Nisbet and Spendelow 1999). Roseate Terns and other well-studied colonial species would also likely lend themselves well to our structured decision-making approach for site selection for predator control, incorporating an adaptive management approach going forward to gain confidence in the role of predator management in temporal changes in productivity and abundance.

Addressing Uncertainty for Data Poor Species

The greatest uncertainty identified at the workshop was in the potential effectiveness of predator removal for Least Terns. There is far less baseline information on reproductive success and population growth rates for this species than for Piping Plovers, and the field methods for gaining such information are not as well developed, although incubating-adult counts may be useful for tracking temporal trends (Hillman et al. 2013). Even deciding on a proper fundamental objective presented a challenge. In the workshop, benefits to Least Terns were quantified in terms of number of nesting sites or pairs potentially benefiting, rather than demographic metrics such as abundance, survival, or population growth because these metrics are more difficult to measure for this species. A useful next step would be to discuss the data needs for Least Terns and the pros and cons of making decisions based on demographic responses. In our case, because Least Terns are largely sympatric with Piping Plovers, we assumed that predator management for the data-rich species would have benefits for the data-poor species. Moreover, although demographic data are largely lacking for Least Terns on the Atlantic Coast, managers likely have a good sense of their distribution and habitat requirements due to a very large

annual investment in protecting colonies and performing colony counts. In such cases, expert opinion-based decision making can be reliable. For example, habitat suitability models for the capercaillie (*Tetrao urogallus*) based on several rounds of expert consultation on habitat rankings converged on similar results to data-driven models (MacMillan and Marshall 2006)"plainCitation":"(MacMillan and Marshall 2006. Alternatively, decision-making approaches that model demographic responses to management of many species simultaneously, including data-rich and data-poor species, have been shown to reduce uncertainty in the response of data-poor species where expert opinion is available as a supplement (Martin et al. 2005). Adaptive management with an experimental approach combined with a strategy for site selection for predator management that incorporates benefits to multiple species will have broad applicability in the Atlantic Flyway. For example, Wilson's Plovers (*Charadrius wilsonii*) nest sympatrically with Snowy Plovers (*Charadrius nivosus*) and American Oystercatchers on Florida beaches. In North Carolina, Wilson's Plovers benefitted from predation management aimed at benefitting American Oystercatchers (DeRose-Wilson et al. 2013). Monitoring data from Florida for many understudied species, including Wilson's Plovers and Black Skimmers (*Rynchops niger*), have been stored for many years in a collaborative database with data for Snowy Plovers and American Oystercatchers (https://public.myfwc.com/crossdoi/shorebirds/). Both preliminary data and expertise exist that would lend themselves well to a prototyping session such as ours for site selection for predation management.

Summary

Ultimately, predator removal decisions are challenging and measuring effectiveness can be difficult. Even in the absence of certainty (which is rare in wildlife management decisions), wildlife managers must make decisions about whether to implement predator removal at a given site in a given year. At the workshop, we developed a framework for using expert opinion to guide wildlife managers through the decision-making process, and ultimately identified combinations of sites that would maximize the value of the decision subject to budget constraints. A structured decision-making framework helps make these decisions transparent, despite a lack of data. For species with a wealth of monitoring information such as the Piping Plover, a careful study design that looks at treatment and reference sites before and after management during the same period would reduce uncertainty in the effectiveness of predator management. Expert opinion provides a critical starting point for making decisions going forward. We demonstrated how expert opinions can be used to value sites and to weight objectives used in valuation, in order to assess the benefits of different alternative decisions (i.e., combinations of sites to manage). We recommend such an approach as a best practice for choosing sites to control predators for beach-nesting birds, as it creates a transparent and repeatable process for decision-makers to articulate the rationale for their decisions related to this often-controversial practice. We recommend further evaluation of the hypothesis that management to benefit a data-rich focal species will also benefit data-poor sympatric species, such as Piping Plovers and Least Terns in our case. In most scenarios on the Atlantic Coast, there will be at least one data-rich species under consideration, where monitoring the effect of the decision is scientifically straightforward. An adaptive management approach to site selection, using expert opinion-based decisions as a starting point and treatment and reference sites going forward, will provide a framework for increasing knowledge about the effects of predator management on currently data-poor species. This approach will also facilitate refinement of fundamental objectives for such species and should improve confidence in the decision-making process over time. In all cases, defining and monitoring the fundamental objectives for each species, including biological and social objectives, is crucial and will require standardized and repeatable methods.

Acknowledgments

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Table 1. Objectives, measurable attributes, attribute type (natural, proxy, or constructed scale) and desired direction for predator removal decisions to benefit beach nesting shorebirds in Maine (ME) and Massachusetts (MA). Natural attribute types can be directly measured, proxy attribute types are highly correlated with the objective but do not directly measure it, and constructed attribute types are on a relative scale that requires interpretation.

Objective	Attribute	Attribute Type	Desired Direction
Piping Plover Population Growth	Number of fledglings gained from predator removal (ME/MA)	Proxy	Maximize
Piping Plover Distribution	Opportunity for fledglings to colonization or population augmentation of other sites (ME) (0 = none, 1 = yes) Opportunity for fledglings to colonization or dispersal to other sites (MA) (0 = none, 1 = yes)	Constructed	Maximize
Least Terns Benefits	Number of sites with Least Tern pairs potentially benefiting from predator removal (ME) Number of Least Tern pairs potentially benefiting from predator removal (MA)	Proxy	Maximize
Cost	$ per year (ME/MA)	Natural	Minimize
Learning	Power to detect efficacy given present program design (ME/MA)	Proxy	Maximize
Public Support	Stakeholder support (ME) Stakeholder conflict (MA)	Constructed	Maximize Minimize

Table 2. Mixed effects model of productivity of Piping Plovers in Maine. Estimated interactions between year and removal effects omitted for brevity; p is the test of the hypothesis that the estimated value is zero using the Kenward-Rogers correction for degrees of freedom.

	Productivity		
	B	CI	p
Fixed Effects			
With Removal, average	1.92	1.57 – 2.27	<.001
Without Removal, average	1.43	1.16 – 1.69	<.001
Random Effects			
Residual variance (σ^2)	1.881		
$\tau_{00, BEACH}$ (σ_{BEACH})	0.137 (7.29)		
N_{BEACH}	24		
Intraclass Correlation$_{BEACH}$	0.068		
Observations	153		
R^2 / Ω_0^2	0.288 / 0.280		

Table 3. Consequence table containing the mean expert-elicited value of 5 objectives (the learning objective was not quantified in this prototype) for 8 example alternative sets of sites (names of sites have been removed) to conduct predator removal to benefit Piping Plovers and Least Terns in Maine. Some alternatives are omitted for brevity.

	Objectives				
Alternatives	opportunity for colonization or population augmentation* (1 = high)	# fledglings gained	# LETE sites benefiting	Cost ($K)	stakeholder support (3 = no change, 2 = decline)
Direction	maximize	maximize	maximize	minimize	maximize
none	0.0	0.0	0	0	3
Site D	0.3	1.4	0	15	2
Site E	0.2	1.0	0	10	2
Site A	1.0	6.4	1	15	3
Sites D + E	0.5	2.4	0	25	2
Sites A + D	1.0	7.8	1	25	2
Sites A + E	1.0	7.4	1	25	2
Sites A + D + E	1.0	8.8	1	30	2

Table 4. Consequence table containing the mean expert-elicited value of 5 objectives (the learning objective was not quantified in this prototype) for 12 example alternative sets of sites (names of sites have been removed) to conduct predator removal to benefit Piping Plovers and Least Terns in Massachusetts. Some alternatives are omitted for brevity.

Alternatives	Objectives				
	opportunity for colonization/dispersal (2.5 = high)	# fledglings gained	# LETE pairs benefiting	Cost ($K)	stakeholder conflict (1 = low conflict)
Direction	maximize	maximize	maximize	minimize	minimize
none	0.0	0.0	0	0	1.0
Site B	1.0	6.7	112	2	2.0
Site D	1.0	9.0	30	2	1.0
Site E	1.0	1.2	35	1	3.0
Sites B + D	1.5	15.7	142	4	2.0
Sites B + E	2.0	7.9	147	3	4.0
Sites D + E	2.0	10.2	65	3	3.5
Sites B + D + E	2.5	16.9	177	5	4.0
Site G	1.0	2.0	15	2	4.0
Site F	0.5	2.5	25	1	4.5
Site C	1.0	16.0	50	3	2.0
Site A	1.0	11.8	120	3	5.0

Table 5. Objective weights (preferences) for each participant in a structured decision-making workshop on predator management to benefit Piping Plovers and Least Terns in Massachusetts and Maine. Higher values indicate higher preferences for objective outcomes.

Objective	Participant						
	1	2	3	4	5	6	7
Maine							
Number of fledglings gained from predator removal	0.385	0.435	0.351	0.444	0.444		
Opportunity for fledglings to colonization or population augmentation of other sites	0.288	0.217	0.333	0.222	0.222		
Number of sites with Least Tern pairs potentially benefiting from predator removal	0.327	0.348	0.316	0.333	0.333		
Massachusetts							
Number of fledglings gained from predator removal	0.364	0.472	0.485	0.435	0.435	0.444	0.571
Opportunity for fledglings to colonization or dispersal to other sites	0.030	0.175	0.320	0.196	0.217	0.222	0.143
Number of Least Tern pairs potentially benefiting from predator removal	0.606	0.354	0.194	0.370	0.348	0.333	0.286

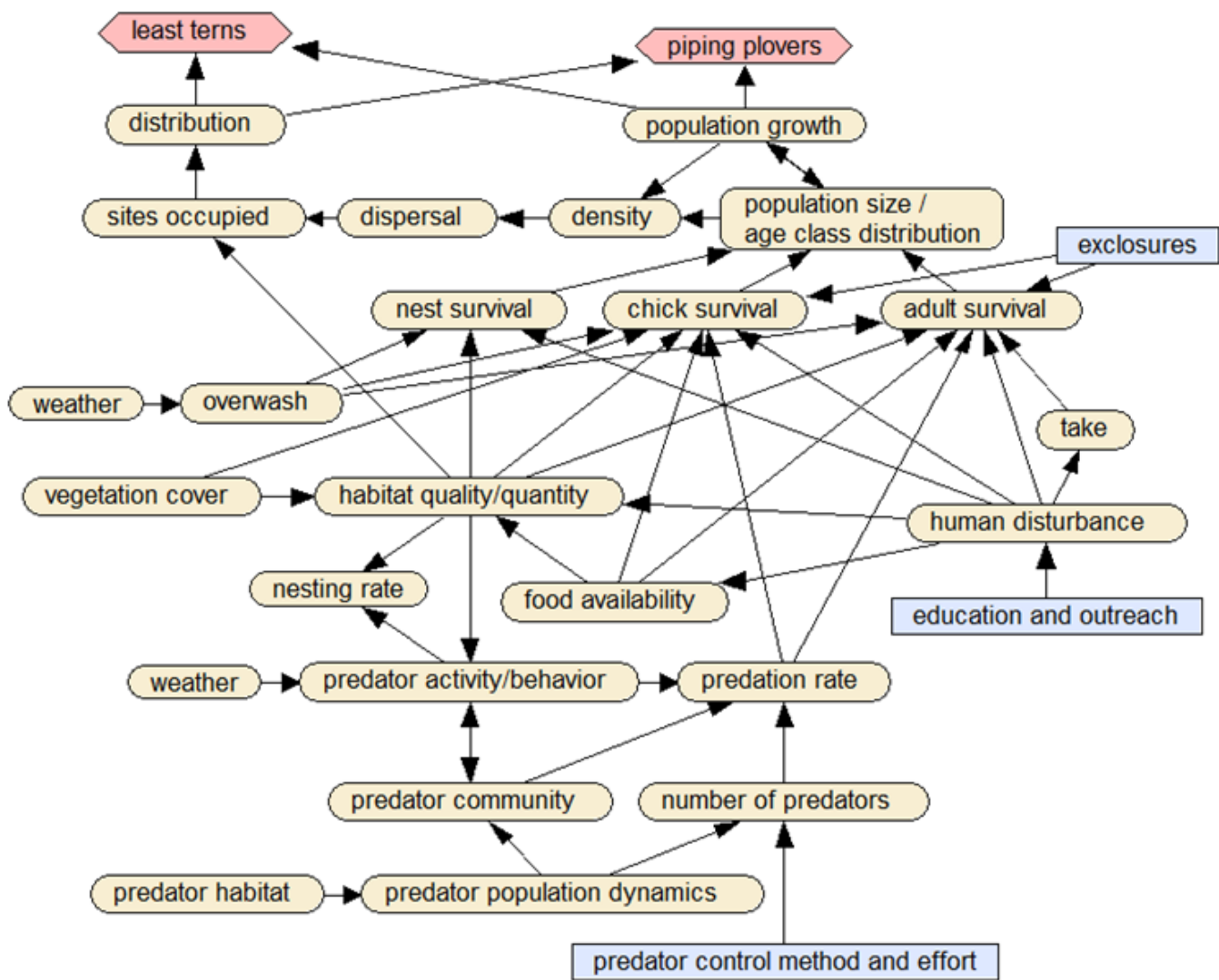*Figure 1. Influence diagram depicting the effects of predator removal (method and effort) on Piping Plover and Least Tern population growth and distribution (blue rectangles = management actions, yellow ovals = ecological variables, hexagons = objectives). Arrows represent the direction of cause and effect.*
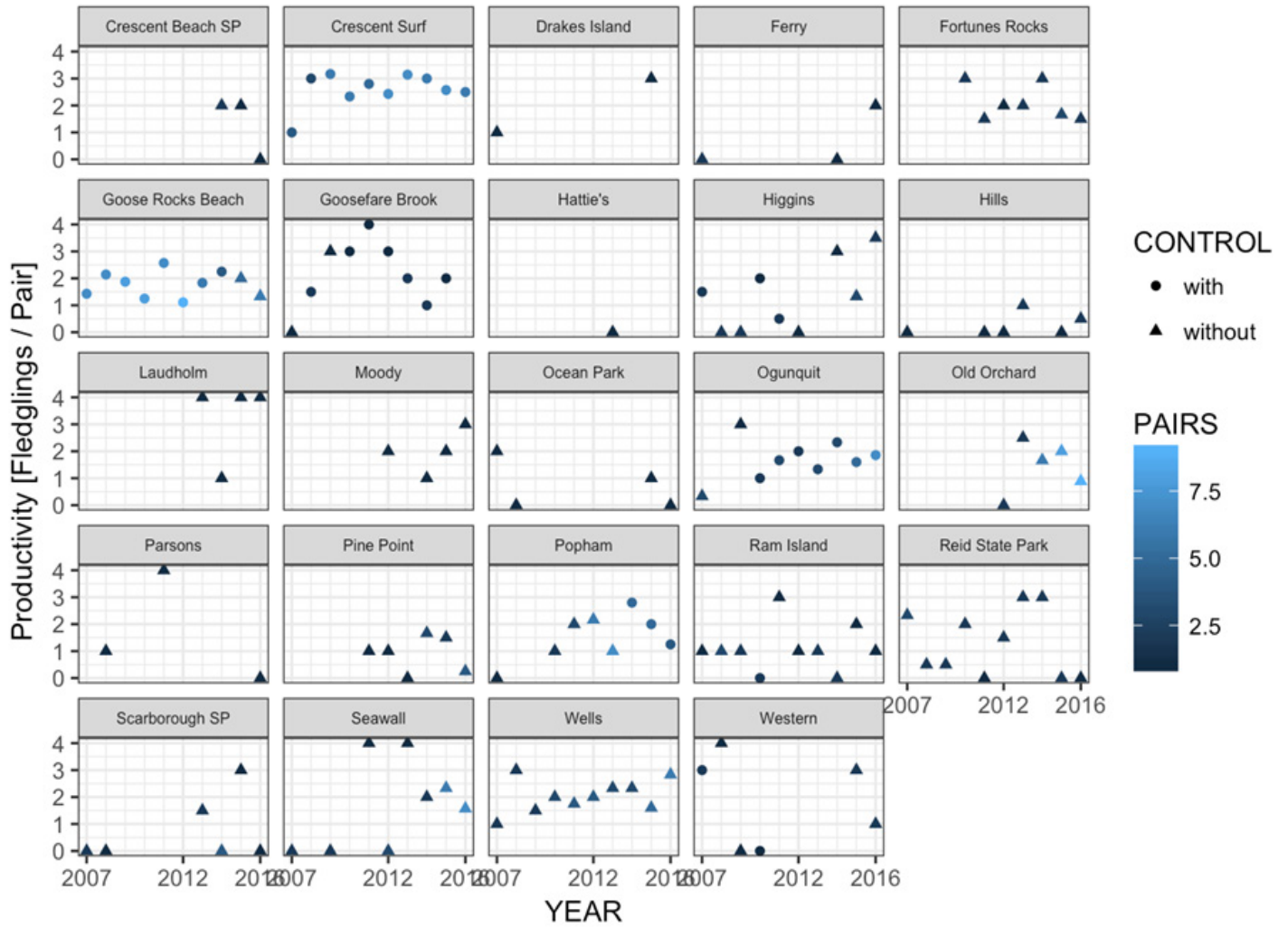
Figure 2. Observed (raw) Piping Plover productivity (known fledges/known nesting pairs) at sites in Maine, 2007-2016.
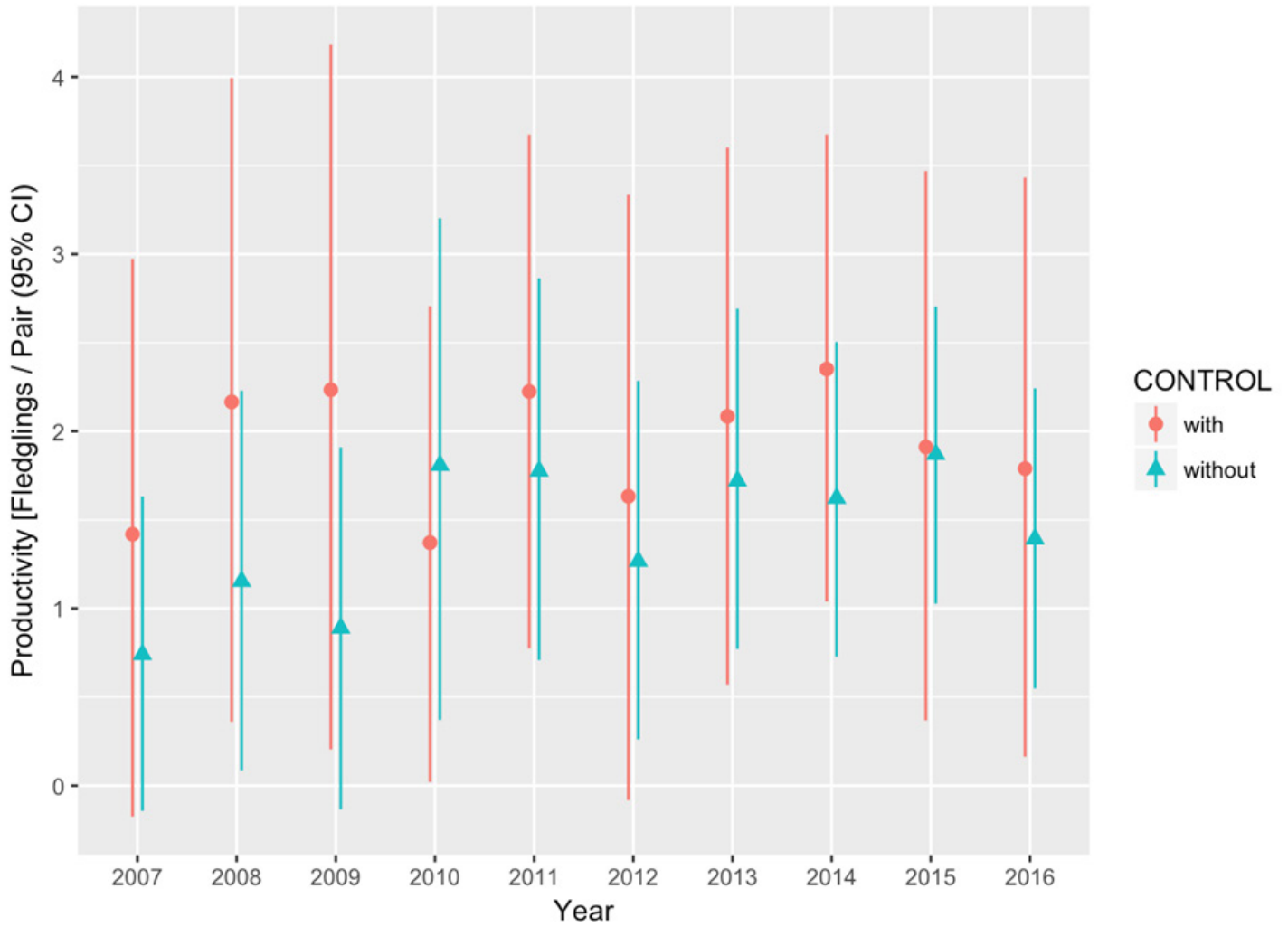
Figure 3. Predicted Piping Plover productivity effects of predator removal by year from mixed effects model (Table 1), based on 24 sites in Maine. 95% Confidence intervals derived from 10,000 bootstrap resamples from the results (parameter estimates and their variances) of a mixed-effects ANOVA of productivity vs. predator removal, year, and their interaction. The random effect in the ANOVA was site.
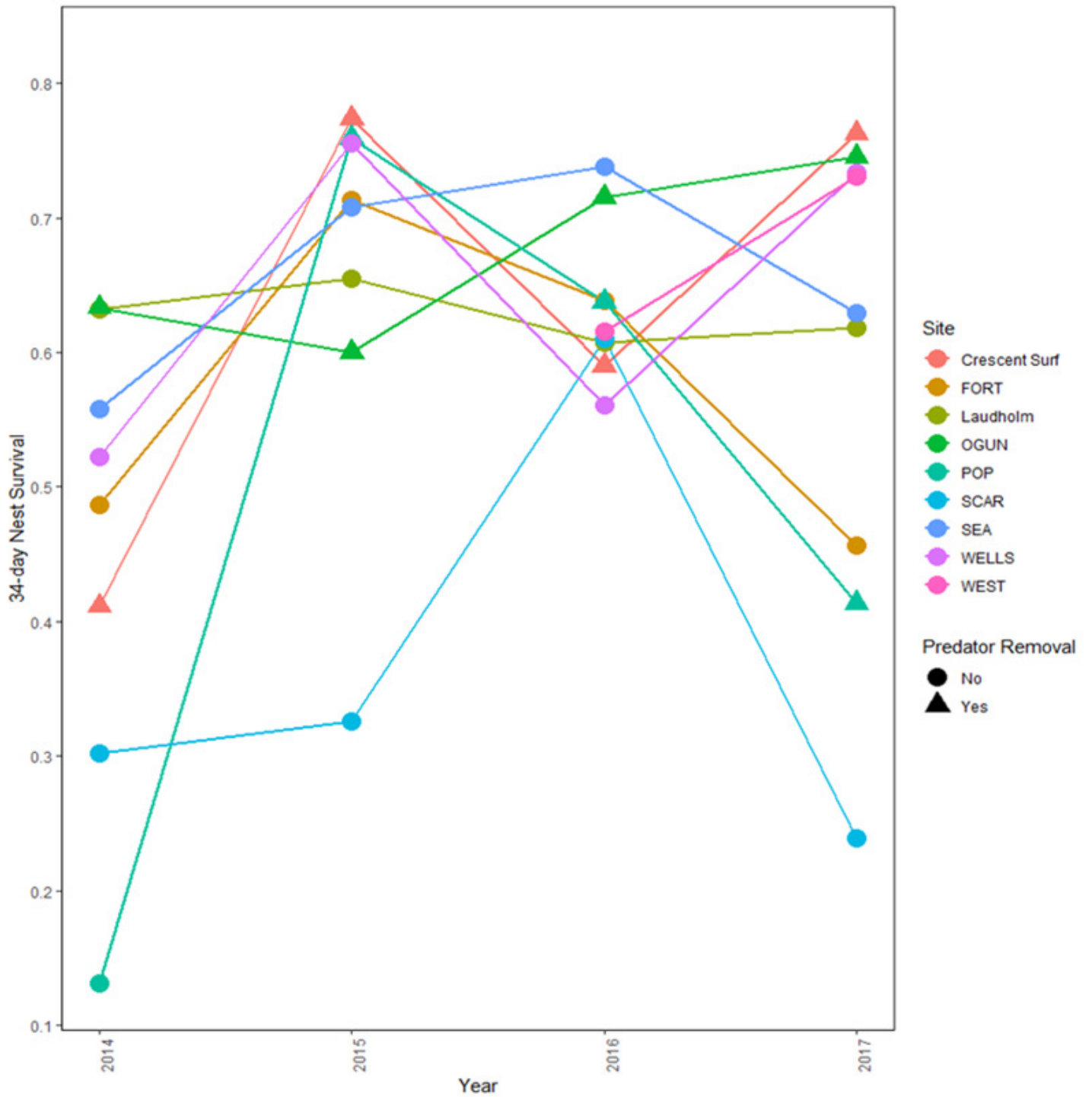
Figure 3. 34-day nest survival of Piping Plovers in Maine, 2014 – 2017.
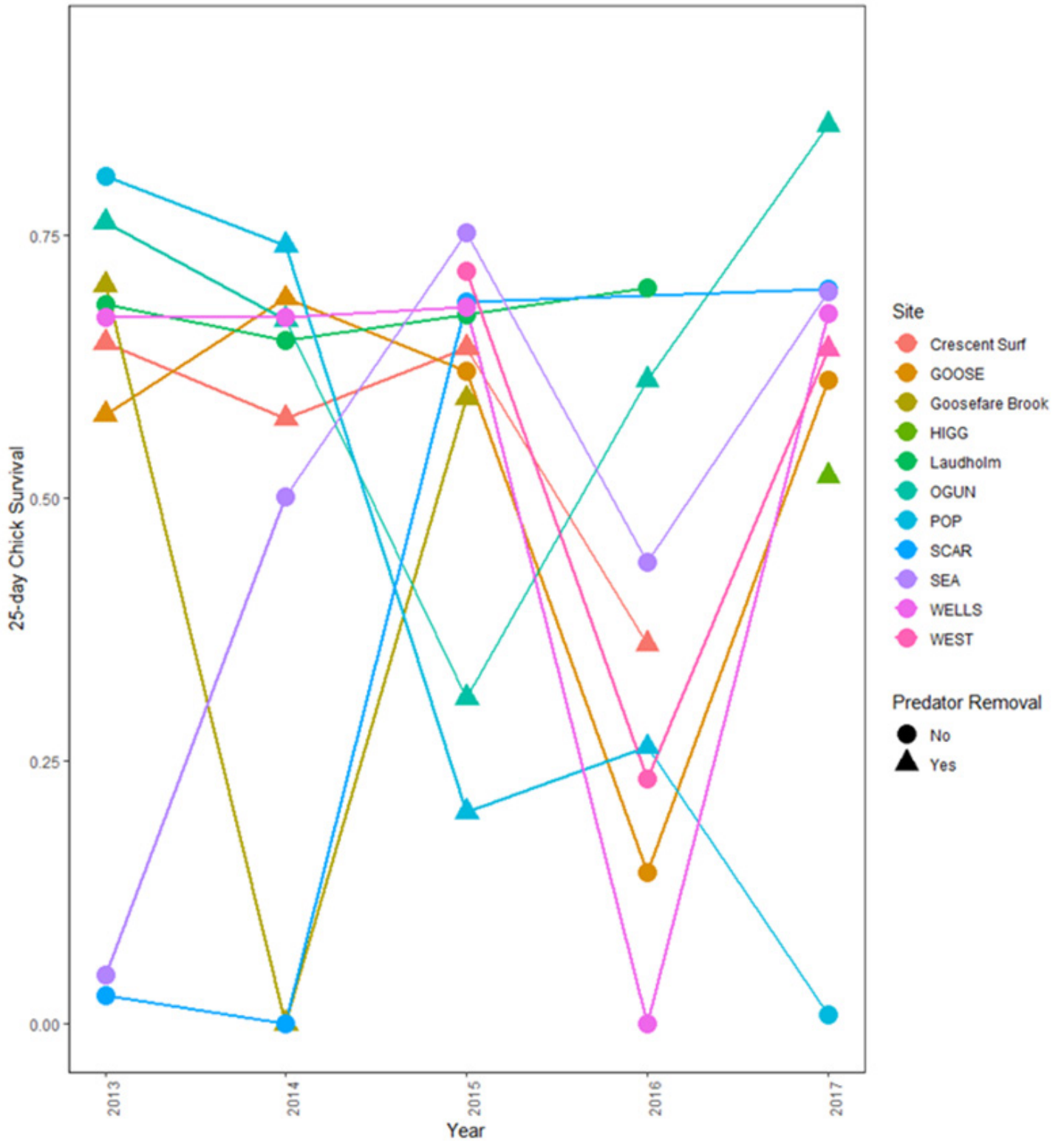
Figure 4. 25-day chick survival of Piping Plovers in Maine, 2013 – 2017.
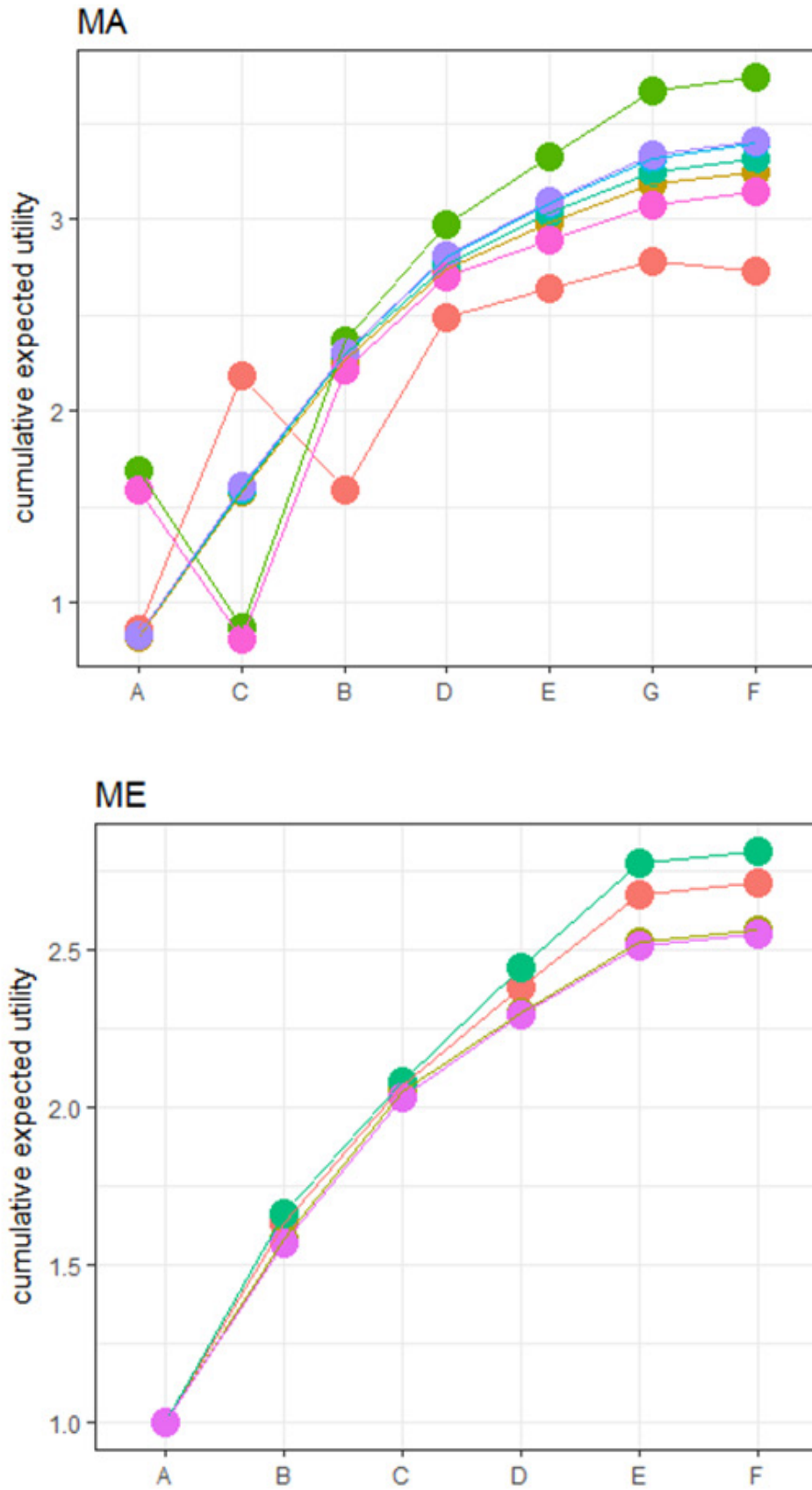
Figure 6. Example cumulative expected utility of implementing predator removal at each additional site based on preferences (weights) of each Massachusetts (MA) and Maine (ME) decision maker (colored dots). Expected utility does not include stakeholder support, which would serve as a constraint to eliminate some sites from being selected. Letters on the x-axis represent a single site.
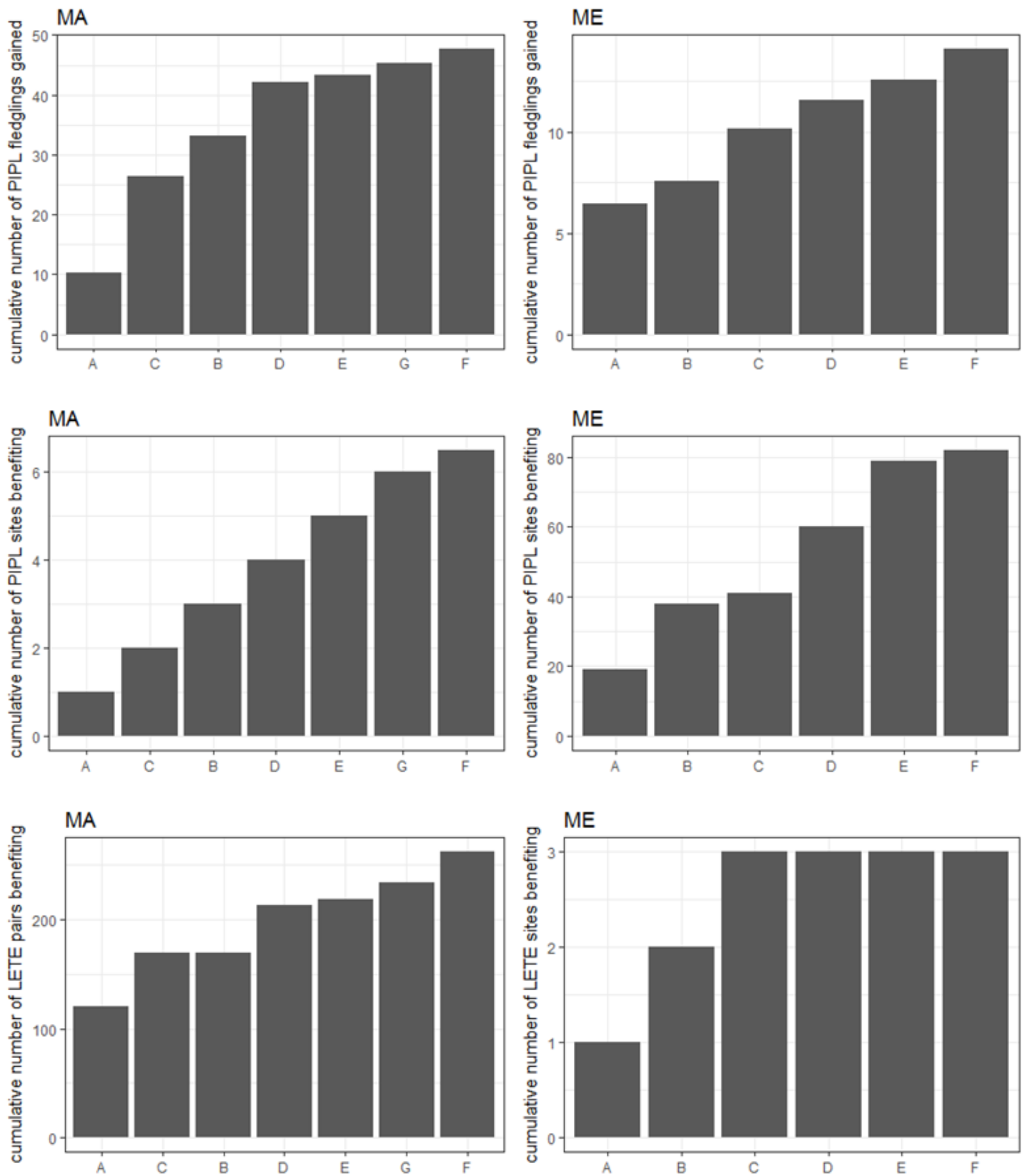
Figure 7. Example of cumulative expected outcomes for each objective in Massachusetts (MA) and Maine (ME) as the number of sites selected for implementation increases (examples are shown using individual #6 and #3's weights from Table 5 above). As the number of sites increases, benefits per site selected decreases (asymptote). Letters on the x-axis represent a single site.

GLOSSARY

For a full overview of terms and definitions, see:

An Overview of Structured Decision Making - ALC3183 – Resources, National Conservation Training Center, USFWS (https://training.fws.gov/courses/ALC/ALC3183/resources/index.html)

0/1 Knapsack Problem – The 0/1 knapsack problem is based on the idea that every strategy considered consists of a variety of costs and benefits, and that in a situation of limited resources a decision is made based on the measures which are most likely to bring the most benefit. In other words, given the weights and values of *n* items, these items are placed into a "knapsack" of a capacity *W* to get the maximum total value in the knapsack. Often, all subsets of items are listed, the total weight and value of all subsets is calculated, and only subsets whose total weight is smaller than *W* are considered. From the subsets whose total weight is smaller than *W*, the subset with the maximum value is chosen.

Alternatives – Alternative decisions are focused directly on achieving objectives and require participants to think creatively to achieve the widest range of possibilities without constraints or limitations and to avoid moving towards a single solution. Alternatives should reflect substantially different approaches to the problem.

Consequences – It is important to understand the consequences of different actions in terms of the outlined objectives. In the SDM process, models are tools that help to predict the consequences of making a particular decision.

Constraint – Constraints are limitations or restrictions surrounding the decision in the SDM process and can be either real or perceived. While the decision problem is being identified, it is important to break down perceived constraints to later help with creatively identifying alternatives.

Expected Utility (EU) – Expected utility considers the fact that the value of a commodity is different from one person to another due to differences in circumstances. Decisions are compared on the basis of their expected utility under the assumption that all consequences of a decision are equally likely.

Expert Elicitation – The use of advice from experts that goes beyond well-established knowledge which is obtained and combined to aid in the decision-making process. Expert elicitation follows a formalized, documented procedure for obtaining and combining probabilistic judgments. If traditional science and statistics cannot provide all the inputs needed for a model or policy analysis, decision makers have few alternatives to asking experts.

Measurable Attributes – To describe the consequences of alternatives and make trade-offs between achieving objectives, it is necessary to identify a measure for each objective, which is referred to as an attribute. Three different attribute types (proxy, natural, and constructed) have been identified. *Natural* attributes have a common interpretation. *Proxy* attributes involve a scale that can be counted or measured. *Constructed* attributes can be developed to measure the achievement of an objective when no natural attributes exist (i.e. a scale is constructed and must be interpreted by stakeholders). Measurable attributes are also known as "performance measures."

Objectives – In the SDM process, goals and concerns are identified and then converted into objectives. The goals and concerns are articulated through asking questions regarding the situation or decision at hand (e.g. what are you trying to achieve, what makes this particular decision difficult, what would be the best outcome, what would be the worst outcome, etc.).

Primary Decision Maker(s) – The party(ies) that are ultimately responsible for making the decision. Problems may have a single decision maker or multiple decision makers, but stakeholders are not decision makers.

Problem – Defining the problem can often be the most difficult part of the SDM process. In the SDM framework, problems are actually decisions (i.e. making the decision is the problem).

Rapid Prototyping – A prototype is an original type, form, or instance that is a model on which later stages are based. Rapid prototyping is an approach to structured decision making that involves quickly framing a simple prototype of the decision problem then stepping back to assess its basic structure and major components.

Trade Offs – Evaluating tradeoffs is the part of the SDM process where all options for solving the problem are outlined in order to identify the best alternative action, as measured by the objectives, using predictions from the models. At this point, a decision can be made, and a preferred action can be implemented.

Trigger – A trigger is a set of conditions, information, and/or considerations that prompts a decision-making process for addressing a specific problem.

SUPPLEMENTAL MATERIAL BP6: PREDATION MANAGEMENT OUTREACH TOOLS

A. EXAMPLES OF PREDATION MANAGEMENT TALKING POINTS

1. Overarching Predation Management Messaging

Beaches are special places for people and wildlife, including piping plovers.

- Beaches are important to people for many different reasons. Some use them for enjoyment and recreation, while others depend on them for their livelihoods or their homes.
- However, nesting and migrating shorebirds depend on beaches for survival as well. It is important that we find a long-term strategy to share our beaches, or a whole suite of species will become extinct.
- Piping Plover can only live on beaches with very specific features. Historically, plovers could find these beaches up and down the Atlantic coastline; now, they only have about 5% of that space left, and the beaches that are left are impacted by recreation and other activities.
- Young plovers face a critical point of survival while nesting on our beaches. They need to eat and build up their flight muscles, for they have a long journey ahead of them to reach their wintering areas.
- Due to conservation efforts, Piping Plover and other native shorebirds are recovering from declines brought about by expanding development and recreation over the past 70 years.
- However, our work is not done. Climate change, sea-level rise, and increased storm frequency and intensity are changing the beaches. This has left humans and wildlife sharing a shrinking coastline.

Predator populations artificially influenced by people can devastate shorebird communities.

- In some places, predation is currently the most serious threat to breeding Piping Plover, resulting in the loss of eggs, chicks, and adults.
- Many populations of predators have increased due to their ability to take advantage of human-provided shelter and foods, such as garbage, road-kill, and bird feeders. As human populations continue to grow, generalist predator populations increase, taking advantage of human-supplied food and dens.
- The availability of trash at summer beaches increases populations of crows, skunk, raccoons, foxes, and coyotes, among others.
- There are now too many predators on many beaches for predator/prey interactions to function naturally. It's not evolution that is favoring these predators; it's human activity and alteration of the landscape that are favoring them.
- Even coastal parks and wildlife refuges no longer represent natural conditions, reflecting hundreds of years of human activity.
- Predator presence and disturbances at nesting areas have been documented through visual observations of predators and their tracks and through game cameras deployed at plover nests.
- Selectively removing individual predators can make a critical difference in Piping Plover egg and chick survival. For a number of years, piping plover chicks weren't surviving at one beach, contributing to a decline in the state's population. Plover productivity increased 198 percent over two years when selected predators, including coyote, fox, raccoon, and skunk, were removed.
- One lone predator can be devastating to beach-nesting shorebirds. For example, a necropsy found 3.4 pounds of tern chicks in the stomach of an eastern coyote removed from a nesting shorebird colony (Plymouth, Massachusetts) in 2010. This total weight could equate to 50–100 chicks predated on a single night by a single coyote.

Choices by individuals can help us protect plovers and other beach wildlife.
- You have the power to help protect Piping Plover and other shorebirds!
- You can help by keeping dogs on leashes, respecting wildlife protection fences and signs, walking around nesting or resting wildlife, and treading lightly on this beach habitat.
- You can also help to restore the balance between threatened species and predators by not feeding wildlife, removing all food scraps and other trash from the beach, and ensuring residential waste is kept in wildlife proof containers.

We support removing predators only when sound science indicates it is our last or only resort to recovering the plover.
- We love animals and make it our mission to protect them. However, we are trying to save entire populations of animals, not just individuals. Sometimes we need to remove an individual in order to save a population of another species, especially to protect species that are threatened or endangered.
- We have invested significant time and expense to discourage predators and reduce their impacts on nesting Piping Plover through non-lethal methods. Some methods we use include placing wire exclosures around nests, using electric fencing to keep predators away from nests, installing perch deterrents, and frequent litter cleanups to keep predators away from nesting locations. Despite these efforts, predation continues to be a significant cause of plover nest and chick loss.
- Field observations suggest that most eggs and chicks are preyed upon by a small number of individual predators that have keyed in to nesting areas. We do our best to focus lethal predator management strategies on those individuals alone.
- Failing to act would lead to an increased decline in Piping Plover populations.

2. Talking Points—For Removing Crows And Blackbirds
- Our goal is to use a method of removing crows and blackbirds that limits predation on Piping Plover eggs and chicks, while only targeting crows that are active in fenced-in plover nesting areas.
- No effective non-lethal methods are currently available to keep crows away from plover chicks. Crow effigies, artificial crows placed in a way so as to appear dead in an effort to scare off live ones, are ineffective. Other methods that attempt to frighten crows away will also frighten and disturb the nesting plovers.
- DRC-1339 is a chemical that is poisonous to crows and blackbirds in very small doses, but mammals and most other birds are only affected by much higher doses. For example, one egg injected with a tiny amount of DRC-1339 will kill a crow, but 300-700 of these eggs would be needed to kill a mouse.
- A very small amount of DRC-1339 is injected into hard boiled eggs, which are placed into fenced-in shorebird nesting sites. The placement methods used make consumption of the egg by non-target species highly unlikely.
- The poison does not last long in the environment, breaking down when exposed to sunlight and high temperatures, so it does not pose a long-term threat to the environment.
    - DRC-1339 is also metabolized quickly after being consumed, so will not build up in the deceased animal's body. Therefore, there is little to no potential for animals that consume the carcass to become poisoned, or for the chemical to build up in the food chain.

3. Talking Points–Predator Removal At A Private Beach Property Under A Conservation Easement
Why is a predator removal program being implemented?
- Predation is a serious threat to breeding Piping Plover resulting in the loss of eggs, chicks and adults throughout the Piping Plover's range.
- As human populations continue to grow, wildlife populations increase which take advantage of human-supplied food and dens. The availability of trash at summer beaches increases local populations of skunk, raccoons and foxes.
- Reducing predation is an effective way to increase the number of chicks hatched and fledged. For a number of years, plover productivity at this site failed to meet the U.S. Fish and Wildlife's Recovery Plan standards for population growth and stability, contributing to a decline in the state's population. Plover productivity

increased 198 percent over two years when predators including coyote, fox, raccoon and skunk, were removed.

- We only support removing predators when sound science indicates that it is our last or only resort to meet the objective of the federally mandated Recovery Plan.

What evidence is there to show these animals are the problem?

- Predator presence and disturbances at nesting areas have been documented through visual observations of predators and their tracks and through game cameras employed at plover nests. A number of predators, specifically coyote, raccoon, and skunk have captured on the game cameras coinciding with chick losses, egg loss and nest abandonments due to predator disturbances at exclosures have been documented over a number of years.

How will predator removal be accomplished?

- Non-lethal traps such as padded foothold traps and box traps will be used to capture the target species. The professional trappers will be required to produce a log of the number of animals caught giving the species, date caught, approximate age, sex, condition, and weight. Appropriate permits have been secured.
- Since current state regulations forbid relocating mammalian predators trapped predators will be humanely dispatched.
- All traps used to capture mammals will meet the existing Best Management Practices for Trapping.

What are the alternatives – why aren't they being implemented?

- Significant time and expenses have been invested to discourage predators and reduce their impacts on nesting Piping Plover. Non-lethal methods currently employed include placing wire exclosures around nests, using electric fencing to keep predators away from nests, installing perch deterrents and frequent litter cleanups to keep predators away from nesting locations. Despite these efforts, predation continues to be the leading cause of plover nest and chick loss.
- No action would lead to an increased decline in the population at this site.

How is the safety of the public and pets being taken into account? What if cats or dogs are caught during the trapping process?

- Traps will be placed only in areas used by the target species. These will be along game trails in dense *Phragmites* and shrubs, or near dens, which by definition are rarely visited by pets.
- This risk is also minimized because only non-lethal traps such as padded foot hold traps will be used. If a pet were caught they would be discovered within 24 hours and be released by the trapper.
- Signage is placed on the property to warn human visitors of the presence of traps and to advise dog owners to leash their dogs.

Has predator removal been utilized in the past?

- Predator removal programs to increase piping plover productivity have been implemented at this site over a number of years. Plover productivity increased XX (site-specific) percent over two years when predators including coyote, fox, raccoon and skunk, were removed.

How will the effect of predator removal be measured?

- The results of the trapping will be measured by the number of animals removed, and monitoring the presence/absence of tracks on the beach and near plover nesting areas, and the number and cause of plover loss from predators. Seasonal plover monitors will observe whether predator tracks are seen on the beaches and if they are near exclosures. In addition, trail cameras will be deployed at several of the nest sites which will capture predator activity.

Consider additional questions like the length/timing of management, who will be conducting the management and the cost of the program.

4. Talking Points–Predator Removal At An Atlantic Coast Site

1. Our site is a special place for both people and wildlife. We work hard to provide as much visitor-use access as possible, while ensuring wildlife and habitat are unimpaired.
2. Nesting and migrating shorebirds have been coming here for centuries. Protecting our beach ecosystem provides these birds habitats for breeding, feeding, and sheltering, all of which are critical for their survival.
3. Our site must remain in compliance with the Endangered Species Act. When listed species are not meeting recovery objectives, our site must change its strategies to protect these species by implementing new or additional methods.
4. Climate change, sea-level rise, and increased storm frequency and intensity are changing the beach ecosystem and have left humans and wildlife sharing a shrinking coastline.
5. There are now too many predators in this area for predator/prey interactions to function naturally. Individuals can help restore the balance between threatened species and predators by not feeding wildlife, removing all food scraps and other trash from the beach, and ensuring residential waste is kept in wildlife proof containers.
6. Choices by people have direct impacts on the success of protecting threatened and endangered species. Please help protect these species by keeping dogs on leashes, respecting wildlife protection fences and signs, walking around nesting or resting wildlife, and treading lightly on this critical beach habitat.

1. Our site is a special place for both people and wildlife. We work hard to provide as much visitor-use access as possible, while ensuring wildlife and habitat are unimpaired.
- Staff, interns, and volunteers work hard to ensure that birds are being protected and as much visitor-use access as possible is being allowed every day – All temporary closures are evaluated and adjusted daily to reflect tides and bird activity; temporary closures are also evaluated regularly to determine bird tolerance to human disturbance with buffers being adjusted accordingly; and where and when possible, pedestrian detours are established around closed sections of beach.
- These closures (including high tide and boat landing) and detours have been successfully and generally well received implemented in many areas of the park.
- Our site and others like it are set aside for resource protection and visitor use; however, visitor use does not mean all access, all the time, in all places. Endangered shorebirds are further protected by a host of additional laws and policies including the Endangered Species Act (1973), 16 US Code, Chapter 35, Section 1531.
- Appropriate visitor use activities, in general, are those that do not negatively impact resources or other visitors.
- Protecting wildlife and its habitat is complex given annual visitation coupled with land use changes that have occurred past and present in the area. Finding a balance that protects our resources over the long term while accommodating multiple uses remain a challenge because conditions are always changing.
- Working with the U.S. Fish and Wildlife Service, we have received approval to "flexibly manage" a limited number of Piping Plover nesting on or near high visitation beaches (i.e. life-guarded beaches) where the beach has narrowed to the point where fully protecting piping plovers would render the beach unusable to all visitors at high tide.

2. Nesting and migrating shorebirds have been coming here for centuries. Protecting our beach ecosystem provides these birds habitats for breeding, feeding, and sheltering, all of which are critical for their survival.
- Piping Plover were so common in this area that Thoreau, visiting in the 1850s, considered their call to be the beach sound he most remembered.
- Piping Plover and the other species of native shorebirds suffered dramatic population declines as a result of unregulated hunting in the late 19th and early 20th century.
- By the mid-20th century many populations had largely recovered, due to state and federal laws protecting them, but expanded development and recreational activities and habitat loss in coastal areas following World War II brought about a new era of population declines.
- Our site is essential to the survival of beach dependent species.

3. Our site must remain in compliance with the Endangered Species Act. When listed species are not meeting recovery objectives, we must change strategies to protect these species by implementing new or additional methods.

- The *purpose* of the ESA is "…to provide a means to conserve ecosystems upon which endangered and threatened species depend."
- It is the *policy of congress* that "All Federal departments and agencies shall seek to conserve endangered and threatened species and shall utilize their authorities in furtherances of the purposes of [the Endangered Species] Act."
- Listed species and their critical habitat must be considered in every discretionary action of a Federal agency.
- A primary goal in management of threatened or endangered species is to minimize the possibility of "take." Take is defined as: "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or to attempt to engage in any such conduct."
- The recovery of a species is accomplished by eliminating, reducing, or mitigating those factors that caused its decline. In the case of piping plovers, these negative impacts are habitat loss, unnatural levels of predators, and human disturbance.

4. Climate change, sea-level rise, and increased storm frequency and intensity are changing the beach ecosystem and have left humans and wildlife sharing a shrinking coastline.

- The climate is changing….
- Background sea-level rise is 2.63 mm/yr (in the area) on average
- Over the last 100 years, the area's Atlantic coast is eroding 3 ft/yr on average
- Nesting Piping Plover, terns, and American Oystercatcher are obligate coastal species and use low-lying coastal habitats for nesting, roosting, and staging. This makes them vulnerable to effects of climate change, particularly sea level rise.
- Incidences of extreme weather are projected to increase due to climate change. Our site is experiencing an increased frequency of late spring/summer storms making nesting areas more vulnerable to wash-overs.
- Flooding and overwash can destroy habitat and nests, but it can also remove vegetation that made areas previously unsuitable for nesting or roosting (that's a positive thing).

5. There are now too many predators in the area for predator/prey interactions to function naturally. Individuals can help restore the balance between threatened species and predators by not feeding wildlife, removing all food scraps and other trash from the beach, and ensuring residential waste is kept in wildlife proof containers.

- While more intact than most coastal areas, the beach and upland ecosystems of this area no longer represent natural conditions or processes. They have been altered by 350+ years of human activity and the numbers of people, pets, vehicles, and predators present on beaches are a reflection of these alterations.
- Many populations of predators have increased due to their ability to take advantage of human-provided foods (garbage, road-kill, bird feeders). Populations of these "subsidized predators" exert unnaturally high predation pressure on Piping Plover nests, chicks, and adults.
- It's not evolution that is favoring coyotes and crows, the two most common predators of shorebirds in this area; it's human activity and alteration of the landscape that are favoring them.
- Field observations at our site suggest that the majority of plover nests lost to American Crow are due to a few individual crows that have learned to "key-in" to nesting areas.
- The last decade of data (2005 through 2014), indicate that 33% of Piping Plover nest loss has been due to predation (418 nests lost from 1275 total nests). Of these nests lost to predation from 2005 – 2014, crows were responsible for 42% of the nests lost and coyotes were responsible for 23% of nests lost.
- In 2014, 70% of plover nests loss was due to predation. Of these nests lost to predation, crows were responsible for 33% of nests lost and canid species (Eastern coyote and red fox) accounting for 45%.

6. Choices by people have direct impacts on the success of protecting threatened and endangered species. Please help protect these species by keeping dogs on leashes, respecting wildlife protection fences and signs, walking around nesting or resting wildlife, and treading lightly on this critical beach habitat.

- Visitors not complying with the leash law and entering "No Pet" areas are major concerns.
- 2011 – 2013 - shorebird staff encountered 1,436 dogs off leash in the park while monitoring shorebirds on the beaches.
- 2014 – 404 dogs off leash encountered so far by shorebird staff
- It is often observed that by the time shorebird staff approach the visitor, they've seen them and have put their dog on a leash. This of course indicates that they were intentionally disobeying the rules.
- This year, an abnormal amount of disregard for protected/"Area Closed" shorebird habitats, including:
    - people entering nesting areas to retrieve driftwood and other beach debris,
    - taking short cuts, retrieving balls, and frisbees within fencing,
    - fishermen walking through protected areas who refused to leave after being approached by field technicians,
    - people generally entering the closed areas and walking directly up to "exclosed" nests
- And, we have observed an outbreak of vandalism to shorebird symbolic fencing and signs, including:
    - tearing down/removing, and/or burning posts,
    - cutting the string between each fence post for long stretches of beach,
    - fire inside of fencing.
- Young fledged terns are still dependent on the care-giving adult so anything that interferes with the parent-offspring bond or their preparations for this long journey may affect their survival. Young birds need to eat and build up their flight muscles, for once they leave North America they may not see land again until they stop briefly in the Caribbean before continuing on to the north coast of South America.
- Human activity too close to resting/staging Roseate Tern disturbs or displaces them, causing the Roseate Tern to expend precious energy and preventing them from feeding and resting.

B. EXAMPLES OF PREDATION MANAGEMENT RELATED PUBLIC OUTREACH
Georgia Research into Predator Control Helps Rare Oystercatchers
BRUNSWICK, Ga. (10/30/2014)

Two years' worth of photographing and trapping raccoons, feral hogs and other predators at American Oystercatcher nest sites is providing needed insight into how and when controlling predators can help these rare red-beaked shorebirds.

The project, supported by a National Fish and Wildlife Foundation grant through Southern Company's Power of Flight program, explored the role of managing predators at key nesting areas for American Oystercatchers. Southern Company is the parent company of Georgia Power.

Once common along the Atlantic and Gulf coasts, oystercatchers numbered only about 10,200 birds as of 2008. The good news, however, is that National Fish and Wildlife Foundation estimates indicate the population is growing again and expected to top 13,200 by 2019.

Researchers in Georgia had predators trapped in some oystercatcher nest sites, set trail cameras at those and areas that weren't trapped to assess predator pressure, and monitored nests. Sites varied from state-protected Little Egg Island Bar in the Altamaha River delta in Glynn County to Little St. Simons and St. Catherines islands. Partners included the Georgia Department of Natural Resources, the University of Georgia, St. Catherines, Little St. Simons and the U.S. Fish and Wildlife Service.

Project leader Tim Keyes, a wildlife biologist with DNR's Nongame Conservation Section, said results are still being sifted following the completion of fieldwork this summer. But some take-homes are clear.

"We were documenting higher nesting success and higher fledgling rates when we did some trapping," Keyes said. "... Generally, I think it confirms that a trapping program is necessary in some areas."

From 121 American oystercatcher pairs documented this year on Georgia's coast, researchers counted 32 chicks, the most ever recorded and production boosted in part by fewer high tides, which can wash over and destroy nests. Biologists banded 28 of the chicks for future monitoring.

"Basically, sites we trapped had chicks survive to fledging," Keyes wrote. "Sites we did not trap had no checks fledge."

Analysis of study data could help resource managers determine where and when shooting or trapping predators – which is time-consuming, costly and sometimes contentious – will most benefit oystercatchers. For example, findings suggest that raccoon activity at some sites seemed to increase near the start of nesting season. Raccoons were the primary predator at nest sites.

Keyes said the project also underscores the importance of nesting areas where there are no raccoons, hogs or coyotes, such as on isolated sandbars like Pelican Spit, St. Catherines Island Bar and the spit at Gould's Inlet.

Unfortunately, these places are usually very low in elevation, ephemeral – lasting only a short time – and prone to overwash. The impact of human and pet disturbance on oystercatchers, which shy from such contact, is another challenge for conserving this and other beach-nesting species.

"Some of these non-predator sites are used by boaters, some of whom let their dogs roam," Keyes said.

In July, a domestic dog killed an oystercatcher chick on Williamson Island, near Little Tybee Island. Pets are prohibited at Williamson, which is designated a "bird island" by DNR and protected as critical habitat for shorebirds and seabirds.

Keyes said about one oystercatcher pair in three must fledge chicks each year to stabilize Georgia's population. While even the increased success rate this summer fell short, the hope is that continued conservation efforts, boosted by the new details on controlling predators, puts that goal within reach.

DNR's Nongame Conservation Section works to conserve American oystercatchers and Georgia's other rare and endangered animals and native plants. Yet the agency receives no state general funds, depending instead on fundraisers, grants and donations.

Help by purchasing the new nongame wildlife license plate – a bald eagle in flight! – or renew your older eagle or Ruby-throated Hummingbird plates. Thanks to a law change this year, you can upgrade to a DNR wildlife plates for only $25 more than a standard tag, and more of those fees will be dedicated to conserving Georgia wildlife.

Supporters can also contribute directly to the Georgia Nongame Wildlife Conservation Fund. These programs support conservation of wildlife not legally fished for, hunted or collected. Learn more at www.georgiawildlife.com/conservation/support.

The National Fish and Wildlife Foundation protects and restores America's wildlife and habitats. Created by Congress in 1984, the foundation directs public conservation dollars to pressing environmental needs and matches those investments with private contributions. The organization works with individuals, foundations, government agencies, nonprofits and corporations.

In 26 years, the National Fish and Wildlife Foundation has funded 3,700 organizations and leveraged $490 million in federal funds into $1.6 billion for conservation. Learn more at www.nfwf.org.

Georgia Wildlife Resources Division

2070 U.S. Hwy. 278, SE, Social Circle, GA 30025

Natural Resource Damage Assessment and Restoration Program

Draft Plan to Restore Piping Plovers from Buzzards Bay Oil Spill

Thousands of gallons of oil spill into the Bay

On April 27, 2003, the Bouchard Barge 120 grounded on a shoal in Buzzards Bay and spilled an estimated 98,000 gallons of No. 6 fuel oil. About 100 miles of shoreline in Massachusetts and Rhode Island were oiled, restricting the public's use of the shoreline and resulting in the death of fish and wildlife, including the piping plover.

Piping plovers are migratory shorebirds that are protected under the federal Endangered Species Act, as well as under the Massachusetts and Rhode Island state Endangered Species Acts.

Trustees assess injuries

Pursuant to the Oil Pollution Act of 1990 and related state laws, when a spill like this occurs, federal and state agencies act on behalf of the public as trustees for natural resources and are given authority to pursue compensation for oil spill-related impacts on natural resources.

Trustees first assess natural resource injuries (known as a natural resource damage assessment or "NRDA") caused by an oil spill; they then determine the appropriate type and amount of restoration needed to compensate for the injuries.

For this case, the natural resource trustees are the U.S Department of Commerce (National Oceanic and Atmospheric Administration), the U.S. Department of the Interior (U.S. Fish and Wildlife Service, or USFWS), the Commonwealth of Massachusetts (Executive Office of

Energy and Environmental Affairs, represented by the Massachusetts Department of Environmental Protection), and the State of Rhode Island (Rhode Island Department of Environmental Management).

When oil began washing onto beaches used by piping plovers that were feeding and nesting, the trustees worked cooperatively with parties responsible for the spill to assess the injuries to piping plovers and to determine damages necessary to compensate for those injuries.

The settlement is based on a negotiated estimate of 12 adult birds and five young that died as a result of the spill. To restore these birds and the young they would have raised, in December 2010, the responsible parties agreed to provide the trustees with $715,000 to implement a comprehensive restoration program for piping plovers, including the costs of

oversight and monitoring. The funds were part of a $6 million settlement that also included damages for shoreline and aquatic injuries and recreational lost use.

A three-part approach to restore piping plovers

In September 2011, the trustees held two public information meetings to describe the restoration planning process and to seek restoration ideas. Based on input received from the meetings and information from biologists familiar with piping plovers, the trustees have prepared a draft restoration plan and environmental assessment for piping plover.

The plan identifies and evaluates five alternatives to restore piping plovers. The preferred alternative is to implement an enhanced management program at breeding

Piping plovers like this one were oiled while looking for food after the spill.

Amanda Boyd/USFWS

USFWS

An intern helps to construct a barrier to help protect piping plover nests from predators.

sites in Massachusetts and Rhode Island. The program would consist of three activities to increase the survival and productivity of nesting piping plovers: predator management, enforcement, and outreach and education. Reducing predation is a key component of the program because predation is currently the most serious threat to breeding piping plovers. It results in the loss of eggs, chicks and adults throughout the piping plover's range. In Massachusetts, nearly 30 percent of nests are unsuccessful in some years due to predation.

Further, as human populations continue to grow, elevated predation pressure from species such as foxes, raccoons, skunks and crows that take advantage of human-supplied food can overwhelm shorebirds like piping plovers, which are much less abundant.

Biologists currently invest significant time and expense to discourage predators and reduce their impacts on nesting piping plovers at numerous sites in Massachusetts

and Rhode Island. Methods currently employed include placing wire exclosures around nests, using electric fencing to keep predators away from nests, and installing perch deterrents to keep predators away from nesting locations.

These activities will continue to be implemented where feasible, but for beaches where predation is one of the primary threats, we propose to selectively remove individual predators that have learned to target plover nests, chicks or adults. Removal efforts will be implemented by USDA-Wildlife services using approved lethal techniques for wildlife damage management.

Reducing predation is an effective way to increase the number of chicks hatched and fledged and to compensate for the losses sustained in the oil spill. The trustees only support removing predators when sound science indicates that it is our last or only resort to meet the wildlife mission of our agencies.

In combination with predator removal, we also propose to increase enforcement of local beach ordinances as well as to undertake additional outreach and education on piping plover nesting beaches. The objective of these management actions is to prevent or reduce activities that harass or harm nesting piping plovers.

Rigorous protection efforts are currently necessary to restore this rare migratory bird. The selected approach will help increase the size and productivity of the plover's population in Massachusetts and Rhode Island.

Providing input on the plan and taking next steps

The trustees are currently seeking public comment on the draft plan. After considering and incorporating public comments, the trustees will prepare a final plan. The trustees will then partner with land managers who are interested in implementing the preferred restoration alternative through projects on-the-ground.

Projects will be awarded later this year through the government's Grants.gov website. Project performance will be monitored to

USFWS

Piping plover chick.

determine if additional measures are needed to improve on the restoration.

Interested members of the public can review and comment on the draft plan. The public may also be able to volunteer or take part in restoration monitoring.

The plan is available at http://www. fws.gov/newengland; hard copies are also available at the Jonathan Bourne Public Library in Bourne and the New Bedford Free Public Library in New Bedford. Please forward written comments by August 1, 2012 to: USFWS, 70 Commercial Street, Suite 300, Concord, NH 03301, attention: Molly Sperduto; or email to molly_sperduto@fws. gov. Comments are due by August 1, 2012.

A separate restoration plan is under development for damages to other natural resources, such as lost recreational use and impacted shoreline and aquatic habitats. More information on those resources can be found at: http://www.darrp.noaa. gov/northeast/buzzard/index.html

For more information, please contact: Molly Sperduto, USFWS, (603) 223-2541, molly_sperduto@fws.gov

Millie Garcia-Serrano, MassDEP, (508) 946-2727, Millie.Garcia-Serrano@state.ma.us

Mary Kay, RIDEM, (401) 222-4700 x2304, Mary.Kay@dem.ri.gov

U.S. Fish & Wildlife Service
1 800/344 WILD
www.fws.gov
June 2012

C. EXAMPLES OUTREACH MATERIALS AND LANDOWNER AGREEMENTS

1. Outreach material–proposed use of DRC-1339 to selectively remove crows
Source: Biodiversity Works, Martha's Vineyard, Massachusetts

Piping Plover nesting on Martha's Vineyard have experienced increasing levels of crow predation on eggs and chicks. While Piping Plover can successfully distract a single crow from their chicks, they are unable to manage multiple crows that work together. Crows have reached unnaturally high populations due to human food subsidies on the landscape (agriculture, bird feeders, shellfish discard piles, compost piles, etc.). As generalist species, crows (both American and Fish Crow) can live in many different habitat types and eat a variety of food. Piping Plover, however, are specialists. They can nest and live only in beach habitats and eat only beach or estuarine invertebrates along the shoreline. While humans have increased habitat for crows, we have decreased habitat for Piping Plover. Some say that this means piping plovers are not 'fit' for today's world. We do not agree. With some assistance, Piping Plover can survive and our beaches can still support a diverse array of wildlife.

We are not fans of lethal control to solve problems, but no methods are available to keep crows away from plover chicks. Crow effigies are ineffective, and any method attempting to frighten crows away will also frighten the plovers and cause disturbance to them. Our goal is to find a method of removing crows that limits predation on eggs and chicks, targeting only crows that are active in areas fenced for Piping Plover.

Proposed methods:
- In early April – at 3 backdune areas - create a symbolic fencing area with signs and posts and string as we typically do to protect Piping Plover nests.

- Build a 'mock' Piping Plover predator exclosure in the center of the fencing, near the primary dune and place 4 hard-boiled eggs inside the wire fence exclosure.

- Place a motion-triggered camera outside of the exclosure to monitor activity.

- Check the exclosure in the afternoon and thereafter twice daily for uptake of bait.

- Check the memory cards on the cameras each day to monitor egg uptake

- Once crows begin taking the bait, USDA –APHIS technicians will come and place 2 - 4 hard-boiled eggs in each of the mock exclosures, each injected with .01 grams of DRC-1339, inside the wire mesh predator exclosure. They will mark the exclosure with a small sign that indicates a poison bait is inside the fencing in case any humans should enter the posted area and walk up to the exclosure. The wildlife cameras will remain on and will continue to monitor uptake.

- The mock exclosures will be monitored daily for uptake. Any bait left unconsumed in the mock exclosure after 5 days will be removed by USDA-APHIS.

- They will return 2 weeks later and apply another round of treated eggs in mock exclosures in slightly different locations in the same general area.

- Application will be completed by May 20, if not before.

How does this avicide kill crows?
Each egg contains a lethal dose for a crow. DRC 1339 is absorbed into the bloodstream of the crow and impairs liver and kidney function. The crow will die 3 – 50 hours after consuming a treated egg. They have not found crows sick or dying on the beach.

Is it possible an egg will be left outside of the fencing by a crow or dropped elsewhere?
The Crane's beach data is on chicken eggs and shows that most of the crows ate the eggs where they found them. Crows do sometimes carry food away and cache it, but that behavior is more typical for shiny trinkets or food that is too large to consume in one meal. At a Martha's Vineyard Site last year, crows consumed eggs inside the fencing or just outside of the fencing.

Will the poison used affect other animals or humans if they consume one of these eggs?
The risk of this happening is very low as the eggs will be inside a 4-foot tall fence. The amount of toxicant in each egg is a small dose, but sufficient to kill a crow because they are highly susceptible to the toxicant. Most predatory birds and mammals require much higher dosages to be toxic. Toxic dose for a sheep would be 130 treated eggs. A mouse would have to consume 300 treated eggs, and a rat 400 for a toxic dose. Animals that eat a crow carcass will not be affected because DRC-1339 is metabolized by the crow and dissipates at a very quick rate. According to USDA Animal and Plant Health Inspection Service (APHIS), raptors and scavenger mammals that were fed blackbirds killed by DRC-1339 for up to 200 days did not show symptoms of poisoning and no deaths occurred.

Eggs will be inside here, but there won't be a net on top.

Example of a Mock Exclosure for Crow Control

There will be signs and a perimeter fence around the exclosure like this one that will prevent people from approaching it. The treated eggs will be in an exclosure like this one for 5 days (Monday – Friday). Then, we will take a break for two weeks, followed by another 5 days (Monday – Friday) of treated eggs.

Image showing crows eating eggs inside mock exclosures at a Martha's Vineyard site last spring.

Available at: http://furbearermanagement.com/trapping-matters-workshops-and-wild-fur-schools/

MESSAGES
To communicate effectively, you must consistently use messages that "ring true" with your target audiences. The messages that will be most effective in communicating about trapping will vary, depending on who the target audience is, the medium of communication used, the source of the information, and many other variables. However, considerable research has shown that the "priority" and "supporting" messages listed below are effective with a broad cross-section of the public.

Priority Messages
Given limited time, space, and/or budget, these messages are the priorities (the first things that should be mentioned in any communication event):
- The kinds of wildlife that are trapped are abundant – regulated trapping does not cause wildlife to become endangered.
- Trapping is managed through scientifically-based regulations that are strictly enforced by conservation officers.
- The state fish and wildlife agency continually reviews and develops rules, regulations, education programs, and capture methods to ensure the humaneness of trapping.
- Regulated trapping provides many benefits to wildlife and people.

Supporting Messages
Following are supporting messages that can be used to expand on and explain the key messages if needed and if time and/or space is available.

It is important to keep in mind that these messages can help explain and support the priority messages, but they are not necessarily by themselves reasons why trapping should be allowed to continue. For example, the fact that nature produces a surplus of animals each year helps explain why regulated trapping does not cause wildlife to become endangered. However, by itself, it's not a reason why trapping should be allowed to continue—robins, cardinals, and other species produce surpluses, but we don't trap them.

The priority messages are listed below (#s 1-4), with appropriate supporting messages listed beneath each one.

1. The kinds of wildlife that are trapped are abundant – regulated trapping does not cause wildlife to become endangered.
    A. Only a few species of wildlife can be legally trapped by licensed trappers.
    B. No threatened or endangered animals are legally trapped, except for protection or restocking programs.
    C. Many wildlife populations naturally produce a surplus of animals each year that can be removed from the wild without harming the populations (sustainable use).
    D. The environment contains only enough food, water, and habitat for a certain number of animals of each species (carrying capacity).
    E. Without the regulated capture and removal of some animals, a wildlife population may exceed its habitat's carrying capacity. Potential results include:
        i   Threats to human health and safety;
        ii   Damage to the animals' habitat;
        iii Damage to agricultural crops or other human structures;
        iv   Death from starvation or disease outbreaks

F.   The trapping of some wild animals is a legal activity in which some Americans choose to participate.

2.   Trapping is managed through scientifically-based regulations that are strictly enforced by conservation officers.
   A. Trapping is endorsed and controlled by trained wildlife professionals who dedicate their lives to ensuring the welfare of animals. [The Wildlife Society (professional society of wildlife management professionals) recently reaffirmed its position on the value of trapping to wildlife management.)]
   B. Trapping is not allowed year-round (except for nuisance control). It is limited to short seasons which help to prevent the capture of females with dependent young.
   C. Most state fish and wildlife agencies provides trapper education courses to ensure that trappers have the most up-to-date information on effective, efficient, humane trapping tools and techniques.

3.   The state fish and wildlife agency continually reviews and develops rules, regulations, education programs, and capture methods to ensure the humaneness of trapping.
   A. State wildlife agencies, working closely with the U.S. Department of Agriculture, state trappers associations, and experienced veterinarians, have spent over $40 million over the past 20 years to develop Best Management Practices (BMPs) for trapping. (BMPs detail the most effective, efficient, humane trapping tools and techniques.)
   B. Wildlife professionals support the use of the best available technology and techniques for trapping (as exemplified by the unanimous support for the best management practices project by state wildlife agency directors).
   C. The Wildlife Society (professional association of wildlife management professionals), endorses best management practices for trapping.
   D. Trappers and wildlife management professionals support these efforts because they care about the welfare of wildlife.

4.   Regulated trapping provides many benefits to wildlife and people.
   A. As a way to maintain a balance between wildlife and people:
      i.   By reducing or preventing damage to agricultural crops and human property
      ii. In certain situations, reducing or preventing threats to human and pet health and safety (e.g. minimizing exposure to diseases such as rabies).
   B. Managing and protecting endangered species such as the least tern, piping plover and sea turtles.
   C. As a way to collect important ecological information about wildlife.
   D. Funding for wildlife conservation -- trapping license fees paid by trappers are used for the protection of wildlife habitat and populations.
   E. In many states, some people rely on trapping of wildlife for food or a source of supplemental income.
   F. Most of the animal can be used: the fur to make coats, gloves, mittens, trim on coats and sweaters; the meat for human food; and the rest of the animal for other by-products such as soap, tires, and lubricants.

2. Landowner agreement–limited predator trapping on private property to benefit Piping Plovers
Source: BiodiversityWorks, Martha's Vineyard, Massachusetts

Thank you for allowing us to protect nesting piping plovers on your private beach property. In most cases, we are able to protect the nests and chicks of these rare birds by roping off nesting areas and using a variety of fencing techniques to prevent predators (crows, skunks, and gulls) from eating the eggs. However, if we are unable to protect the nest with fencing due to the habitat configuration, or if crows have been hunting chicks in the area, or cats are hunting on the beach, some limited trapping, particularly in the spring (late April – end of May) could provide considerable benefit for these rare birds.

Piping Plover and other beach-nesting birds evolved with crows and skunks as predators, but these predator species are far more abundant today than they were thousands or even hundreds of years ago. Skunks and crows have many food subsidies on the Vineyard (agricultural fields, compost piles, shellfish discard piles, lawns, trash on the beach, and natural food) that boost their populations. They are abundant generalist species that can live almost anywhere and eat almost anything while piping plovers are uncommon specialist species living only in beach habitats. Reducing predator numbers on nesting beaches is one option we can use to increase hatching fledging success for all species of beach-nesting birds, and we do not undertake predator trapping without trying other options first.

We have permits from the Massachusetts Division of Fisheries and Wildlife to set restrain traps with bait to capture skunks, crows, and/or cats humanely. The traps all have covers, grass bedding, moist food, and water in warmer weather. We check the traps twice per day (morning and late afternoon). Skunks and crows captured in the traps are euthanized in a Carbon Dioxide (CO_2) chamber, which is a humane method approved by the American Veterinary Association. We remove limited numbers of skunks and crows at each site, which typically means less than 6 skunks and 6 crows in a season. We cannot trap and move these predators to another site because crows would just fly back, and it is illegal to trap and release a furbearer (skunk) elsewhere in Massachusetts (you might spread a disease or virus to a new area).

Any cats captured are boarded (10 days, or until claimed) while we determine if they are a pet, stray, or feral cat. We send a photo to the town animal control officer, post signs with photos in the area, and check with neighbors before we board the cat. If we find the cat's owner, we work with them to find a solution where their cat no longer hunts on the beach during nesting season. If the cat is stray/feral, we take it to a local shelter (with assurances that it will not be released to continue hunting the beach) or we take it to an MSPCA shelter off-island.

At the end of the season, we submit a report on our trapping effort and captures to MassWildlife in keeping with our permit requirements. The report uses general site names and the town.

This document serves as an understanding between BiodiversityWorks (BWorks) and you, the private landowner or caretaker/representative, regarding our limited predator-trapping program, which is supported through a grant from the U.S. Fish and Wildlife Service.

We are requesting your permission to set live traps in areas we discuss with you (backdune areas and footpaths near the beach) to capture crows, skunks, and cats that hunt the beach. All cats are returned to their owner, or taken to a shelter. There are options for crow and skunk removal, so please check boxes to indicate your preference:

1) □ BWorks staff euthanize any captured skunks or crows in a secluded area on site

    (the least amount of stress on them) and …
        □ bury them on site, in a 4 feet deep hole in the backdune.
        □ take them off site and bury them in an appropriate area elsewhere

2) □ BWorks staff transport skunks or crows off-site for euthanasia.

Site Name: _____

Your name: _____Signature _____

Circle one: landowner caretaker   representative
BiodiversityWorks will set traps in approved locations and remove predators according to landowner preference selected.
Staff Name: _____Signature_____

Permit details and contact information for USDA Wildlife Services officials by State. We highly recommend that all users of this document consult tables for details on what permits are required. We also encourage users to partner with appropriate state and federal officials, such as USDA Wildlife Services, when conducting predation management.

State	Migratory bird permit for avian predators		State permit for predator management (mammalian or other)						Comments
	Federal	State	State permit (government agency)	Type of permit	State permit (private contractor)	Type of permit	Permitting/trapping regulations	State trap checks requirements	
CT	Yes	Yes (1,2): 1) Nuisance Wildlife Control Operators; and 2) USDA when performing derpredation projects on federal/state/ municipal lands No: Landowners/ municipalities with Federal Depredation Permits (i.e., gulls, hawks, etc.).	Yes: 1) Agency staff (i.e., Fish Hatcheries); and 2) USDA-when preforming control projects on federal, state, municipal lands, including airports.	Wildlife Damage Control: CGS 26-3 and 26-7	Yes: 1) NWCOs: licensed to provide commercial control for various spp.; 2) NWCOsL Special permits to take certain furbearers (I.e., beaver, muskrat, otter, coyote, fox, mink); and 3) Airport Depredation permit No: Private landowners may take (trap) furbearers damaging property	1) NWCO License 2) NWCO Special Permit, 26-47-1(e) 3) Airport Damage Control CGS 26-3 and 26-7	1) CGS 26-3: Commisioner may take wildlife when damaging property, diseased, threat to people; 2) CGS 26-7: Authorization of Volunteers; 3) CGS 26-47 (b): NWCO Licensing; and 4) CGS 26-47-1(ed): NWCO Special Permit	1 time/day	CT gives 5 day review of proposed Federal depredation permit. CT does not cosgin. USDA doing depredation work for landowners, businesses or municipalities under state MOU.
DE	Yes	DE Cosigns	Yes					1 time/day	
FL	Yes	No (unless a state protected species, covered under Taking Nuisance Wildlife law)	Yes	N/A (See comments section on mammal take)	N/A (See comments section on mammal take)		http://myfwc.com/license/wildlife/nuisance-wildlife	At least 1 time/day	Under state law 68A-9.010 Taking Nuisance Wildlife all mammals (except T and E) can be removed without a permit when causing damage except black bear, deer, bats, and bobcats. Those 4 require their own special permit. Under this law the methods of take are what is regulated. Cage traps, snares, and shooting are allowed under this law but steel traps (Footholds, Conibears, dog proofs) require a speacial permit for use.
GA	Yes	No	Yes	MOU for us. Nuisance Wildlife Control Permit for Government Agencies for others	Yes	Nuisance Wildlife Control Permit	http://georgiawildlife.com/regulations/trapping	1 time/day	
ME	Yes	Yes	No	Scientific collection permit	Yes	Depredation	https://www.maine.gov/ifw/hunting-trapping/trapping-laws/regulations.html	At least 1 time/day	
MA	Yes	MA cosgins	Yes	Special Purpose Letter Depredation Permit	Yes	Problem Animal Control (PAC) License	https://www.mass.gov/service-details/problem-animal-control-agents	1 time/day	[Yes; box traps.] [No; foothold traps (However, yes on Federal Lands as State perceived exception).] [Yes; conibear w/10-day approved permit through Township, Health Dept, and State.]
MD	Yes	MD cosigns	Yes					1 time/day	

State	Migratory bird permit for avian predators		State permit for predator management (mammalian or other)						
	Federal	State	State permit (government agency)	Type of permit	State permit (private contractor)	Type of permit	Permitting/trapping regulations	State trap checks requirements	Comments
NH	Yes	no	No	N/A	Yes	Wildlife Control Operators Levels I and II	http://www.gencourt.state.nh.us/rules/state_agencies/fis300.html (See: Part Fis 303)	1 time/day	See: PART Fis 308 WILDLIFE CONTROL OPERATORS
NJ	Yes	Yes	Yes	Depredation Control Permit	Yes	Depredation Control Permit	Permits - http://www.nj.gov/dep/fgw/pdf/permregs.pdf Trapping - http://www.nj.gov/dep/fgw/trapping_info.htm	At least 1 time/day	Foothold traps are illegal to possess.
NY	Yes	No	Yes	Wildlife Damage Management License	Yes	Deer Damage Permit	http://www.dec.ny.gov/outdoor/9209.html	Depends on zone and trap type.	
NC	Yes	Yes	Yes	Depredation Permit	Yes	Depredation	http://www.ncwildlife.org/ Trapping/Trapping-in-North-Carolina	At least 1 time/day	
PA	Yes	Yes	Yes	Special Purpose Permit/ Depredation Permit	Yes	Depredation	http://www.pgc.pa.gov/HuntTrap/Law/Pages/SeasonsandBagLimits.aspx and http://www.pgc.pa.gov/Wildlife/Pages/NuisanceWildlife.aspx	At least 1 time/day	
RI	Yes	State cosigns	Yes	Special Purpose/ Scientific Collection Permit	Yes	NWCO License	Sections 20-1-18, and 20-1-22, in accordance with the requirements of the Administrative Procedures Act, Chapter 42-35 of the Rhode Island General Laws of 1956, as amended http://www.dem.ri.gov/pubs/regs/regs/fishwild/f_wnusnc.pdf	1 time/day	
SC	Yes	Yes	Yes	Special Purpose Permit/ Depredation Permit	Yes	Depredation	http://www.dnr.sc.gov/regs/furharvest.html	At least 1 time/day	
VT	Yes	Yes	Yes	Scientific collection and Depredation Permit	Yes	Scientific collection and Depredation Permit	http://www.vtfishandwildlife.com/	At least 1 time/day	http://www.vtfishandwildlife.com/
VA	Yes	No	No	N/A	Yes	Commercial Nuisance Animal Permit (Not required if they act under published regulations and seasons).	https://www.dgif.virginia.gov/hunting/regulations/furbearertrapping/	At least 1 time/day	Federal agencies are deemed permitted to take and posess wildlife by 4VAC 15-30-50
WV	Yes	No	Yes	Special purpose	Yes	Nuisance permit at individual level or Wildlife Damage Control Agent	http://www.wvdnr.gov/Hunting/hunting_regs.shtm	At least 1 time/day	

USDA Contact Information by State			
State	**Address**	**Phone***	**Fax**
Florida	2820 East University Avenue Gainesville, FL 32641	(352) 377-5556	(352) 377-5559
Georgia	School of Forestry and Natural Resources University of Georgia Athens, GA 30602	(706) 546-5637	(706) 316-9248
Maine	Capital West Business Center 79 Leighton Road, Suite 12 Augusta, ME 04330	(207) 629-5181	(207) 629-5182
Maryland/Delaware/District of Columbia	1568 Whitehall Road Annapolis, MD 21401	(410) 349-8055	(410) 349-8258
Massachusetts/Connecticut/Rhode Island	463 West Street Amherst, MA 01002	(413) 253-2403	(413) 253-7577
New Hampshire/Vermont	59 Chennell Drive, Suite 7 Concord, NH 03301	(603) 223-6832	(603) 229-1951
New Jersey	140-C Locust Grove Road Pittstown, NJ 08867	(908) 735-5654	(908) 735-0821
New York	572 3rd Avenue Extension, Suite 2 Rensselaer, NY 12144	(518) 268-2290	(518) 477-4899
North Carolina	6213-E Angus Drive Raleigh, NC 27617	(919) 786-4480	(919) 782-4159
Pennsylvania	PO Box 60827 Harrisburg, PA 17106	(717) 236-9451	(717) 236-9454
South Carolina	400 Northeast Drive, Suite L Columbia, SC 29203	(803) 786-9455	(803) 786-9472
Virginia	PO Box 130 Moseley, VA 23120	(804) 739-7739	(804) 739-7738
West Virginia	730 Yokum Street Elkins, WV 26241	(304) 636-1785	(304) 636-5397

*Toll Free Number for all WS State offices: 1-866-4USDAWS (1-866-487-3297). Dialing this number within a state should transfer to that state's office automatically.

Piping Plover chick. Jim Fenton

SUPPLEMENTAL MATERIAL BP8: STANDARD OPERATING PROCEDURES FOR DEMONSTRATION SITES

The following SOP includes information for standardized data collection and entry for the Predation management BP project. This SOP is intended to be reference material to guide you through data entry. Data entry can be conducted via an excel sheet or the online database. If you have any questions not addressed in this document, please feel free to email Kelsi Hunt (hunt0382@vt.edu) or Sarah Karpanty (karpanty@vt.edu) .

You will be asked to fill out either a survey-type, web-based form or Excel spreadsheets with your nest and predation management data for each of your sites. We recommend entering the nest data at the end of the breeding season or after you know the fates of your nests and broods because the nest data includes some metrics related to nest/brood fate. You may enter your predation management data as soon as predation management is complete at your site(s), regardless of timing in the breeding season.

A. NEST DATA ENTRY

After the breeding season is complete, you can enter nest data for your site(s). This section will take you through each of the questions/fields of the **Excel spreadsheet** for demo site nest data entry.
**There are separate sheets (tabs along the bottom of the window) for the nest data and each of the management methods that the demo sites may use. The nest data sheet is the first tab. **

1. **State**
Enter the state abbreviation for the location of your site(s).
2. **County**
Input the county name where your site is located. We will use the "State," "County," and "Site" fields to pair your predation management data with nest data, so this must be consistent across data sheets/fields.
3. **Site (or unique code)**
Enter the site name or a unique code to identify your site. We will use the "State," "County," and "Site" fields to pair your predation management data with nest data, so this must be consistent across data sheets/fields.
4. **Unique Nest ID (nest #)**
This is a unique identifier for a single nest.
5. **Nest Coordinates (if available)**
Enter the lat. long of the nest (UTM), if available. Input the nest latitude into the "Nest Lat" field and the longitude into the "Nest Long" field.
6. **Species**
Enter the 4 letter abbreviation for the species of the nest.
7. **Clutch complete?**
Enter "Y" for "Yes," "N" for "No," or "U" for "Unknown" for whether the clutch made it to completion.
8. **# of eggs at completion or last check**
Enter the appropriate number of eggs for this nest. If the nest failed before completion, input the last known number of eggs/number of eggs present at the last nest check.
9. **Exclosed?**

Enter either "Y" for "Yes" or "N" for "No" for whether the nest was exclosed.

10. Nest Fate

Enter the fate of the nest, either "H" for "Hatched," "F" for "Failed," or "U" for "Unknown."

If "Nest Fate-Hatched"

11. # chicks hatched

Enter the number of chicks hatched from this nest, or enter "U" for "Unknown."

If "Nest Fate-Failed" Selected:

12. Nest Depredated?

Enter "Y" for yes, nest was depredated or "N" for no, nest was not depredated. Enter "U" for unknown.

13. On a scale of 1-5, where 1 is low confidence and 5 is positive, how confident are you that chicks were lost to the predation?

Enter your level of confidence (1-5) in attributing the cause of nest loss to predation. Enter "NA" if you entered "Unknown" above.

14. If nest was depredated, by what type of predator?

Enter the predator species, if known. If the predator was unidentified, enter "U" for unknown.

15. On a scale of 1-5, where 1 is low confidence and 5 is positive, how confident are you that the nest lost to the predator entered above?

Enter your level of confidence (1-5) in attributing the nest predator to that selected in the above question. Enter "-" if you entered "Unknown" above. Enter "NA" if you did not assess this.

16. # chicks fledged

Enter the number of chicks that fledged from this nest. Enter "U" for "Unknown" if you attempted to follow chicks to fledging but could not determine their fate, and enter "NA" if you did not follow chicks post-hatch.

17. Chicks Depredated?

Enter "Y" for yes, chicks were depredated or "N" for no, chicks were not depredated. Enter "U" for unknown.

18. On a scale of 1-5, where 1 is low confidence and 5 is positive, how confident are you that chicks were lost to predation?

Enter your level of confidence (1-5) in attributing the cause of mortality to predation. Enter "-" if you entered "Unknown" above. Enter "NA" if you did not assess this.

19. If chicks were depredated, by what type of predator?

Enter the predator species, if known. If the predator was unidentified, enter "U" for unknown.

20. On a scale of 1-5, where 1 is low confidence and 5 is positive, how confident are you that chicks were lost to the predator selected above?

Enter your level of confidence (1-5) in attributing the cause of mortality to the predator selected in the above question. Enter "-" if you entered "Unknown" above. Enter "NA" if you did not assess this.

21. Comments

Enter any additional comments you have that were not addressed in the above fields.

22. Data Entered by

Enter the name of the contact person responsible for data entry. If we have questions about the data, we will contact this person for clarification.

B. PREDATION MANAGEMENT DATA ENTRY

After you have completed predation management at your site, you may begin entering the predation management data for each of your sites. This section will take you through each of the questions/fields of the **Excel spreadsheet** for predation management data entry.

There are separate sheets (tabs along the bottom of the window) for each of the management methods that the demo sites may use. If you conducted a management method that is not included, please email Kelsi Hunt (hunt0382@vt.edu), and she will update the spreadsheet for you.

1. **Cost of Activity**

Enter the cost of the management activity. If you are not able to determine the cost of the specific management activity, input the total cost of predation management for a single session/season and indicate that it is the total cost by entering "(Total)" after the amount. For example, $10,000 (Total).

2. **Any Non-target species affected? If so, describe**

If any non-target species were affected by the management activity, enter the species name followed by a colon and the description of how the species was affected by the activity.

3. **Comments**

If there are additional comments about the management activity, please include them here. We are not looking for any specific information here, but if you have something that you feel is necessary information that is not included in the other sections, you can add it here.

4. **Date**

Enter the dates when the management activities were conducted. Each line of the data sheet should correspond to one day. Enter dates as "mm/dd/yyyy".

5. **State**

Enter the appropriate state abbreviation for your site(s). (For example, VA)

6. **County**

Enter the name of the county where your site is located.

7. **Site (or unique code)**

Input the site names or a unique code to identify your site. We will use the "State," "County," and "Site" fields to pair your predation management data with nest data, so this must be consistent across fields in the different sheets.

8. **Who conducted?**

Enter the agency or organization that conducted the management activity.

9. **Total Number of X**
   A. **Trapping**

In the "Trap Type x" fields, enter the trap types you used at your site. For example, Leg Hold, Conibear, Bal Chatri, etc. Under the appropriate field, enter the number traps set on the indicated date.

   B. **Shooting: This field is not present**

   X. **Poisoning**

Enter the total number of bait stations used on the indicated date.

   Δ. **Trap/Relocate**

In the "Trap Type x" fields, enter the trap types you used at your site. For example, Leg Hold, Conibear, Bal Chatri, etc. Under the appropriate field, enter the number traps set on the indicated date.

   E. **Taste Aversion**

Enter the total number of bait stations used on the indicated date.

10. **Species X**

In the "Species x" fields, replace the "species x" text with the name of the predator species that you targeted with the trapping, shooting, poisoning, etc. method. You may create new columns if there are not enough to cover all of the species that you targeted. Enter all of the species that you targeted, even if you were not successful in removing any individuals!

Under the appropriate species column, enter the number of individuals removed on each day the method was conducted (enter "0" if no individuals were removed).

Refer to the "Example_TrapData" tab to see an example of predation management data entry.

American Oystercatcher populations are on the rise. Predator management is one tool implemented at some sites based on recommendations of the American Oystercatcher working group and likely a factor in the increase. ©Kat Vitulano