A SHOREBIRD MANAGEMENT MANUAL

manomet

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COVER PHOTO: A single Semipalmated Sandpiper chick hatched in the Arctic represents hope for restoring and growing shorebird populations today and in the future through habitat management, collaboration, and conservation actions taken across the Americas. *Photo Credit:* Shiloh Schulte

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Foreword

In 1992, Manomet published the Shorebird Management Manual (Helmers, 1992). Many things have changed since that publication, but shorebirds are still in great conservation need. This revised *Shorebird Management Manual* (hereafter, *"Manual"*) was developed by Manomet with guidance from a Steering Committee of shorebird experts, contributing authors, and the cumulative work of hundreds of conservation scientists, ornithologists, and land managers. The Manual serves as the base curriculum for regional workshops delivered by Manomet to conservation practitioners and stakeholders throughout North America, Central America, the Caribbean, and South America. This Manual is also a stand-alone resource to help guide habitat improvements that benefit shorebirds, and a support document for planning efforts at the flyway, national, regional, and local levels. The authors provide an overview of management actions designed to reduce the impacts of threats to shorebirds, with hope that these can be adapted and applied wherever shorebirds fly. Shorebirds need your help, at whatever spatial scale, wherever you work, to improve the habitat conditions that they need to survive.

Acknowledgments

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We have learned from, and are thankful to the biologists and managers who have selflessly shared advice and field experiences with Manomet staff at shorebird management workshops since the 1990s. This document builds upon the guidance provided by Helmers (1992) and subsequent content developed and shared by Brian Harrington throughout his career. We acknowledge the lifetime work and career of Leigh Fredrickson, whose contributions to wetland management continue today. We are grateful for all those who work to improve the habitat conditions that support local and long-distance migrant shorebirds.

The general outline of this document was informed by nine land managers and biologists from Brazil and the United States. Two documents were heavily summarized here: Mengak et al., 2019 and Hunt et al., 2018. We are indebted to the authors of these significant documents. We are extremely grateful to Natasha Atkins for structural edits, Alden Blodgett for an overall editorial review of this manual, and Cheri Natalino for document layout and design.

STEERING COMMITTEE:

» Juliana Almeida, SAVE Brasil
» Brad Andres, United States Fish and Wildlife Service
» Stephen Brown, Manomet
» Mirta Carbajal, Fundación Inalafquen
» Mark Colwell, Humboldt State University
» Brian Harrington, Manomet
» Doug Helmers, United States Fish and Wildlife Service
» Chuck Hunter, United States Fish and Wildlife Service
» Jim Lyons, United States Geological Survey
» Felicia Sanders, South Carolina Department of Natural Resources
» Jason Olszak, Louisiana Department of Wildlife and Fisheries
» Michael Reed, Tufts University

CONTRIBUTING AUTHORS:

» Ana Agreda, Aves y Conservación/ BirdLife in Ecuador
» Brad Andres, United States Fish and Wildlife Service
» Maina Handmaker, Manomet
» Arne Lesterhuis, Manomet
» Ricardo Matus N., Centro de Rehabilitación de Aves Leñadura
» Pablo Petracci, Gekko-Universidad Nacional del Sur
» Lisa Schibley, Manomet
» Abby Sterling, Manomet

CASE STUDY AUTHORS:

» Ana E. Agreda, Aves y Conservación/ BirdLife in Ecuador
» Brad Andres, United States Fish and Wildlife Service
» Hector Caymaris, Sistema Nacional de Áreas Protegidas de Uruguay
» Mark Colwell, Humboldt State University
» Sarah Dawsey, United States Fish and Wildlife Service
» Jamie Dozier, South Carolina Department of Natural Resources
» Soledad Ghione, Sistema Nacional de Áreas Protegidas de Uruguay
» Greg Golet, The Nature Conservancy
» Sebastian Horta, Sistema Nacional de Áreas Protegidas de Uruguay
» Julia Kelly, National Audubon Society
» Rebecca Magnus, Nature Saskatchewan
» Danielle Montijo, National Audubon Society
» Jason Olszak, Louisiana Department of Wildlife and Fisheries
» Catalina Parrague, Centro de Estudio y Conservación del Patrimonio Natural
» Robert Penner, The Nature Conservancy
» Kristin Sesser, Point Blue Conservation Science
» Khara Strum, Audubon California
» Brad Winn, Manomet

ADDITIONAL REVIEWERS:

» Dean Demarest, United States Fish and Wildlife Service
» Jeffrey Gleason, United States Fish and Wildlife Service
» Heath Hagy, United States Fish and Wildlife Service
» Karis Ritenour, Manomet
» John Stanton, United States Fish and Wildlife Service

PURPOSE

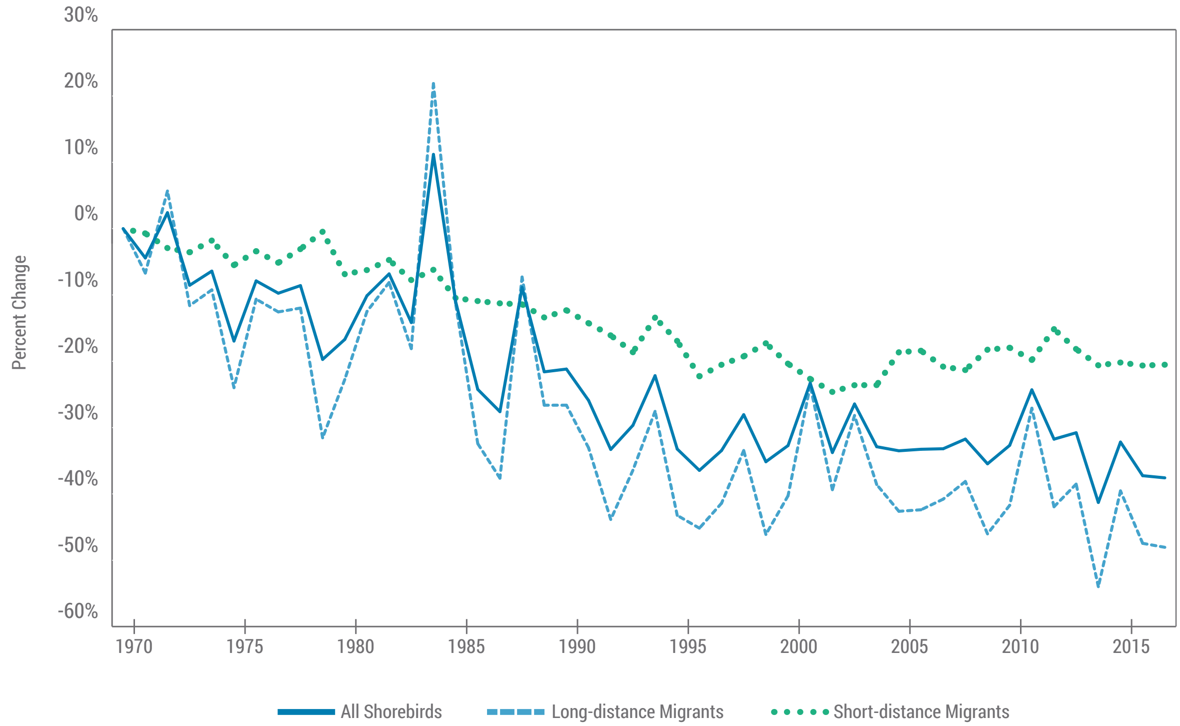
The fundamental goal of this *Manual* is to provide technical support that can help stabilize declining populations of shorebirds in the Americas by providing information to those with the ability to influence or implement beneficial management decisions. Habitat management can help restore shorebird survival and productivity and geographic ranges.

This *Manual* provides information about shorebird ecology, major threats, conservation needs, and suggested approaches to implementing management actions to ensure that habitat needs of shorebirds are met throughout their extraordinary migrations. By compiling this information, we aim to improve the collective understanding of shorebird needs at local, regional, national, and international scales. This information can help site managers recognize local habitat values, understand the stressors or threats to the birds using those habitats, and identify applicable management strategies.

Existing resources provide additional information, syntheses, and expert knowledge about shorebird ecology and techniques to manage wetlands, uplands, and coastal areas in ways that benefit shorebirds as well as other wildlife (Helmers, 1992; Harrington, 2003, 2007; Colwell, 2010; Ma et al., 2010). Recent research and advances in our understanding of shorebird movements and population trends, coupled with continuing and emerging threats, provide the motivation for this *Manual*.

Introduction

Shorebird habitats are some of the most heavily impacted landscapes throughout the world (Galbraith et al., 2002; Sutherland et al., 2012; Murray et al., 2014; Watts and Turrin, 2016). **The destruction and degradation of wetlands, grasslands, and coastlines throughout the Americas over the last century have contributed to the decline and imperilment of shorebird populations (Winn et al., 2013; Atlantic Flyway Shorebird Initiative (AFSI) Business Plan, 2015; Senner et al., 2016). This makes it increasingly important to protect and manage remaining lands in ways that support shorebirds on, unfortunately, fewer and fewer hectares.**



Shorebird populations in North America have declined by almost 40 percent. Long-distance migrating shorebirds have suffered steeper population declines. Data from Rosenberg et al. 2019.

Nonbreeding Red Knots in coastal Georgia USA.
Photo Credit: Brad Winn

Shorebirds use habitats on both public and private lands in many countries. Thirty-four percent of sites in the Western Hemisphere Shorebird Reserve Network (WHSRN) include some level of private land ownership. An estimated two-thirds of migrating shorebirds in the contiguous 48 United States visit professionally managed wildlife areas (Harrington, 2003). Fortunately, studies show that targeted management can provide habitat conditions that shorebirds respond well to, on public and private lands (Harrington, 2003; Elphick et al., 2010; Riensche et al., 2015; Hovick et al., 2017). Beyond shorebirds, improving coastal, grassland, and wetland systems benefits humans by increasing recreation and aesthetic values, improving water quality and groundwater availability, managing flood water, preserving historic and archaeological values, and supporting fish and other wildlife populations (Millennium Ecosystem Assessment Program 2005, U.S. EPA, 2016).

Many shorebird species in the Western Hemisphere and around the world, exhibit alarming population declines (Morrison et al., 2001, 2006; International Wader Study Group, 2003; Milton, 2003; Andres et al., 2012; Rosenberg et al., 2019; Smith et al., 2020). Populations of some of North America's common shorebird species have been declining at rates that point to endangerment within a few decades (Brown et al., 2001; Morrison et al., 2001; Bart et al., 2007; Rosenberg et al., 2019). In most cases, the exact causes of the declines are unknown. Among Arctic-breeding species, declines are likely linked to habitat loss and change in areas used during migration and nonbreeding seasons and to exceeding sustainable harvest levels resulting from hunting (Watts et al., 2015; Weiser et al., 2017). As for temperate-breeding species, loss of nesting habitat, human-related disturbance, and invasive species are significant contributors to population declines (U.S. Fish and Wildlife Service, 1985, 1993; Guntenspergen and Nordby, 2006; Engeman et al., 2010; Sutherland et al., 2012; Munro, 2017).

Of the 57 North American shorebird taxa assessed in 2016, 31 are listed as high conservation concern or greatest conservation concern, or are listed under the U.S. Endangered Species Act. For many species, there simply are not enough data to identify a trend direction (U.S. Shorebird Conservation Plan Partnership, 2016). In 2019, a preliminary status assessment of the 35 shorebird species that breed in Latin America and the Caribbean concluded that more than half are of moderate concern or worse, with two species highly imperiled, six species of high concern, and 17 of moderate concern (Lesterhuis and Clay, 2019).

Piping Plover family in Cape Cod, MA USA. *Photo Credit:* Barbara Folger

Conservation Plans and Networks

Large-scale and geographically specific shorebird conservation plans and strategies such as the Atlantic Flyway Shorebird Initiative (Winn et al., 2013; Atlantic Flyway Shorebird Initiative (AFSI) Business Plan 2015), Pacific Americas Shorebird Conservation Strategy (Senner et al., 2016), and country-wide initiatives for shorebird conservation in Brazil, Canada, Colombia, Ecuador, Mexico, and the United States have been developed in the last two decades (Appendix 1). In some cases, regional shorebird conservation plans exist at the state or site level. Together, this growing collection of plans and planning processes represents unprecedented coordination, collaboration, and commitments to protecting shorebirds in the Western Hemisphere. Taken together, these guiding documents outline regional, country-specific, and flyway-wide conservation needs, targets, threats, strategies, and actions to conserve shorebirds across multiple scales.

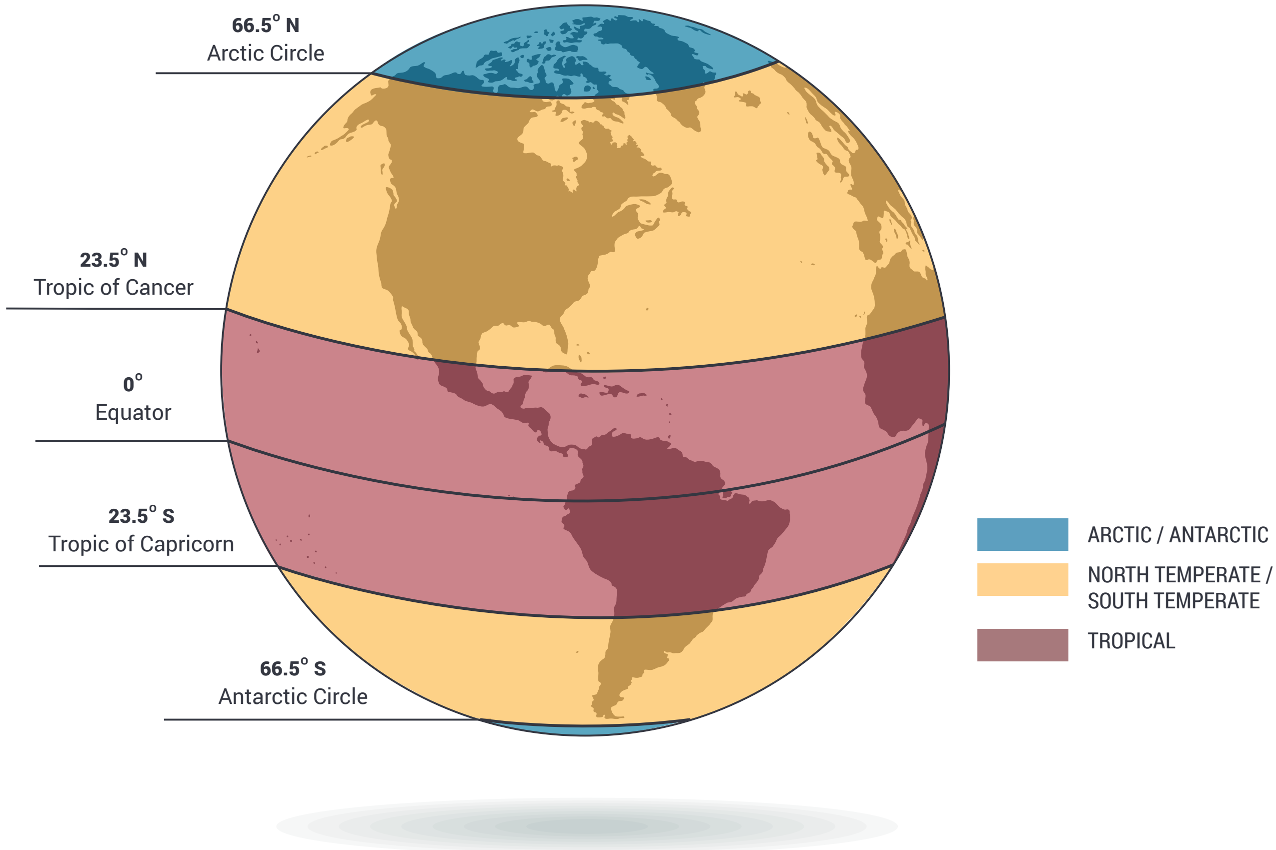
> Improved management of the areas that shorebirds rely on throughout their annual cycle, during migratory, breeding, and nonbreeding periods is a recommendation made in many conservation plans (Atlantic Flyway Shorebird Initiative (AFSI) Business Plan 2015; Senner et al., 2016).

The United States Shorebird Conservation Plan (Brown et al., 2001) divides the U.S. into "shorebird planning regions," each of which is comprised of Bird Conservation Regions defined by the North American Bird Conservation Initiative that are largely compatible with Migratory Bird Joint Venture planning regions. In most cases, Migratory Bird Joint Ventures in the United States and Canada have defined regional shorebird objectives and priority species to guide conservation efforts (Appendix 2). All U.S. states have developed State Wildlife Action Plans, some of which include state-specific priority shorebird species (Appendix 3).

Further, there are multiple organizations and networks that identify and work to protect important areas for shorebirds, including the Western Hemisphere Shorebird Reserve Network (WHSRN), BirdLife International's Important Bird Area program, and the Convention on Wetlands of International Importance, also known as the Ramsar Convention.

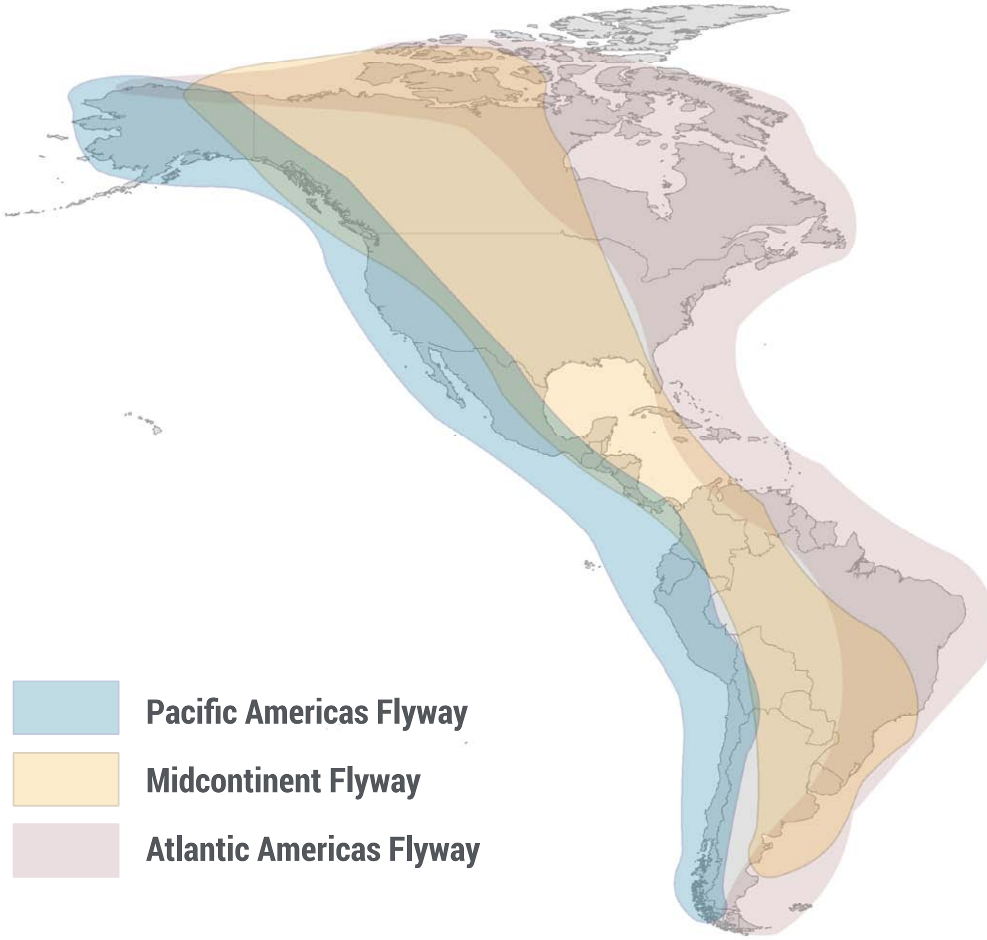
Management Framework

Shorebirds inhabit Arctic, sub-Arctic, North Temperate, Tropical, South Temperate, and Antarctic regions in the Americas. Seventy percent of shorebird species that occur in North America (37/53) and 47% of all shorebird species in the Americas (37/79) breed in Arctic and sub-Arctic habitats. While northern breeding grounds need protection, in most cases through regulatory measures, habitat management can be difficult in the Arctic. **This Manual therefore focuses on management strategies to improve productivity and survival within the Americas south of the Arctic.** Conditions on the nonbreeding grounds affect survival rates of long-distance migrants (Weiser et al., 2017; Rakhimberdiev et al., 2018). Changing conditions in the Arctic may affect this pattern, but evidence suggests that good habitat conditions in the temperate regions can mitigate some of the negative effects of a changing climate wherein long-distance migrating shorebirds will need to refuel more rapidly as they migrate towards breeding grounds (Rakhimberdiev et al., 2018).



Shorebirds use habitats all across the globe. In the Americas, shorebirds use habitats in Arctic, Subarctic, North Temperate, Tropical, South Temperate, and Antarctic regions. The Subarctic is immediately south of the Arctic and generally occurs between 50 N and 70 N depending on location.

Important guidance exists for flyway-wide conservation in the Atlantic and Pacific flyways, and a Midcontinent flyway strategy will soon follow. However, this *Manual* does not use flyways as a framework for management design. Rather, it highlights management choices that can alleviate particular threats to shorebirds in different habitat types, while recognizing that these habitats are linked by migratory patterns.



Generalized map of migratory shorebird flyways in the Americas. *Original source:* Boere et al., 2013.

Some shorebirds use elliptical or latitudinal migratory pathways that blur the boundaries between human-defined north/south flyways in the Americas. In some cases, species migrations are not well captured by the flyway concept and break with conventional wisdom of what migration looks like. For example, Marbled Godwits* have disjunct breeding areas in the prairies of the western United States and southern Canada, but a small number nest in the southern Hudson Bay and James Bay coastal tundra lowlands of Canada. Nonbreeding areas include the Pacific Coast from California into Mexico and the western rim of the Gulf of Mexico. However, a smaller number of nonbreeding birds use the southeastern United States in coastal South Carolina, Georgia, and Florida. Challenging our conventional flyway concept, Marbled Godwits wintering in the southeastern US cross to the western prairies/plains to breed, and Pacific coast wintering birds are known to use both the western prairie and farther east to the Hudson Bay Lowlands, creating a migratory "X" pattern across North America (Olson et al., 2014).

Therefore, the Manual focuses on in situ land and water management implementation, designed to protect, improve the quality, increase the availability, and add to the quantity of key habitat features that benefit shorebirds in all parts of their annual life-cycle. We include resources for increasing public awareness as a means to reduce threats, and we provide tools to incorporate shorebirds into management planning. "Case studies" derived from conservation practitioners, professional biologists, and area managers provide examples of efforts that have reduced threats (e.g., human disturbance, predation) at different stages of shorebirds' annual cycles (e.g., nonbreeding, migration, and breeding).

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* Scientific names for all focal shorebird species in this manual are provided in Appendix 4. Scientific names of non-shorebird species mentioned incidentally are included within the text.

Shorebird Management

What shorebird species might you expect in your area?

- Navigate to page 16 to discover two excellent tools.
- Explore Bird Guides and reach out to local ornithology clubs like Audubon chapters or local biologists.

Shorebird management is referred to in this Manual as an individual action or a sum of actions needed to reverse the negative influences on shorebirds and/or the habitats that support them at the site or regional scale.

Management for shorebirds can include but is not limited to:

» Altering human behavior to alleviate negative impacts directly affecting birds or their habitats

» Educating the public to build supportive constituencies

» Exclusion of human access

» Implementing protective regulation

» Limiting or eliminating the impacts of feral and/or domestic animals

» Improving the physical condition of local environments

» Improving the biological integrity of a site

» Improving habitat quantity

» Reducing, eliminating, or mitigating threats

Managing for shorebirds aims to ensure that adequate food and roosting habitats are available when the birds arrive at a specific site and throughout their stay. Additional conditions are necessary to support nesting shorebirds. A good first step is to assess which shorebirds use the site, the chronology of their occurrence, and the habitats they require. Knowing how, when, and which shorebirds use the site will inform the focal areas for habitat improvements and the time of year when management initiatives should be applied to meet shorebird needs. Some management practices, such as clearing vegetation to improve invertebrate production and availability, will need to happen weeks or months before shorebirds arrive. Understanding the range of threats to shorebirds at the site, the underlying causes of the threats, and any potential opportunities or future actions that may affect shorebirds at the site will help plan management actions.

Both ecological and social landscapes provide key information about how to engage the local community and government in support of your goals. Understanding the political landscape, local community needs, and knowledge about how humans use and value an area will influence how, when, and what management actions are possible. Ecological details about the site such as seed bank, soil type, aquatic invertebrate community, hydrology, phenology of regional shorebird use and movements, needs of other wildlife, access to water, and temporal nature of threats may all factor into decisions about management actions.

Managing habitats to benefit shorebirds requires site-based and flyway-wide collaboration to ensure shorebirds are able to thrive. *Photo Credit:* Monica Iglecia

Management activities will vary in appearance and function at each site and may require a combination of approaches to achieve a desired outcome. Well-timed management implementation and patience over time will allow the benefits of management actions to take root and the desired outcomes to be realized. Connecting with and sharing lessons learned with other conservation practitioners and stakeholders can help identify potential local, national, and international partners to help with habitat improvements.

Factors That Inform the Focus of Habitat Management

Species — Shorebird species have different habitat requirements. Knowledge of these habitat needs form the basis for targeted management.

Timing of Occurrence, Length of Stay — The time of year that shorebirds use your area will determine when habitats will need to be available. Additional information such as the mean length of stay for priority species and their abundance can help set regional objectives and habitat provision needs.

Life Cycle — The life stage in which shorebirds are using your site will influence the focus of habitat management. Migrating and nonbreeding shorebirds require food resources, areas to roost, and safety. In addition to those parameters, breeding shorebirds need safe areas for nesting and rearing young. In inland wetland sites, breeding shorebirds require persistent water sources throughout the duration of the breeding season.

Water Depth — Most, but not all, shorebirds require saturated substrate or shallow water where they forage (Appendix 5). The availability of shallow water and the seasonality of that shallow water will determine if shorebirds are able to use your site. In some cases, like impounded wetlands, wetlands in restoration, or coastal sites where islands and other improvements are being modified, pay attention to the topography of a site and the slope angle along edges. Shallow sloping sides provide habitat because the edges are slowly exposed or covered as wetlands are gradually drawn down or flooded up or as the tide changes throughout the day.

Vegetation — Most shorebirds use open landscapes with minimal vegetation for foraging, roosting, and breeding (Appendices 5 and 6). There are a few exceptions (e.g., snipes). Vegetation provides organic matter that supports invertebrate population growth. However, unmanaged annual and perennial vegetation can become problematic and even exclude shorebirds from otherwise suitable habitats. Invasive and problematic species can also change the dynamic of shorebird habitats.

Food Resources — Water depth, salinity, seasonal flooding, temperature, oxygen, and vegetation can affect invertebrate population growth and densities (Fredrickson, 1991; Fredrickson and Reid, 1991; Laubhan and Fredrickson, 1993; Green and Hilton, 1998; Hynes, 2001). Active management in certain habitats like playas can boost food

What shorebird species might you expect in your area? Here are a few resources to help you find out.

EBIRD

- Go to ebird.org.
- Select Explore >> Select Explore Hotspots.
- Zoom in to your area (e.g., eastern end of St. Croix, United States Virgin Islands).
- Select a nearby Hotspot and view Bar Charts.
- You can use the list of species as a starting point for the species to expect and the bar charts as a framework for understanding when species may be present in your area.
- If a particular hot spot has relatively few visits, a county-level aggregation might be a better source of information about abundance. To see a county-level bar chart use the "Change Location" button on the upper left to select a new region.

INTERNATIONAL SHOREBIRD SURVEY (ISS) MAPPING TOOL: MANOMET.ORG/ISS-MAP/

- The mapping tool holds all data that has been contributed to ISS, the Caribbean Waterbird Census, and Coastal Shorebird Survey (South America).
- Select ISS, CWC, and/or CSS depending on the data you would like to view. Different projects have different color pins for easy identification.
- Select your country (and state if appropriate).
- Select Custom Years; or select 1974 to your current year to see all data.
- Click on "Show Map" to render the data selected. Each pin is an ISS site.
- Click on a pin on the map to bring up a list of shorebirds seen by ISS contributors at that site.
- Click on a shorebird species to see when and how many were seen.
- Click on the date in this page to see the complete original ISS survey.
- Since ISS surveys are generally conducted where shorebirds are seen, finding pins in your area can lead to a better understanding of where species may be present.
- To further analyze shorebird data in your area, download data directly to your computer. After you have selected your years/region/shorebird species parameters, the download button creates a .csv file that holds all the data within those parameters. For a subset of data displayed, you can use the polygon tool (small polygon icon at the top of the map) to select a region of pins. Hitting the download button will send you data within that polygon.

resources (Anderson and Smith, 1998; Davis and Smith, 1998). Appropriately timed slow or staggered draining or flooding during migration can extend shorebirds' access to invertebrates in managed wetlands and agricultural fields. Along coasts, dominant food resources may include specific types of invertebrates or their eggs, if they are the right size and in high abundance. In all habitats, structural vegetation and detritus support diverse assemblages of invertebrates throughout their life stages.

Landscape Associations — Landscape variables can influence habitat use by shorebirds at local and landscape scales. Higher shorebird abundance and richness has been observed in seasonal wetlands between 40 - 95 ha in size (Reiter et al., 2015); models suggest that the highest numbers of shorebirds are expected in wetlands where 15 - 45% of the surrounding 10 km buffer are flooded. When prioritizing water allocation or wetland management for shorebirds, this suggests that, ideally, habitat provision should be clustered together rather than separated across the landscape. We note, however, that particular needs might differ by species; so, when possible, management actions should be carried out using approaches that allow for learning and adaptive management (Macnab, 1983).

QUESTIONS TO HELP IDENTIFY SHOREBIRD NEEDS AT YOUR SITE

- How do shorebirds use the site? Are they breeding, migrating, nonbreeding?
- What species use the site?
- What is the timing of use at the site? What time of year do shorebirds arrive? How long do they stay? When do they leave?
- Does habitat change at the site over the course of the year?
- What are you trying to achieve? (e.g., nesting, foraging, roosting habitat?)
- What landscape considerations need to be made?
- What are the major local threats?
- What is the severity of the threat?
- What is the duration of the threat? Brief or extended?
- Do threats change over the course of the year? (e.g., seasonal recreation)
- What is the geographic extent of the threat?
- What is the proximity of birds to the source of the threat?
- Are the birds conditioned to the threat?

Creating a Site-Specific Shorebird Management Guide

A Shorebird Management Guide (hereafter Management Guide) describes how shorebirds use an area of interest and defines a series of actions that can be taken to reduce local threats and improve conditions for shorebirds. We recommend you develop a site-specific Management Guide with the fundamental goal of this Manual in mind: to help stabilize declining species and restore their populations (**Appendix 7**).

The focus of a Management Guide should be an area or subset of area over which there is some level of jurisdiction for decision-making, like a National Wildlife Refuge, a Wildlife Management Area, a privately owned wetland, or a municipal property. A Management Guide includes a general introduction describing the site, land ownership, and the human context of the area, including a description of potential partners and other stakeholders that should be engaged in future activities. The Management Guide can include maps identifying the area of interest and highlighting areas of high shorebird use, as well as regions where focused threats exist, such as incompatible human activity or a stand of problematic cattails. Identifying conservation targets provides the framework for focused habitat-management actions that will be guided by the list of shorebird species, including priority species, as well as a description of how shorebirds use the area, when shorebirds rely on the region, and what types of habitat are required by the specific shorebirds of interest.

Identifying the threats to shorebirds is an important next step that will inform the objectives, conservation strategies, and management actions with an associated timeline that will be necessary to improve habitats. A Site Assessment Tool developed by the WHSRN Executive Office provides a good framework for assessing threats.

Defining clear objectives within a Management Guide should take into account the natural resource values provided at the site within the larger landscape context and within the life cycle of the shorebirds using the area. Objectives should be quantitative and descriptive if possible. After describing the suite of actions being recommended for the site, it will be important to review the available budget, equipment, skills, and staff capacity and to outline what additional expenses may be incurred by implementing the Management Guide. In some cases, staff may be adequate, but additional equipment may be necessary, or vice versa.

Lastly, and importantly, review the objectives and define the monitoring needs that will be used to measure progress towards meeting those objectives, as well as thresholds that will need to be met in order to meet specific objectives. Data collected using a monitoring protocol will be used to inform actions to address changing conditions at the site, provide guidance if certain actions are not achieving the desired outcomes, and address future decisions.

Photo Credit: Brad Winn

Shorebirds

Shorebirds are a diverse group of birds in the order Charadriiformes. There are 81 shorebird species regularly observed in the Americas (Clements et al., 2019). These species include some of the world's champion migrants, as well as species with restricted ranges. More than three-quarters of these shorebird species are within two families: Charadriidae (plovers) and Scolopacidae (sandpipers, snipes, phalaropes) (Warnock et al., 2001). Hawaiian Stilt (*Himantopus mexicanus knudseni*) and Tuamotu Sandpiper (*Prosobonia parvirostris*) are not included in this *Manual* because their range falls outside of the core geography of the Americas. Other waterbirds, such as 1. seabirds, including gulls, terns, skimmers, and pelicans, 2. wading birds, including herons, egrets, storks, and ibis, 3. songbirds that use wetlands, and 4. secretive marsh birds like rails, are not considered shorebirds in the context of this *Manual*.

FAMILY	NUMBER OF SPECIES
Burhinidae	2
Charadriidae	19
Chionidae	1
Haematopodidae	4
Jacanidae	2
Pluvianellidae	1
Recurvirostridae	3
Rostratulidae	1
Scolopacidae	44
Thinocoridae	4

Taxonomic families of the 81 shorebird species of the Americas.

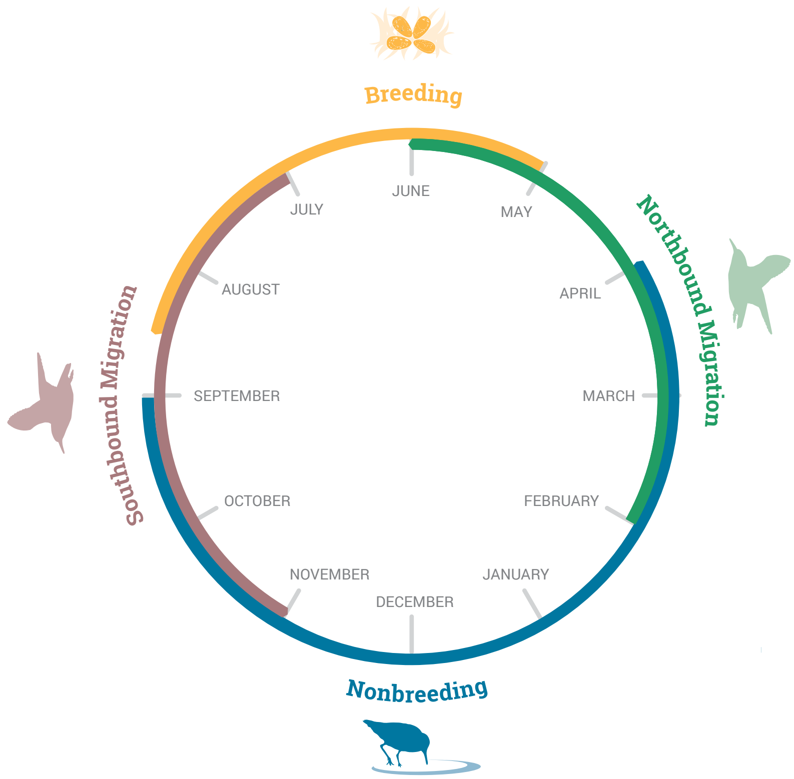
Some shorebirds are difficult to identify, and this is compounded by seasonal plumage changes. Most shorebirds molt (shed their feathers) twice each year, usually with substantial changes in color between breeding and nonbreeding seasons. Identification aids include differences in body size, structural features like length and shape of the bill, and leg length and color. Sometimes, calls or specific behaviors are used to distinguish between similar species.

As a group, shorebirds can be highly opportunistic and forage almost anywhere there are available resources and suitable conditions. As such, categorizing shorebirds by the primary habitat they use and foraging guilds works for some species some of the time but for no species all of the time (Appendix 4). Aligning species by the areas they frequent can be useful when thinking about habitat management.

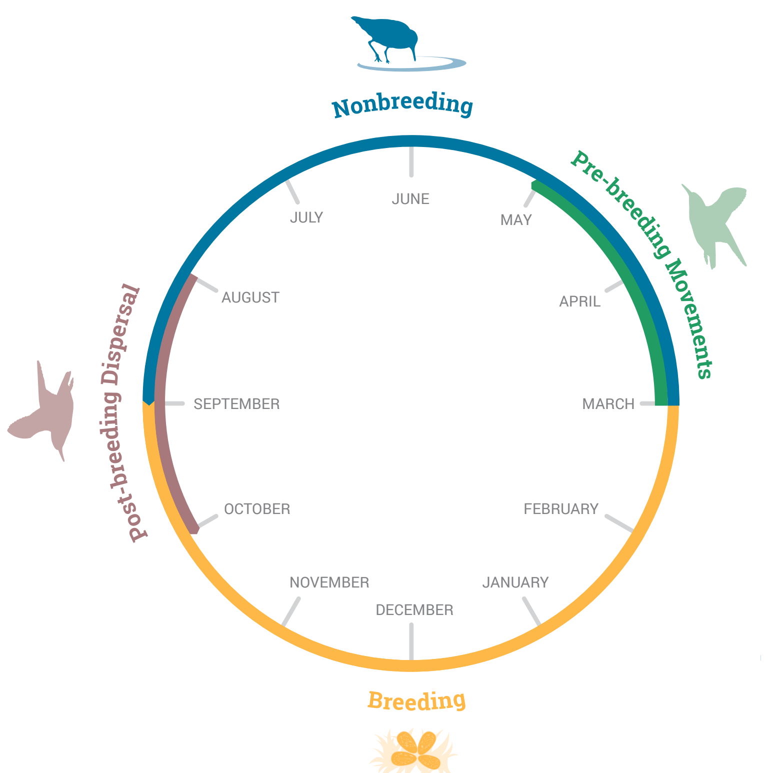
Life History

MIGRATION

Over 80% of shorebird species in the Americas are migratory, making some seasonal movement between nonbreeding and breeding areas. While many shorebirds migrate from Arctic and sub-Arctic breeding grounds to nonbreeding areas in Central and South America, some shorebirds do not migrate at all or move only short distances (Appendix 8). Shorebirds can spend nine months of the year in migration and on their nonbreeding grounds (Burger 1984).



Generalized annual life cycle for migratory shorebirds that breed in North America.

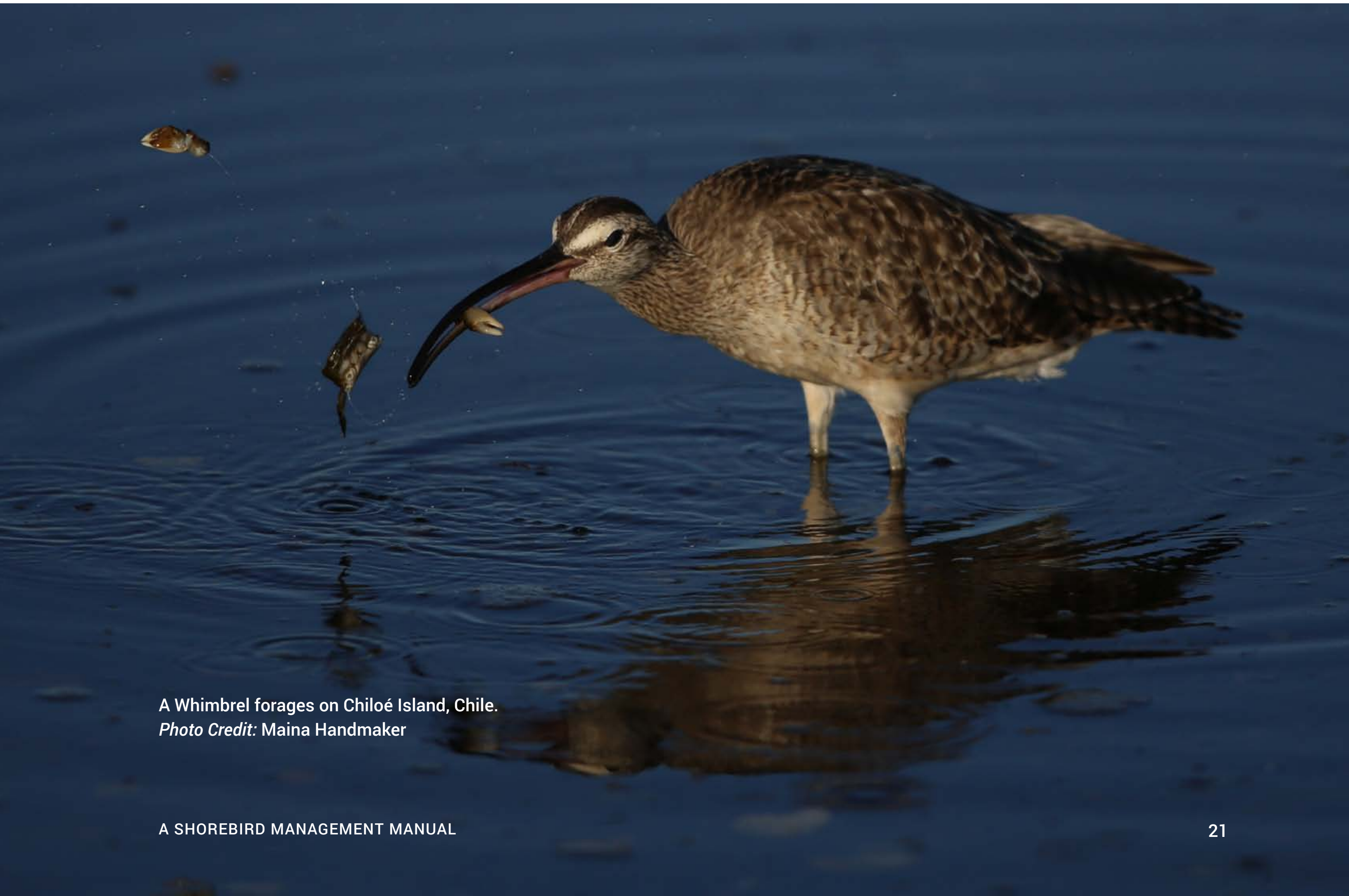


Generalized annual cycle for migratory shorebirds that breed in South America.

Migration requires immense amounts of energy and is dependent upon the availability of food resources at key locations. Fuel for migration is stored under the skin and around internal organs as fats and muscle (Odum and Connell, 1956). In preparation for migration, many shorebirds enter a period of hyperphagia (excessive appetite) characterized by intensive foraging. The longer the upcoming migration, the more fuel individuals require. Fat stores can exceed half of total body mass in shorebirds preparing for extreme long distance migration (Jehl, 1988; Piersma and Gill, 1998). Some species, such as Red Knot, double their body mass in preparation for migration (Baker et al., 2001, 2004). The ability to acquire and store fuel may influence survival during migration and breeding success (Baker et al., 2004).

Shorebird migrations can be categorized into three groups: long (>12,000 km), medium/intermediate (6,000 – 12,000 km), and short (<6,000 km) (Skagen and Knopf, 1993). Some shorebirds exhibit partial migration, where only a fraction of the population migrates while the majority of a population remain as residents. A few species in the Americas, such as the Tawny-throated Dotterel in South America, are altitudinal migrants that move between high altitude breeding areas and lower altitude nonbreeding areas (Wiersma et al., 2018).

Shorebird migrations are characterized by flights that connect sites where individuals rest and refuel. Migration strategies vary between hops, skips, and jumps that move individual birds from one location to another (Warnock, 2010). During hops, shorebirds accumulate small amounts of fuel stores that sustain them until the next stop. During skips, shorebirds accumulate larger amounts of fat and make larger movements to the next site. Sites used by shorebirds employing hopping or skipping strategies are considered stopover sites. The duration of a stay at a stopover site can be hours to days. Shorebirds that use the jump strategy accumulate large stores of fat and make long distance flights nonstop. Sites where shorebirds prepare for these long-distance flights are called staging sites. The duration of stay at a staging site can be days or multiple weeks, and sometimes a large percentage of an entire population can gather at a single site.



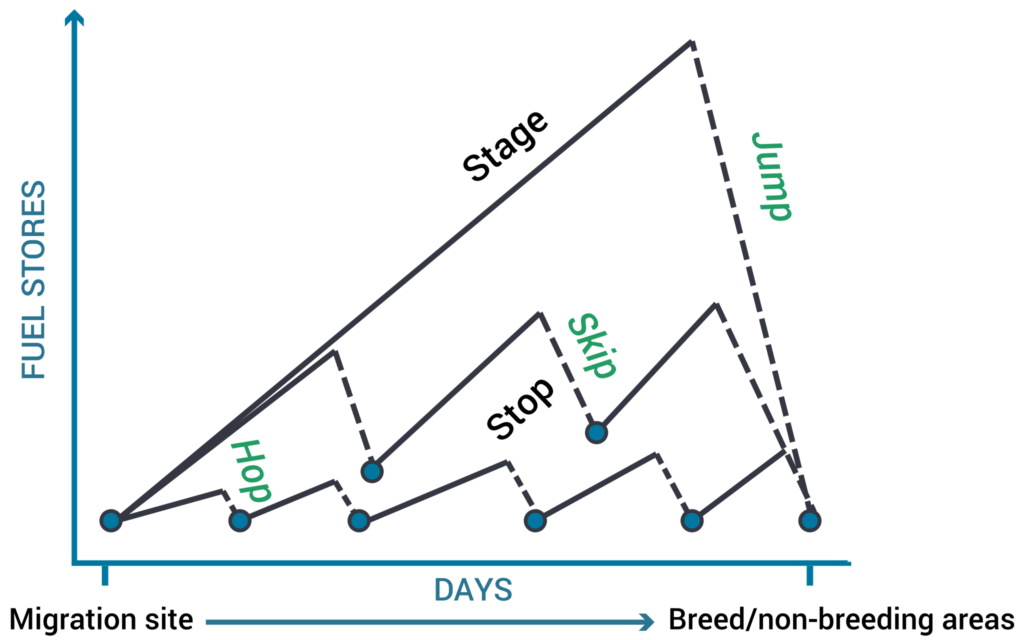
A Whimbrel forages on Chiloé Island, Chile.
Photo Credit: Maina Handmaker

The timing and location of shorebird occurrence at a site along the migratory route can vary by species, age, and, more rarely, sex. Migration tempo is dependent on biotic and/or abiotic conditions at staging sites. The timing of available food resources can influence the arrival dates of migrants. For example, shorebird arrival to staging sites like Delaware Bay or coastal Georgia coincide with the timing of Horseshoe Crab (*Limulus polyphemus*) spawning in order to feed on the eggs. More frequently than not, shorebirds do not take the same route during northbound migration as they do during southbound migration, so specific sites can be important to a species in one season but not necessarily another.

Important Site Characteristics for Shorebirds

1. Predictable and abundant food resources
2. Reliable additional critical resources like resting areas and water
3. Low levels of disturbance (e.g., from humans or predators)

Because of these migration strategies and the importance of a shorebird's ability to gain and maintain fat stores, the loss or degradation of habitat at staging and stopover sites is a significant threat to migratory shorebirds. The consistent availability of quality habitat during migration is a crucial component of successful migration and reproduction; there is concern that the coordinated timing of long-distance migrants may be disrupted by a variety of climate-change-related impacts.



Hop, skip, and jump strategies. Solid line indicates time spent accumulating fat stores, dashed lines indicates flight duration. Closed circles indicate location where migrants stop or stage. *Original source:* Warnock et al., 2010.

NONBREEDING

The temporal and spatial terminus of post-nesting migration is considered, for the purposes of this *Manual*, to be the nonbreeding phase of a shorebird's annual ecological cycle. While some Arctic/sub-Arctic breeding shorebirds can spend as much as half of the year migrating and nesting, for most species, the bulk of the year is spent at one or more sites until the onset of migration.

Some shorebirds show strong fidelity to a single nonbreeding site, such as Piping Plovers on the coast of Georgia, USA (Noel and Chandler, 2008). In many other nonbreeding scenarios, shorebirds make use of many locations within a larger but distinct geographic region, such as Dunlins in Oregon, USA (Sanzenbacher and Haig, 2002). Both nonbreeding scenarios depict the significant need of providing and maintaining high-value habitat for shorebirds during the nonbreeding period. Land managers who are responsible for the biological health of nonbreeding habitat need to be aware of the important role they play in supporting the annual migration cycle of shorebirds.

BREEDING

Fifty species regularly breed in North America's Arctic, sub-Arctic, and/or North Temperate regions. Twenty-eight species breed in the New World tropics and 24 species in the South Temperate region. Most long-distance migrants breed at northern latitudes whereas most short-distance and non-migratory shorebirds breed in the tropics and farther south. More than 80% of northern breeding shorebirds migrate to temperate and tropical regions in Mexico, Central and South America (Myers et al., 1987).

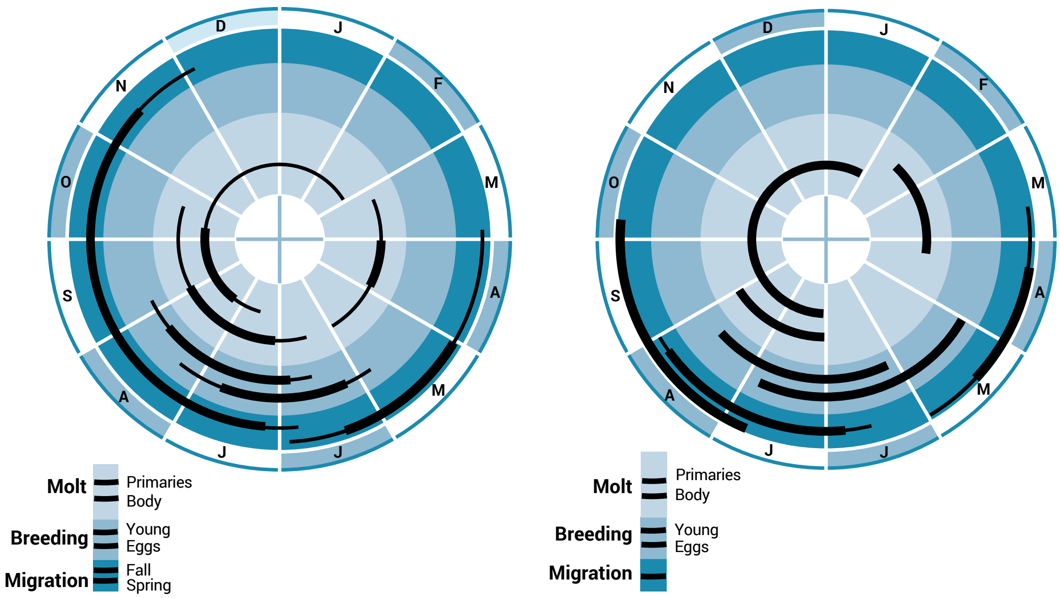
Nearly all shorebirds nest on the ground in a simple nest comprised of a small scrape in the substrate, sometimes lined with rocks, moss, or twigs. Arctic-nesting shorebirds generally lay four-egg clutches while temperate and tropical species tend to lay three or fewer eggs. Laying eggs requires a significant amount of energy; a clutch of eggs can represent between 23% (American Oystercatcher) and 97% (Semipalmated Sandpiper) of the female's total mass (Colwell, 2006), and up to 1.7 times (Spotted Sandpiper) a female's total body calcium (Maxson and Oring, 1980). For most sandpipers, eggs are laid one per day until the clutch is complete. For most plovers and oystercatchers, eggs are laid every two days. Nests, eggs, and plumage patterns, especially on the back, are cryptic to blend in with the surrounding habitat, a necessary attribute for ground nesters. Eggs in the same nest hatch relatively synchronously, typically within the same day.

A Semipalmated Sandpiper nest on Coats Island, Canada. *Photo Credit:* Shiloh Schulte

Nesting habitats and behavior vary by species (Appendix 6). For example, Long-billed Curlews nest in short upland vegetation and can be found hundreds of meters from wetlands, whereas Wilson's Phalaropes use taller vegetation and often nest in wet meadows close to wetlands (Eldridge, 1992). American Avocets and Black-necked Stilts nest on the edges of sparsely vegetated wetlands and nest semi-colonially (in loose groups), while Spotted Sandpipers nest solitarily on sandy or rocky substrate. Some species use structures built by humans and will occasionally nest on building rooftops, such as American Oystercatchers; Piping Plovers will sometimes nest in parking lots, and Killdeers commonly nest alongside gravel roads.

The length of breeding seasons and the tendency to lay multiple clutches varies by latitude (Colwell, 2010). Most Arctic-breeding shorebirds will rarely lay another clutch if the first attempt is destroyed, likely because the breeding season is so short at higher latitudes. In contrast, temperate and tropical breeding shorebirds are more likely to lay multiple clutches and, in general, have more time in which to lay eggs and rear young.

A Diademed Sandpiper-Plover and nest in Valle del río Yeso, Chile, 3,000 m above sea level.
Photo Credit: Diego Luna Quevedo

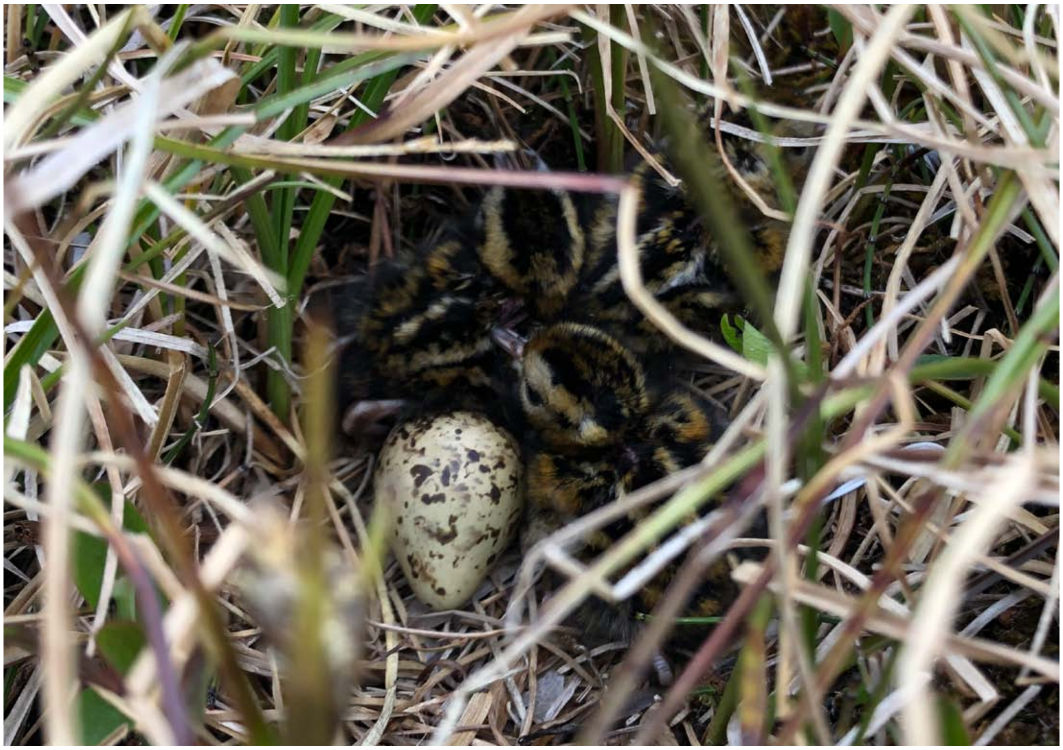


Life Cycle figures showing the differences in breeding season length for Arctic-breeding Red Phalaropes (left) and temperate breeding Wilson's Phalaropes (right). *Original source:* Birds of North America, Cornell Lab of Ornithology.

From the nest to fledging, young shorebirds are highly vulnerable and depend heavily on cryptic coloration and behavior for defense from predators. Parents will sometimes distract predators from nests by feigning injury, including a 'broken wing display' or by sounding alarm calls. Upon hatching, shorebird chicks are precocial; they begin walking within hours. Many shorebird chicks are able to feed themselves almost immediately, with the exception of a few species. American Oystercatchers feed their young and teach them to find and open prey items (American Oystercatcher Working Group, 2012). Once chicks are walking, adult shorebirds are vigilant protectors and assist with thermoregulation through brooding. The dominant survival mechanism for young shorebirds is to crouch and hide from danger.

American Oystercatcher nest and chicks. *Photo Credit:* Shiloh Schulte

Generally, shorebirds have low fecundity and productivity, which makes populations particularly susceptible to declines when adult mortality is high, and can slow recovery of population size following perturbations (Brown et al., 2001; Turrin and Watts, 2016).



Red Phalarope chicks, Alaska National Wildlife Refuge, AK USA. *Photo Credit:* Shiloh Schulte

Habitat Resources

Shorebirds occur from the Arctic to Antarctica, at elevations from sea-level to thousands of meters. Shorebirds use both tidally influenced and non-tidal wetlands, ranging from very low to very high salinity. Most shorebirds in the Americas are closely affiliated with the treeless landscapes of coasts, freshwater wetlands, saline lakes, barren tundra, and grassland communities of the North Temperate, Tropical, and South Temperate regions. The majority of species favor aquatic margins, found where water and land meet. A few shorebird species use the forests and affiliated habitats of the Temperate and Boreal regions of North America, while others live at high elevations above treeline in the Páramo grasslands or Puna zones of the Andes. Perhaps the most unusual habitat used by shorebirds is the open ocean. Red and Red-necked Phalaropes breed in the Arctic and spend their non-breeding months on the high seas of both the Atlantic and Pacific Oceans.

Shorebirds forage in a variety of natural communities across the Americas. Most species favor shallowly flooded or saturated sediments composed of different ratios of sand, mud, and silt. Exceptions to this are the rocky coast specialists utilizing the rich invertebrate and algal communities of natural rock shorelines or hard, human-made, structures such as jetties. These rocky shore specialists include Surfbirds, Purple Sandpipers, and Wandering Tattlers.

In addition to food resources, shorebirds need roost sites where they can safely rest and preen within flight distances of their feeding areas. Most species tend to avoid tall and thick vegetation, such as shrub lines and forest edge, to minimize vulnerability to predators. During the breeding season, shorebirds require safe nesting areas that are close to food resources for their precocial young.

Shorebirds use human-altered wetlands and uplands, including impounded wetlands, sewage treatment plants, agricultural fields (such as freshly tilled or harvested row crops), pasture, rice fields, and aquaculture ponds (such as those for shrimp, crayfish, and finfish). All of these can have value as foraging sites under the right conditions and some may provide important roost areas, especially during high tide. Impounded wetlands designed primarily for waterfowl management can be excellent for shorebirds outside of waterfowl seasons, when temporary lowering of water-depths can make bottom-dwelling invertebrates available for shorebirds to eat. Similarly, if draining aquaculture ponds for harvest can be seasonally staggered within peak migration windows, shorebirds can feed on the invertebrate fauna in the ponds, gaining access to otherwise scarce resources. Freshly exposed mud within aquaculture operations or temporary sheet flooding on agricultural lands can attract migrating shorebirds.

Many species use multiple habitat types during their annual cycle. Some spend most of the nonbreeding periods in marine or estuarine settings, yet depend on non-marine areas for nesting and brood rearing. Others have east-west or even altitudinal (elevational) migrations, such as Diademed Sandpiper-Plovers. Sanderlings favor high-energy barrier beaches for most of the nonbreeding season but nest in rugged and remote barren tundra in the Canadian Arctic. Another twist to Sanderling migration is the stopover of large numbers in the center of the North American continent at saline lakes (e.g., Chaplin and Reed Lakes) in southern Saskatchewan, Canada, to feed on abundant brine shrimp (*Artemia* sp.) (Beyersbergen and Duncan, 2007).

Important Habitat Features

- Abundant and available food
- Shallow water/exposed saturated sediments/ grasslands
- Minimal tall vegetation/ open landscape
- Roosting site(s), supratidal, shallow water, dry terrestrial
- Low predator nesting/ brood rearing areas
- A mosaic of favorable habitat conditions for daily and seasonal choice

Left: Expansive mudflats provide habitat for migratory shorebirds in the Bay of Fundy Canada. *Photo Credit:* Monica Iglecia.
Right: A Surfbird forages in a barnacle colony. *Photo Credit:* Kim Stark

Shorebird habitat classifications used in this *Manual* are defined by the USFWS and a partnership of NatureServe and NOAA (Cowardin et al., 1979; Federal Geographic Data Committee, 2012):

» Coastal – Tidal Wetlands

» Inland – Non-tidal Wetlands

» Managed Impoundments

» Uplands, Grasslands, and Grazed Lands

» Woodlands

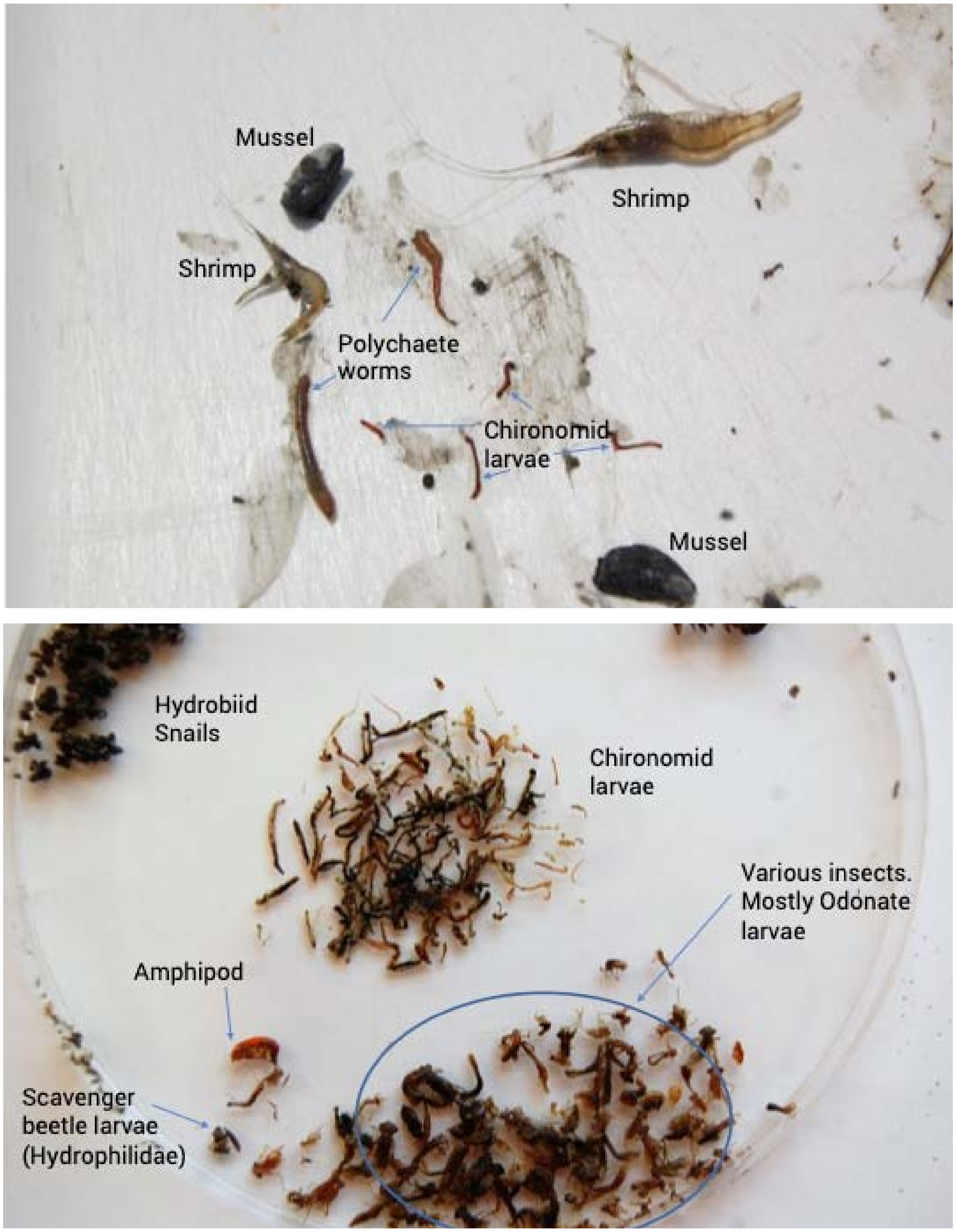
» Agriculture and Aquaculture

Left: A Sanderling captures a brine shrimp at Chaplin Lake, Saskatchewan Canada.
Right: American Oystercatcher adult teaches chick how to eat a bivalve. *Photo Credit:* Brad Winn

Food Resources

Shorebirds are opportunistic foragers that require abundant, high density food resources in all seasons. Many species have a flexible diet, consisting mostly of aquatic and terrestrial invertebrates but can include small fish, vegetation, berries, algae, and biofilm (a mix of diatoms and bacteria and an extracellular polymeric matrix they produce (i.e., mucus) that forms as a thin layer on the surface of intertidal mudflats and is rich in fatty acids). This flexibility allows shorebirds to forage in both inland and coastal habitats.

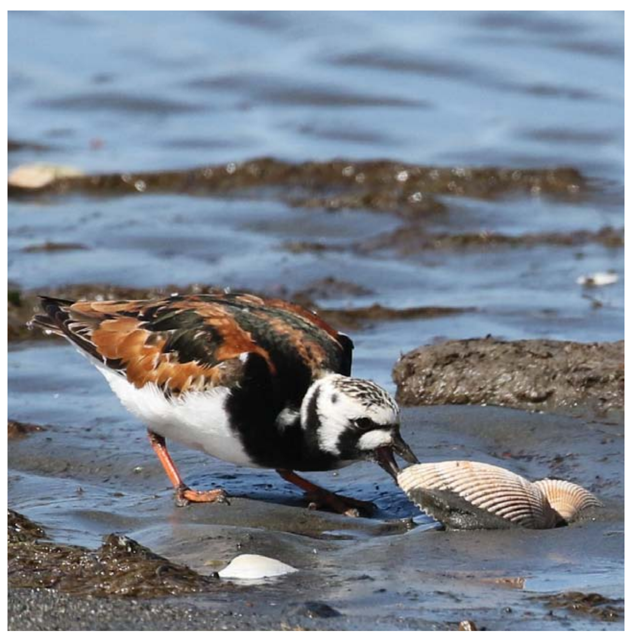
Shorebirds eat a wide variety of invertebrates (Appendix 9). Dominant prey items include Coleoptera (beetles), Diptera (chironomids and flies), Hemiptera (true bugs), Decapoda (crabs), Hymenoptera (ants), and Amphipoda (amphipods), and Gastropoda (snails) and Bivalvia (clams and mussels) (Skagen and Oman, 1996; Smith et al., 2012). Yet, some shorebirds, like oystercatchers, show preferences for specific invertebrate types or sizes, which may be more common in non-migratory species (Hockey, 1996; Skagen and Oman, 1996; Espoz et al., 2008). Prey items in low-salinity (<50 parts per thousand, ppt) habitats are dominated by amphipods, copepods, and chironomid larvae (e.g., blood worms) compared to higher salinity lakes where *Artemia* and *Ephydra* are more abundant (Velasquez, 1992; Takekawa et al., 2006). In freshwater wetlands, chironomid larvae are a dominant food resource that live and reproduce rapidly in shallow, open water, free of vegetation. Coastal prey items are dominated by polychaete worms, insects, and crustaceans.



Invertebrates collected in a managed wetland in coastal South Carolina. *Photo Credit:* Beau Bauer

Shorebirds also eat other food items. Greater Yellowlegs feed on small fish; many shorebirds will feed on crab eggs; Whimbrels eat native and cultivated berries at certain times of year; multiple species feed on small amounts of seeds and tubers; and calidrid sandpipers feed on biofilm (Alexander et al., 1996; Kuwae et al., 2008). Seedsnipes forage on buds, succulents, and seeds (Fjeldså and Kirwan, 2018*a*, *b*). While not common, shorebird diet has also been documented to include jellyfish and fish eggs (Gerwing et al., 2016). Ruddy Turnstones and Sanderlings are known to forage in the feces of large seabirds, and Snowy Sheathbills forage on carrion and feces.

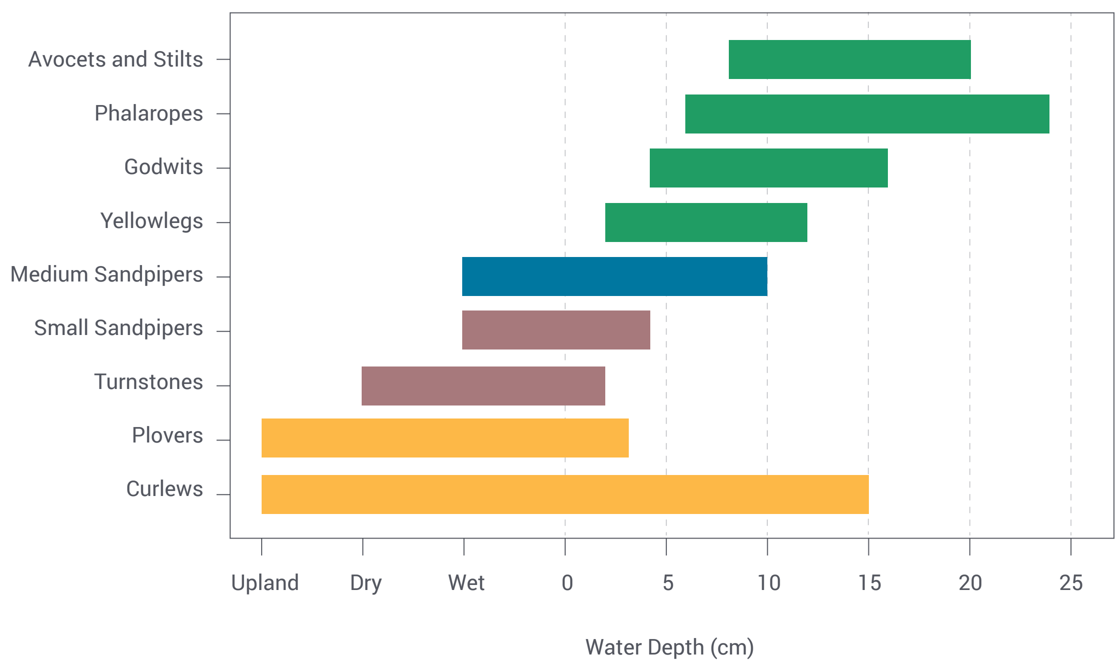
Physical characteristics of shorebirds play a role in the prey types they eat. The short, thicker bills of plovers are primarily used on exposed intertidal sediments to nab invertebrates seen at or near the surface, often clamping onto polychaete worm heads to be pulled up and consumed. On the opposite end of the scale, godwits, dowitchers, and curlews can probe deep into saturated soils or submerge their heads underwater completely to probe littoral sediment. Probing foragers can open the distal ends of their bills once they have inserted them into the substrate to grab prey, rather than needing to open their bills before probing into the earth.



Top: A Willet eats a crab. *Photo Credit:* Maina Handmaker. **Bottom left:** A Black-bellied Plover uses force to extract a worm. **Bottom right:** A Ruddy Turnstone flips over shells to find food items. *Photo Credit:* Kim Stark

Species with stout bills like Ruddy Turnstone can forage difficult-to-open prey items including barnacles, bivalves, clams, and chiton (Nettleship, 2000). Oystercatchers have specialized bills useful for opening bivalves. Narrow-billed shorebird species, such as Red-necked Phalarope, can quickly consume tiny invertebrates with rapid bill movements, using the surface tension of water along its bill - informally referred to as slooping (Rubega and Obst, 1993). These phalaropes are also known for spinning in tight circles to create an upwelling that draws food to the surface of the water (Obst et al., 1996).

Partitioning of food resources can be clearly defined in some situations but can be lacking in others (Bocher et al., 2014). Water-depth can determine food access to different taxa (Isola, 2000), based on the morphological (structural) differences among species, like leg and bill lengths. Shorebirds with specialized bills for probing can feed on invertebrates in sediments (infaunal) – both those in shallow water and exposed soil – as well as on invertebrates in the water column. Some shorebirds glean from rocky shores; some specialize in hunting insects in short grasses of natural grasslands and grazed lands of interior uplands. Interestingly, some species do both. Long-billed Curlews eat tubeworms on their coastal beach nonbreeding areas, but on their breeding grounds, they feed on terrestrial invertebrates, sometimes catching insects in flight (Dugger and Dugger, 2002).



Water depths used by shorebird groups. *Original source:* Helmers, 1992.

Some shorebird species have strong fidelity to certain locations corresponding with seasonal abundance of a particular food resource. Species like Red Knot show strong preference for specific invertebrates at different stages in their annual life cycle when these foods are super-abundant (Espoz et al., 2008). And more than 200,000 shorebirds, including Red Knots, Ruddy Turnstones, and other species, descend upon the Delaware Bay in the United States during northbound migration to feed on lipid-rich Horseshoe Crab eggs (Clark et al., 1993). This phenomenon occurs on various scales along the Atlantic Coast of the United States.

Horseshoe Crab eggs provide critical fuel for northbound migrating shorebirds on the Atlantic Coast of the United States. *Photo Credit:* Laura Chamberlin

SHOREBIRD ENERGETIC NEEDS

The energetic needs of shorebirds vary by season, but the availability of food resources throughout the annual cycle may influence survival and breeding success (Baker et al., 2004; McGowan et al., 2011). A few studies have quantified the food resources required by shorebirds to meet their energetic needs (Appendix 10). To support shorebirds in inland wetlands in the United States, densities of chironomid midges need to be 100/m^2 or more (Eldridge, 1992), but much greater densities (5,000/m^2) may be needed to support an influx of large numbers of shorebirds (Davis and Smith, 1998). In an applied approach, Migratory Bird Joint Ventures in the United States have set habitat objectives for shorebirds based on bioenergetic models developed for regional shorebird populations (Central Valley Joint Venture 2006, LMVJV Shorebird Working Group 2019).

FACTORS THAT AFFECT FORAGING

Shorebirds feed in substrates ranging from dry upland habitats to saturated mud to water 25 cm deep (Helmers, 1992; Colwell and Taft, 2000). Many shorebirds forage for invertebrates by wading in open, shallow water, free of substantial tall and/or dense vegetation. Phalaropes can forage while swimming in deeper water. In coastal and tidally influenced areas, foraging time is limited by tide height and slope of the subsurface. In interior regions, weather and day length, as well as water depth, affect a shorebird's ability to forage. In both tidal and non-tidal habitats, some shorebirds feed at night (McNeil et al., 1992). In addition to slope and water depth, factors such as disturbance, proximity of trees and other cover to shorelines, and predator presence can affect how shorebirds forage in an area.

WHAT FOOD RESOURCES ARE AVAILABLE IN YOUR AREA?

Top: Using a dip net to sample invertebrates.
Bottom: Dragonfly and Damselfy nymphs.
Photo Credit: Maina Handmaker

1. Collect samples
   - Tools for collecting terrestrial invertebrates: canvas or nylon mesh net
   - Tools for collecting aquatic invertebrates: canvas or nylon mesh net or activity trap (nekton), 10 cm x 10cm core sampler (benthic invertebrates)
2. Rinse and sieve samples (typical sieve size = 0.1 – 1mm)
3. Preserve in 70 – 95% ethanol for future identification
4. Identify invertebrates using a microscope or magnifying lens

NOTE: Sample collections will represent what is available but not necessarily what shorebirds are selecting, but can be a valuable method to understand the food resources that are available to shorebirds.

The bathymetry (underwater topography) of an inland wetland, tidal channel, or even beach slope can affect how shorebirds are able to use a site. Wetlands that are large, generally shallow, and topographically varied provide habitat for a greater diversity of waterbird species than do wetlands that are small and deep (Colwell and Taft, 2000). Shallow sloping edges with a gentle incline allow shorebirds to forage along the edges of a wetland and follow the water line as the water recedes, be it seasonally or within a tide cycle. Apart from phalaropes, most shorebirds do not swim, although the pre-flight juveniles of many species will dive underwater and swim to escape predators. Shallow water and gentle slopes ensure that some proportion of a wetland will be accessible to shorebirds as water levels rise and fall. A shoreline slope ratio of 10-12: 1 (horizontal: vertical) provided good foraging habitat for breeding Black-necked Stilts and American Avocets and their young in interior wetlands of California (Davis et al., 2008).

Challenges for Shorebird Conservation: Biological Risks

- Broad geographic ranges crossing geopolitical boundaries
- Large aggregations at specific sites during migration
- Low reproductive potential (3-4 eggs)
- Small population sizes of many species
- Multiple threats to preferred habitats

Throughout their life cycle, shorebirds must manage risk of predation. When foraging, shorebirds make tradeoffs between areas with high food abundance and areas with obstructed views or perching trees, from which predators like Peregrine Falcon (*Falco peregrinus*) and Merlin (*Falco columbarius*) can make a stealthy approach. In visually obstructed areas, shorebirds must maintain higher vigilance than in open areas without visual barriers (Beauchamp, 2015). Western Sandpipers mitigate danger by foraging in areas with fewer obstructive features, even when those areas contain lower invertebrate densities (Pomeroy et al., 2006). Human recreational use of shorebird foraging habitat can cause shorebirds to spend more time moving than foraging, compared to less disturbed areas (Murchison et al., 2016).

From a management perspective for shorebird food resources, the focus should remain on the overall health of naturally occurring invertebrate populations through hydrologic regimes and environmental processes, and minimization of disturbance during important periods. Management actions are provided by habitat type in the following sections.

Threats

Human-driven habitat loss, climate change, and introduced and invasive species are some of the top threats to biodiversity as a whole, a pattern that holds true for shorebirds (Hoffmann et al., 2010). Threats to shorebirds have biological impacts ranging from indirect loss of habitat (e.g., recreational use of a beach) and reduced fitness resulting from disrupted foraging to direct mortality and loss of habitat. The fundamental goal of habitat management is to increase shorebird population sizes; management actions that reduce threats can improve survival and recruitment and have a positive impact on populations.

The highest ranked threats in the Atlantic and Pacific Flyways are:

1. Modified Natural Systems
2. Agriculture and Aquaculture
3. Residential and Commercial Development
4. Human Intrusions and Disturbance
5. Invasive and Problematic Species
6. Hunting (Biological Resource Use)
7. Climate Change

Seven threats to shorebirds rank highly in both the Atlantic Flyway Shorebird Business Strategy and the Pacific Americas Shorebird Conservation Strategy (Appendix 11). While not ranked as a top threat in either flyway plan, a short discussion about pollution is provided. There are site-specific threats that may be unique, or regional-level threats that have not been included. While managing the greatest current threats is critical, it is also necessary to plan for emerging future threats. Multiple actions will likely be needed to holistically address shorebird needs at any given site, and some may have to be adapted to meet the unique needs of a particular location.

The majority of the management actions included in this *Manual* fall within the following Conservation Measures Partnership Direct Actions related to 1. Land/Water Management, 2. Species Management, 3. Awareness Raising, 4. Law Enforcement and Prosecution, 5. Livelihood, Economic & Moral Incentives, 6. Conservation Designation & Planning, and 8. Research & Monitoring (Conservation Measures Partnership, 2016).

Managing Habitat Resources and Modified Natural Systems

The modification of natural systems refers to the actions that degrade or alter natural processes and environments, typically in order to 'manage' these natural systems (Conservation Measures Partnership, 2016). Natural system modification directly affects the foundation of habitat available for shorebirds. These modifications include changes to shorelines and wetlands by altering hydrology (ditching, draining, filling), restricting natural sediment flow, moving or altering river and inlet channels, dredging, or diking. Upland modifications that impact shorebirds include changes to grassland habitats through suppression of fire or other natural disturbances that maintain short grass habitats, or changes to freshwater wetlands and riverine habitats through development of impoundments and water diversions. Agriculture and aquaculture are modified systems where management actions have the potential to improve their capacity to support shorebirds.

Coastal - Tidal Wetlands

Shorebirds forage in virtually all tidal marine and estuarine wetland systems. Many species use the supratidal areas found on the coasts of North, Central, and South America for roosting, often seeking an open mosaic of intertidal flats, gently sloping beachfront, sand bars, and/or dunes held in place by herbaceous vegetation. Nonbreeding shorebirds tend to use a combination of one or more high tide roosting areas near large intertidal feeding areas (Zharikov and Milton, 2009).

A key feature of good coastal shorebird habitat is an extensive intertidal zone with an array of sediments that supports a variety of invertebrates (Granadeiro et al., 2007). These organisms thrive in extraordinary daily extremes of being submerged in ocean water and then exposed to the air and sun with the movement of the tides. Shorebirds access the invertebrates during flood and ebb tidal periods when the sediments are saturated, making the foods more readily available. Saturation of mud and sand by marine and estuarine waters reduces soil compaction and allows shorebirds to probe for food. The extent of intertidal surface depends on the slope of the coast and the tidal amplitude at any location.

Physical features in coastal habitats that support shorebirds include wide open sand areas, tidal inlets with free flowing sediments and shoals and sand bars. ***Photo Credit:*** Brad Winn

Grain size of benthic sediments and invertebrate distribution can be strong predictors of shorebird density and habitat use in an estuarine tidal flat (VanDusen et al., 2012). Sediment grain size influences the composition of the benthic invertebrate community but may also influence the availability of invertebrates to shorebirds; higher silt sediments can hold water longer than more porous sediments, resulting in pooling water as the tide recedes. Shorebirds (probing shorebirds in particular) are then able to access aquatic invertebrates longer than in other, more quickly draining sediments. However, habitat heterogeneity, including a variety of benthic sediments, is important to ensure a variety of foraging guilds and prey preferences (VanDusen et al., 2012).

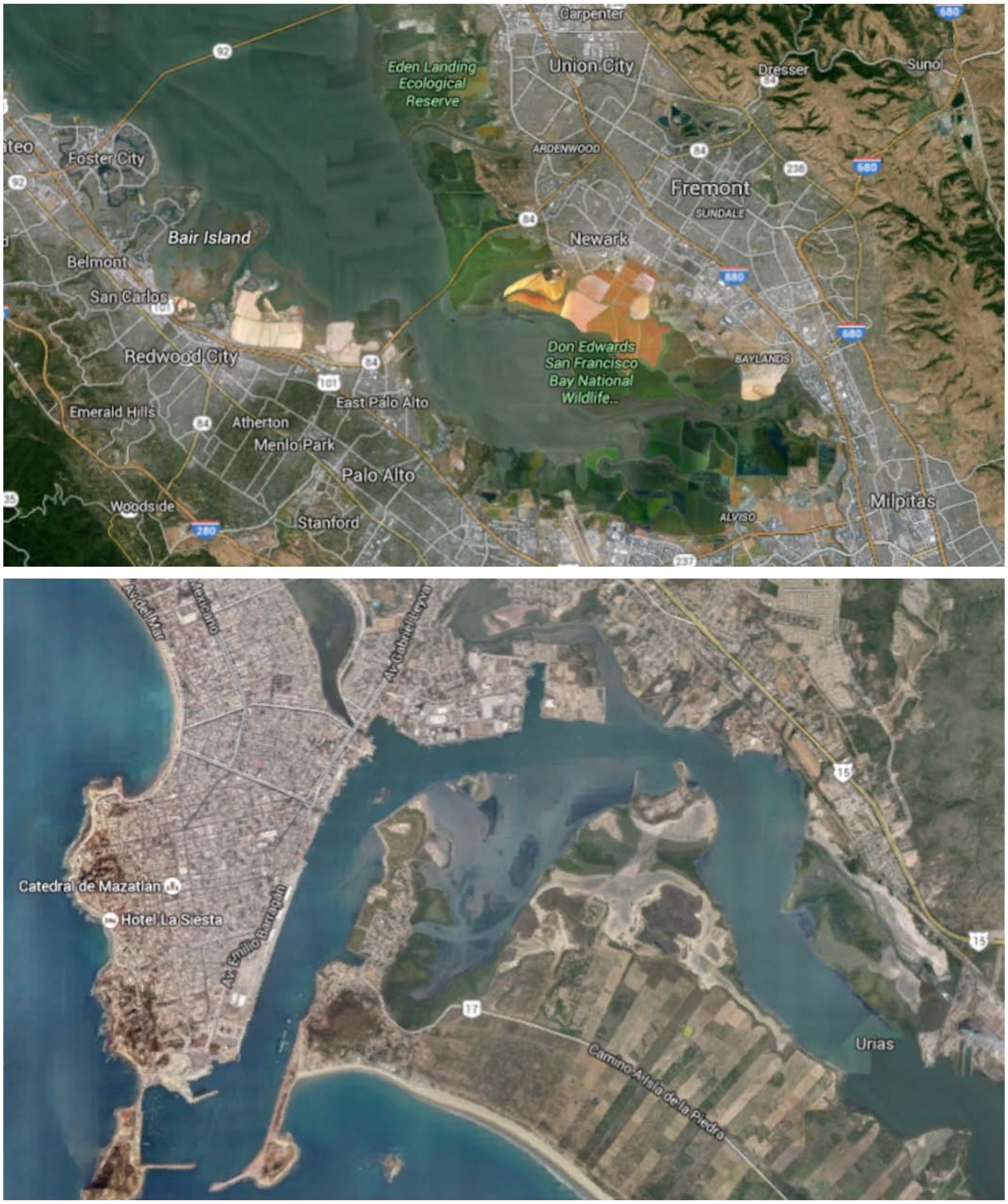
Coastal shorebirds, like Sanderlings, tend to favor the tidal edge, moving with the water line on outgoing and incoming tides to catch prey. Physical features of tidal areas influence species distribution and patterns of use; and species use intertidal areas differently (Danufsky and Colwell, 2003; VanDusen et al., 2012). For example, Red Knots and Western Sandpipers favor sand spits and tidal flats associated with coastal inlets versus other beachfront (Harrington, 2008). Coastal inlets provide a mosaic of wet and dry sand areas that can benefit shorebirds in all stages of their annual cycles.

Managing for shorebirds at coastal locations often involves working to protect, restore, or create the heterogeneity of feeding and resting areas that are often lost with traditional coastal engineering protocols and recreation management, such as raking sand, beach nourishment, and installation of hard infrastructure. Human disturbance, including many forms of recreation, is also a significant threat.

Left: Beach inlets and island ends provide a higher ratio of intertidal foraging opportunities. Low angle beach profile and minimal vegetation provides wide angle view of approaching predators. *Photo Credit:* Brad Winn
Right: Shorebirds congregate on a sandy island in coastal Georgia USA. *Photo Credit:* Brad Winn

HABITAT MANAGEMENT IN COASTAL - TIDAL WETLANDS

In many cases, coastal engineering projects result in degraded or eliminated intertidal feeding habitat. Where sediment movement has been restricted with repetitive dredging, or where structures such as dams, jetties, bulkheads, rip rap, and groins have been created to enhance navigation or protect upland properties, the processes that support invertebrate distributions and availability have usually been negatively impacted. The results of coastal stabilization associated with the development on beachfronts limits or destroys these natural processes, eroding the biological integrity and habitat availability.



Examples of heavily altered coastal and estuarine habitats seen from space,
San Francisco Bay USA (top) and Mazatlán Mexico (bottom). P*hoto Credit:* Google

The historic negative impacts of coastal engineering have potential for positive outcomes through the use of more holistic and informed decision-making and management techniques. More and more coastal management authorities in the United States are recognizing the benefits of maintaining the natural processes of sediment flow to benefit residential and commercial interests, as well as maintaining biological values for the benefit of people and wildlife (Hanley et al., 2014; Guilfoyle et al., 2019). Maintaining natural coastline features has proven to help ameliorate storm-driven wave energy and reduce shoreline erosion. Living shorelines, engineering with nature, and natural infrastructure are terms that are becoming more commonly used. Extensive intertidal flats critical to shorebirds can help slow wave energy for the benefit of upland residents, including humans.

The following management actions and approaches to reduce the negative effects of habitat modifications on shorebird habitats have been summarized from expert knowledge and publications:

» Protect important areas and habitat features, including nearby roosting areas on beaches or inlets where shorebirds may congregate. Multiple roost areas at the landscape scale are important refugia to avoid predators, human disturbance, and inclement weather.

» Do not remove wrack line material from undeveloped sections of beach (Guilfoyle et al., 2019).

» Identify and reduce alterations and disturbance to (i.e., protect) all areas designated as key shorebird habitats (Guilfoyle et al., 2019).

» Protect natural geomorphologic processes that aid habitat renewal (i.e., place sand in areas that will not impede natural washover; avoid filling ephemeral pools) (Guilfoyle et al., 2019).

» Clearly mark all sensitive areas to be avoided before relocation of dredge material (Guilfoyle et al., 2019).

» Avoid burying marshes, tidal flats, or other valuable benthic resources. Maintain at least a 500 m buffer around these resources (Rice, 2009).

» Remove barriers to channel formation in tidal areas. Tidal channels in Bandon Marsh, Oregon, USA had disproportionately more foraging northbound shorebirds, higher densities of Corophium spp invertebrates available closer to the surface, and softer sediments more easily probed by shorebirds (Miller and de Rivera, 2014).

» Protect natural inlets and inlet function from modification such as dredging or coastal hardening techniques. Higher biological values are associated with unmodified inlets, and this includes shorebird abundance and diversity (Peterson et al., 2006; Granadeiro et al., 2007; Rice, 2009).

» Be mindful of sand sources for beach nourishment projects. Borrow sites for beach rebuilding should be subtidal well away from the nearshore sand-sharing system. Recommended distance depends on slope and sand quality. Mining nearshore intertidal shoals or sand spits has immediate and detrimental impacts to coastal wildlife including shorebirds (Rice, 2009).

» Restore beaches using appropriate sediment grain size (based on life-history needs of relevant species), which will also aid recolonization of the area by native benthic organisms (Guilfoyle et al., 2019)

» Sand placement on top of established intertidal sediment has had negative effects on the abundance of invertebrates, specifically polychaetes within at least 15 months of sand application (Wooldridge et al., 2016). However, native invertebrate communities may have varying responses to beach nourishment projects.

» Public access should be limited at new beaches or sandbar islands if created to provide wildlife habitat. U.S. Army Corps and state wildlife agency authorities can and should regulate access to dredge-deposit islands or other habitat resources created; doing so helps ensure that new or improved habitats provide new or mitigate for lost habitat.

» Timing of beach rebuilding depends on local conservation priorities and regulations. Beach- nesting shorebirds often take precedent over migrants. Dredging windows should be established to reduce disturbance to migrant shorebirds within important stopover areas. Food resource areas should be protected from overfill.

» Sand fencing is often used to catch sand and help rebuild dunes in areas but can create predator perches and block beach areas for flocking birds (Rice, 2009).

» Vegetation planting (e.g., native Sea Oats *(Uniola paniculata)*) can help build dunes and create additional nesting areas for beach-breeding species. However, plantings should not advance successional transition in otherwise open beach and mudflat landscapes.

Inland - Non-tidal Wetlands

Non-tidal wetlands provide important foraging opportunities for shorebirds--particularly in the continental interior for migrating and, to some degree, nesting individuals (Helmers, 1992). Many shorebirds are found in non-tidal lacustrine wetlands, including lakes and reservoirs, and intermittent wetlands, such as playa lakes. Shorebird species use playa lakes that contain sparse vegetation (less than 25% total vegetation cover), adequate amounts of mudflat (at least 10 – 15% of area) with water less than 4 cm in depth representing 10 – 20% of the area, and abundant invertebrate populations (Davis and Bidwell, 2008). Some species, such as Spotted Sandpipers, use non-tidal, lake, or channeled riverine habitats, and shorebird species like Greater and Lesser Yellowlegs use a myriad of more vegetated palustrine wetland types, including bogs, ponds, vernal pools, and freshwater marshes.

Non-tidal wetland complexes dominate much of the interior wetland habitat of the United States and Canada, including prairie potholes of the Northern Great Plains and the playa lakes region of the Southern Great Plains. The Altiplano, in parts of Argentina, Bolivia, Chile, and Peru, provides a variety of high-elevation lakes, saltpans, and bogs. Habitat in these regions is spatially and temporally variable, dependent on rainfall and hydrology. Diversion of water for agricultural use and sediment runoff can reduce habitat value.

The landscape matrix may influence the use of specific habitat at one site, especially as shorebirds rely on a mix of permanent and semi-permanent wetlands in inland areas (Albanese and Davis, 2013). Despite the fact that ephemeral wetlands tend to be smaller and more dispersed than are other habitat types, they provide important habitat to migrating birds, add value to the landscape composition, and should not be overlooked for management opportunities.

Saline/alkaline lakes and ponds play a special role for some shorebird species in western North America and the Andes of South America. More than one third of shorebird species in the Americas use saline lake habitats for nesting, migration, and the nonbreeding season (A. Lesterhuis, pers comm). For example, Wilson's Phalaropes amass in huge concentrations of tens and even hundreds of thousands of birds in saline lakes of both North and South America including the Great Salt Lake, USA, and Mar Chiquita, Argentina. Both saline and freshwater lakes and reservoirs, especially those with large mudflat areas, can provide stable and consistent wet habitat beneficial to shorebirds (Taylor and Trost, 1992).

Thousands of Wilson's Phalaropes using the north-west part of Mar Chiquita lagoon where prey are abundant and accessible in the shallow water and muddy substrate. *Photo Credit:* Marcela Castellino

Managing inland wetlands for shorebirds usually involves large-scale protection of the waterbody from alteration or complete loss resulting from water diversion for agricultural use, ditching, and draining for agriculture, mining, or development. The consolidation and stabilization of wetlands to support reliable recreation, navigation, or aesthetics can negatively affects shorebird habitat because water levels are held constant rather than allowed to follow natural hydrologic regimes that would provide shallow water at times aligned with shorebird needs.

HABITAT MANAGEMENT IN INLAND NON-TIDAL WETLANDS

Altered hydrology, water diversions, and changes to water availability threaten the functionality of inland non-tidal wetlands (Skagen and Knopf, 1993). Seasonal and annual variation in weather can change habitats, reducing opportunities at some sites while creating new opportunities at others. For instance, as ephemeral ponds dry, they provide temporary foraging sites for migrating birds, but as the soils dry out completely, birds will shift to other areas, such as larger bodies of water where drying conditions might expose edges (Albanese and Davis, 2013). Factors such as openness, slope, and vegetation are all critical components of quality habitat in inland non-tidal wetlands.

In landscapes that include a complex of many smaller wetlands, management should support habitat complexity by protecting and managing habitats at a large scale, rather than focusing on single site management. This type of large-scale management will require collaboration and communication across a large area to ensure shorebirds are able to find the habitats they need across such a variable landscape (Skagen and Knopf, 1993).

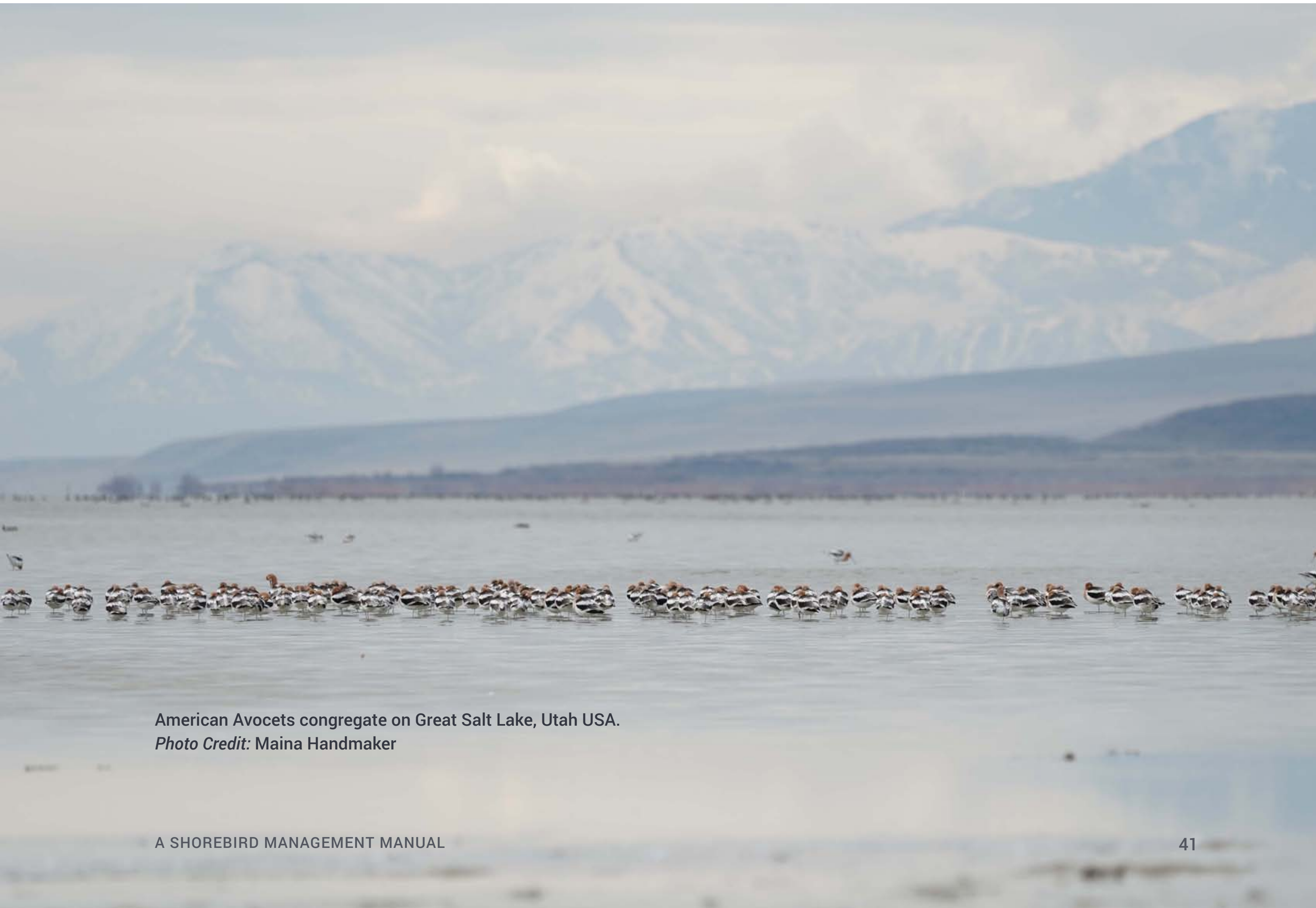
Long-billed Dowitchers and Wilson's Phalaropes forage at Cheyenne Bottoms, Kansas USA.
Photo Credit: Monica Iglecia

Lakes and Rivers

Modifications such as diversions or the construction of dams and reservoirs threaten the natural structure and course of lake and riverine systems and, thus, the available shorebird habitat. Management of modified lake and river systems parallels, in many ways, management of impoundments because the natural flow of water and sediments is altered and vegetation will need to be managed (see Invasive Alien and Problematic Native Species). Consistent water levels are important for supporting nesting shorebirds and other waterbirds; abrupt fluctuations in water levels can strand or flood out nests. Slow decreases in water levels from evaporation can benefit shorebirds by creating slowly exposed feeding areas.

Managing habitat in lakes and rivers may include:

- The creation of novel habitats can provide alternative nesting, resting, and feeding resources or replace lost value resulting from human activity. For example, Piping Plovers nest on the alkali wetlands and sandbars available along the edges of major rivers of the USA and Canada. Sandbars are created as rivers transport and deposit sand. However, dams have decreased water flows and reduced the development of these important sandbars (Jacobson et al., 2009). Erosion and vegetation encroachment have further reduced the size of available sandbars or resulted in unsuitable conditions. After the 1950s, Piping Plovers began using the novel habitats along the shorelines of managed reservoirs (Anteau et al., 2012). Engineered sandbars created with dredged material provides breeding sites for Piping Plovers on the Missouri River, USA. In both natural and newly created habitat, vegetation control will likely be required as ongoing management (Catlin et al., 2011).
- Aligning drawdown of reservoirs directly influences the availability of habitat; drawdowns can be timed to match shorebird needs. The timing of drawdown of the Kentucky Reservoir in the Tennessee River Valley, USA, influenced shorebird use, vegetation, and invertebrate resources (Wirwa, 2009). Further, habitat is not provided uniformly in the reservoir; shorebirds cluster within a 20m band of the waterline. This information can be used to estimate the area available for shorebirds in the reservoir at any given time (Wirwa, 2009).
- Regulating water levels in accordance with shorebird habitat needs. For example, in the Tennessee River Valley of the United States, reservoir drawdowns were delayed until May and provided foraging habitat for spring migrating shorebirds, including Pectoral Sandpipers and Semipalmated Plovers (Newcomb et al., 2014).



American Avocets congregate on Great Salt Lake, Utah USA.
Photo Credit: Maina Handmaker

Saline Lakes

Saline lakes have historically been subjected to alterations of their natural processes. Changes to inflows, taking water from the lakes directly, and the extraction of nearby groundwater for humans have collectively lowered water levels.

Saline lakes and associated shorebird and waterbird species like Wilson's Phalaropes face continued challenges caused by draining and water diversions and a warmer, drier future.

See Case Study 1 for an example of working with private landowners to improve nesting habitat around saline lakes for Piping Plover.

In addition to reducing habitat area, lowering water inputs and levels raise water salinity, which has resulted in fewer shorebirds in the saline lakes of the arid west of the United States (Senner et al., 2018). In parallel, too much water can also reduce invertebrates and waterbird abundance in saline lakes, indicating narrow salinity thresholds for the birds and invertebrates that rely on these habitats (Rubega and Robinson, 1996; Senner et al., 2018).

Management actions and approaches to reduce the negative effects of habitat modifications include:

» Protect water inputs and manage water levels at saline lakes to maintain their value to shorebirds, other waterbirds, and humans.

» Develop large-scale collaboration with water users and develop policies to safeguard future water usage. In the 1980s and '90s, water from Owens Lake, a saline lake in eastern California, had been diverted to supply the city of Los Angeles. The drying shoreline of the lake, coupled with high winds and aerosolized lakebed particles, caused a human health hazard to nearby communities. The city of Los Angeles was held responsible for maintaining air quality standards. Collaborations with the city of Los Angeles helped restore air to state standards by adding enough water to the lakebed to minimize dust and restored waterbird habitat, as well (Braxton Little, 2018).

» Multispecies management may be important at saline lakes for specific species. Wilson's Phalaropes feeding in saline lakes of the Atacama Desert in northern Chile were found to have higher rates of prey acquisition when in close proximity to foraging Chilean Flamingos (Gutiérrez and Soriano-Redondo, 2018). A similar phenomenon has been observed in lakes in Manitoba, Canada, of a feeding association between Wilson's Phalaropes and Northern Shovelers (Siegfried and Batt, 1972).

Managed Impoundments

Managed wetlands are human-made inland or coastal impoundments that require active management. In most cases, wetlands are impounded through diking whereby the natural hydrology is impeded and water levels must be managed by water-control structures. In some cases, managed wetlands are developed to compensate for habitat loss. Interior and near-coastal fresh and brackish impounded wetlands provide an opportunity for state, federal, and private land managers in North America to create unvegetated mudflats and shallow water during migration to supporting shorebirds where and when they need those conditions most.

Depending on the location and regional bird needs, managers can manipulate water levels to produce food resources and accessible conditions for breeding, migrating, or wintering shorebirds. In some situations, managed impoundments are some of the only suitable habitat for supporting shorebirds within entire regions, such as highly developed agricultural areas in the Midwestern United States.

A managed impoundment at the Cape Romain National Wildlife Refuge, South Carolina USA.
Photo Credit: Felicia Sanders

HABITAT MANAGEMENT IN MANAGED IMPOUNDMENTS

Managed wetland impoundments are modified natural systems. In some cases, managed wetlands can provide habitat for more bird species, higher bird abundance, and more diverse plant assemblages than do non-managed systems (Kaminski et al., 2006; Fitzsimmons et al., 2012). Managed wetlands in altered landscapes can also help improve water quality and flood-water storage capacity (Duffy and Kahara, 2011).

There are many resources on managing these types of wetlands to provide habitat for wildlife (e.g., Fredrickson, 1991; Helmers, 1992; Smith et al., 1995; Colwell and Taft, 2000; Nelms et al., 2007). Managing for multiple species is increasingly critical given immense wetland losses (Laubhan and Fredrickson, 1993; Davidson, 2014). Actions to improve habitat for shorebirds on managed wetlands focus on manipulating water and vegetation to provide the conditions and food resources that meet the seasonal requirements of shorebirds. These actions can be compatible with wetland management for waterfowl (Helmers, 1992) and do not necessarily result in reduced habitat quality for ducks and geese.

Many impounded wetlands are managed as moist-soil systems. Moist-soil management is the process of regulating water levels and vegetation seasonally to encourage the growth of desirable wetland plants that provide the seeds, forage, tubers, and aquatic invertebrates for feeding nonbreeding waterfowl (Fredrickson and Taylor, 1982). Typically, moist-soil managed wetlands are flooded throughout the boreal winter with drawdowns occurring during the boreal spring or early summer to stimulate germination and growth of plants. The specific practices implemented in moist-soil impoundments vary regionally and even by site, depending on the seedbank of plants, the focus of the habitat management, and other factors like salinity (Bowyer et al., 2005).

Wetland management is considered to be more of an art than a science, likely because each site presents unique challenges and opportunities to achieve the specific habitat and wildlife goals desired. Management practices at a site may be limited by financial resources, the quantity of water and timing of its availability, and regulatory requirements (Iglecia and Kelsey, 2012).

Managed wetlands in coastal Georgia USA attract a variety of regularly occurring as well as rarely occurring shorebird species such as Greater Yellowlegs and Ruff. *Photo Credit*: Brad Winn

Practices that will benefit shorebirds in managed impoundments include, for example:

» Provide water levels in moist-soil managed wetlands at depths shorebirds can use. In wetlands with varying topography, the opportunity to provide more shallow areas accessible to shorebirds may exist, and some duck species, like teal, will benefit. In some areas (e.g., Midcontinental USA), moist-soil wetlands can begin the drawdown process after waterfowl depart for northbound migration (April) resulting in good conditions for northbound shorebirds (May).

» Stagger or stage the flood-up or drawdown across multiple units or within one unit. This can be used to accommodate migration chronologies of different shorebird species or to extend the availability of habitat within the wetland for shorebirds throughout the season. This practice also reduces the likelihood of overall prey depletion within the wetland complex.

» Replace very wide boards in water control structures with smaller width boards (e.g., 2-3 cm wide to allow fine scale manipulation of water depths.

» If flooding-up to provide habitat for shorebirds, add water 2-4 weeks before their expected arrival to allow invertebrate populations to grow.

» Actively manage vegetation to keep areas open and accessible for shorebirds. Good shorebird habitat is often provided after vegetation management followed by subsequent shallow flooding.

» Use shallow disking rather than deep disking when using mechanical means for vegetation management. Deep disking buries plant matter that would otherwise provide substrate for invertebrates.

» Do not select wetland units in close proximity to tall trees that may harbor avian predators when selecting units to provide shorebird habitat.

» Maintain levees and water control structures as they are critical for directing water management.

» In wetland units where rehabilitation has taken place (i.e., drainage followed by heavy vegetation management), water can be reapplied in the boreal fall to provide shorebird habitat and reduce the vigorous growth that would occur if water was applied in warmer months.

» Use short-duration (a week or more) drawdowns during migration and the nonbreeding season to expose mudflats and food resources for shorebirds. This should only be done if there is ample water to bring levels back up to desired levels. This practice has been used in California's Central Valley to provide mid-winter food resources to shorebirds.

See Case Study 2 for an example of strategies to provide shorebirds and waterfowl habitat in brackish impoundments.

Practices specifically for northbound migrant shorebirds in North America **(summarized from Fredrickson, 1991; Laubhan and Fredrickson, 1993; Iglecia and Kelsey, 2012):**

» Flood wetland during the boreal autumn and maintain flooded status until the spring northbound waterfowl migratory period. Then drawdown wetland slowly during the subsequent shorebird migratory period to continuously provide access to invertebrates in new areas.

» Drawdowns during April-May (in North America) generally make good moist-soil vegetation and good mudflats for shorebirds.

» Conduct vegetation management to ensure units targeting northbound migrants have significant areas of open water, and that no more than 50% have persistent emergent vegetation (e.g., Cattails). Wetland units may have non-persistent emergent vegetation (e.g., annual plants) because they will senesce. In general, less vegetation is better.

» Pulse or sheet flooding for moist-soil management may provide habitat for shorebirds for a very brief period of time, if the flooding occurs during migration. Stagger the sheet flooding of these units.

Practices for southbound migrants and breeding shorebirds in North America **(summarized from (Fredrickson, 1991; Laubhan and Fredrickson, 1993):**

» Drawdown units that have remained flooded through the boreal spring and early summer slowly.

» Shallowly disk the dry units before flooding to reduce vegetation and provide biomass for invertebrate production.

» Flood dry units 2-3 weeks before southbound migrants arrive to allow for invertebrate production, which will occur more rapidly in warmer months.

» Wetlands that have held water in May and June to supply breeding habitat for wildlife, such as long-legged waders, icterids (e.g., Tricolored blackbird, *Agelaius tricolor*), waterfowl, or Giant Garter Snakes (in California, *Thamnophis gigas*), can be drawn down during the early part of southbound shorebird migration (mid-July through August), a time of year when this habitat is often lacking.

» If providing habitat for breeding shorebirds, ensure consistent availability of shallow water for nesting birds, broods, and young throughout the nesting season.

» Pre-breeding season vegetation management may be required to ensure appropriate vegetation height and density for the breeding species at the site. Prescribed burns can be used to reduce tall vegetation and make habitats more suitable for nesting shorebirds. Moderate to heavy grazing on wet meadows can enhance habitat for Long-billed Curlews and Willets (Eldridge, 1992).

- Rotate impoundments through a deep flooding cycle October through June with a drawdown in July-August to help re-set vegetation community and provide habitat for southbound shorebirds. However, shallow warm season flooding can create suitable conditions for invasive plants, so additional management may be necessary.
- Although airboats may be essential for vegetation management, minimize use in vegetation during shorebird breeding season to protect birds and nests from harm.

Managing Water Depth

Water depth limits which shorebird species are able to use a wetland. Adding and removing water from wetlands can provide shorebirds access to food resources when wetlands may otherwise be unsuitable. In an interior wetland in the USA, the maximum diversity and abundance of waterbird use occurs in wetlands managed at average depths of 10 – 20 cm where the gradients in topography ranged from 30 - 40 cm (Taft et al., 2002). However, this may be too deep for some shorebirds, depending on the topography of the wetlands. Near Delaware Bay, USA, shorebirds readily used impoundments if shallow water was available, especially during peak migration (Parsons, 2002). In coastal impoundments in North Carolina and Florida, USA, actively managing shallow water (0 – 4 cm) increased shorebird use, but water depths need to be consistent rather than fluctuate, and sufficient prey items must be present (Collazo et al., 2002).

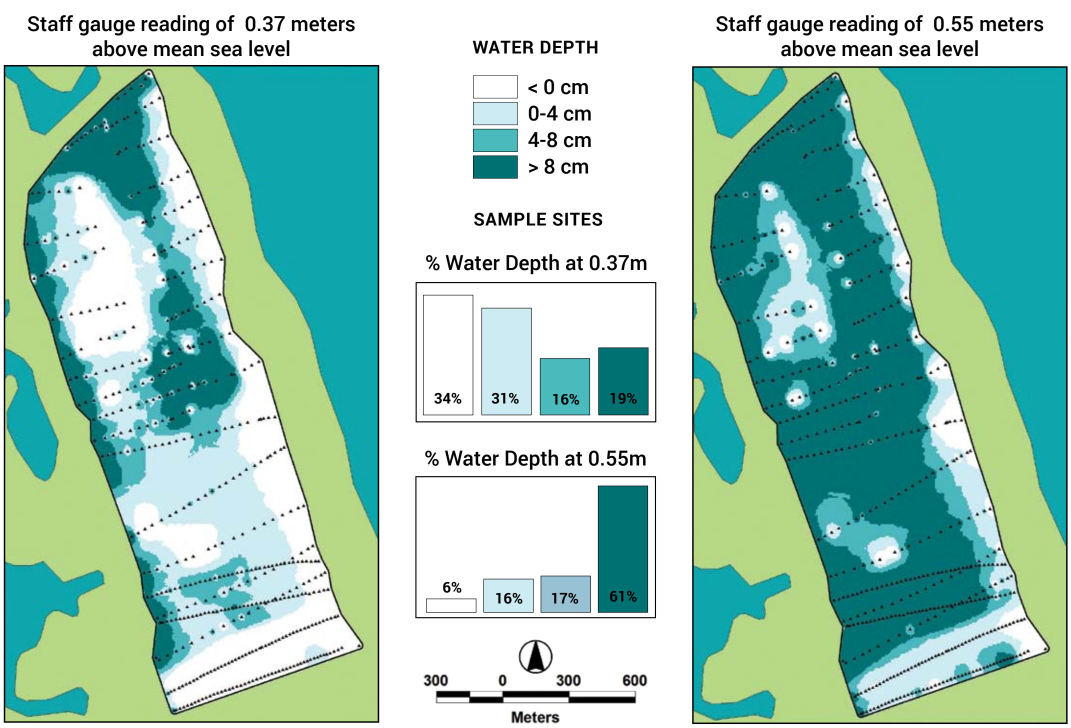
Inset: A model version of a water control structure called a rice trunk helps used to managed water levels at Tom Yawkey Wildlife Center in South Carolina USA.
Below: A rice trunk in place to manage water levels at Tom Yawkey Wildlife Center in South Carolina USA. *Photo Credit:* Monica Iglecia

Bathymetry to Inform Water Management

The topography of a wetland dictates how much habitat is provided to various waterbird guilds. Water levels are rarely uniform across restored wetlands; in many cases, adding 10 cm of water will not directly result in 10 cm of water depth across the wetland unit but will result in various water depths dependent on the shape and slope of the wetland bottom. The availability of accessible habitat at any given time will be some fraction of the overall area. Understanding the topography of the wetland units will allow a manager to understand how much water is needed to produce a desired area at target depths.

To understand the relationship between water depth and available habitat, install a permanent water gauge in the wetland unit (Collazo et al., 2002). When the unit is completely full with water, traverse the impoundment in intersecting transects that cross the unit with a high precision (+/- 1 m) Geographic Positioning System (GPS) collecting depth and location data every 50 m (this is a guideline, but spacing of sampling may vary depending on the size of the unit and the precision sought). Collect more densely spaced data points along slopes to increase precision. Using a spatial mapping program (e.g., ESRI ArcMap) to interpolate the depth data and interpret the expected proportion of habitat available when the permanent water gauge is at different levels. Using the map, define the depth readings on the permanent water gauge that define the bounds of water levels that will provide the desired habitat for various waterbird guilds.

Water Depth at Pea Island North Pond Impoundment



Areas within a unit providing habitat of varying water levels as modeled using bathymetry correlated with a staff gauge reading above mean sea level in North Carolina USA. *Original source:* Collazo et al., 2002.

Growing Invertebrates

Increasing the production of shorebird food resources is important to support shorebirds at a site. There is no single prescription for how to maximize the diversity and abundance of invertebrates because of differences caused by multiple factors, including invertebrate life cycles, geographic location, vegetation stages, climate, management, water chemistry, and soil types. In some cases, invertebrate diversity and abundance are higher in managed than unmanaged wetlands (Anderson and Smith, 2000; Davis and Bidwell, 2008). Other studies have found that intermediate management intensities, such as flooded agriculture, also produce significant invertebrate densities but had less invertebrate diversity (Hagy et al., 2011). Wetland water source can also influence invertebrate populations; surface water tends to produce more invertebrates than does groundwater (H. Hagy, pers. comm.).

Aquatic invertebrates in seasonal wetlands increase in density and diversity with longer flooding periods (Rosenzweig, 1995). Well-timed drawdowns of long-term standing pools and flooded wetlands should expose abundant resources to shorebirds. In freshwater managed impoundments in the southeastern United States, wetlands and agricultural fields mowed prior to flooding had four times more invertebrates than did areas that had not been mowed (Kaminski and Davis, 2014). In an interior constructed wetland in California, USA, invertebrate breeding ponds were designed to ensure food resources for breeding shorebirds; invertebrate ponds were placed within foraging areas that were 2.1 m wide, 15.2 m long, and 46 cm deeper than the surrounding subsurface (Davis et al., 2008).

Vegetation Management

Vegetation management will influence the value of wetlands for shorebirds. Dense, unbroken stands of emergent vegetation like Cattails (*Typha* spp.) and Spartina (*Spartina* spp.) exclude shorebirds and even waterfowl. However, living as well as dead and decaying vegetation provide substrate needed for invertebrate production. In an experiment in Cattail removal using various treatments in Cheyenne Bottoms, Kansas, disked and high-intensity grazing treatments received the highest shorebird response. However, species responded to treatments differently. Yellowlegs, godwits, and dowitchers reached highest abundance in flooded wetlands that had been intensely grazed, whereas sandpipers and snipes were more abundant in disked areas (Kostecke, 2002).

To balance the open habitat needs of shorebirds and other waterbirds with the productivity of vegetated wetlands, leave some areas with tall vegetation to provide the structure and organic matter needed to support invertebrate populations (Hagy and Kaminski, 2012). Vegetation management can be done throughout the year, but often occurs in warmer months. It can be completed by mechanical means (e.g., disking, mowing, scraping), or fire, grazing, flooding, and herbicide, depending on the size of the task and the type of vegetation.

Precautions

Any changes to management can result in responses that may require additional focus. For example, in some regions, slow drawdowns of flooded wetlands may increase undesirable vegetation, which will in turn require additional management. Each site and region will have different seed loads in the soil and will respond differently to alternative management practices.

While flooding wetlands at certain times of year can produce significant invertebrate resources for shorebirds, it also has potential to influence mosquito population growth and increase risk of disease outbreaks. Care should be taken when flooding wetlands, particularly during warm months, to balance habitat provision with mosquito production (Kwasny et al., 2004). Wetlands should be continuously monitored and have water circulated, released, or pulsed through the system to prevent low dissolved oxygen events and/or reduce potential outbreaks of cyanobacteria. Inland wetlands should take extra care to keep water moving and add fresh water to units during warm months to prevent low dissolved oxygen and reduce the potential for botulism and avian cholera outbreaks.

Annual rotation of all management activities in wetlands is needed to avoid conditions that can cause vegetation problems, lead to introduction of exotic species, or create conditions that can cause problems of disease (Helmers, 1992; Harrington, 2003).

Water quality is another factor that can affect many aspects of wetland and wildlife health. Where possible, prioritize surface water use to limit pressure on groundwater resources. Water sources like agricultural runoff can include heavy metals like selenium and/or salts that can have immediate or long-term deleterious effects on shorebirds, especially during the breeding season (Rubega and Robinson, 1996).

Uplands, Grasslands, and Grazed Lands

Grassland-wetland complexes of the prairies of North America are second only to the Arctic for number of breeding North American shorebirds (Grotto-Trevor et al., 2001). Grasslands in Patagonia support both migratory and resident grassland-dependent shorebirds. Grassland and grazed land specialists include Upland Sandpiper, Buff-breasted Sandpiper, Tawny-throated Dotterel, seedsnipes, and American Golden-Plover. Other shorebird species that regularly use natural and grazed grasslands include White-rumped Sandpiper, Baird's Sandpiper, Long-billed Curlew, and Pectoral Sandpiper. Shorebirds that breed in uplands and grassland areas, such as Upland Sandpipers, often prefer native grass for nesting but may use hay and some cover crops (Dechant et al., 1999). These upland breeders usually like sparse to medium density, heterogeneous grass or a mosaic of grass heights for nesting and foraging. Many species need nearby shallow wetlands.

Grassland-associated shorebird species were once associated with lands grazed naturally by native herbivores but, throughout the Americas, are now dependent upon domestic livestock to create the short-grass conditions conducive for survival.

American Golden-Plovers rely on grassland habitats on privately owned ranches like Medaland Ranch, Argentina during their annual cycle.
Photo Credit: Angeles Loredo

HABITAT MANAGEMENT IN UPLANDS, GRASSLANDS, AND GRAZED LANDS

Upland and grassland habitats, particularly within a grassland-wetland complex, provide important nonbreeding and breeding habitat for some shorebird species. Despite their biological value, native grasslands and prairie habitats in both North and South America have undergone significant development. Less than two percent of tallgrass prairie remain in North America (Samson and Knopf, 1994), and the pampas grasslands of South America have been severely altered by the development of agricultural lands, heavy grazing, and the loss of important grazing mammals. Today, shorebirds of upland and grassland habitats rely on the native habitats that remain and the human-altered areas with similar habitat features, including but not limited to pasturelands, sod farms, golf courses, freshly cut hayfields and sugar cane fields, and recently planted agricultural fields (Lanctot et al., 2009).

Management practices in upland habitats may include (from Kantrud and Stewart, 1984; Eldridge, 1992):

» Protecting remaining native habitat, especially large tracts.

» Restoring habitat.

» Active management that mimics natural and historic disturbances including burning, mowing, and managed grazing.

Habitat protection and restoration are important strategies but are not discussed further in this manual.

Grazed Lands

In North America, burning, mowing, and managed grazing are used alone or in combination to manage vegetation and improve habitat for migrating and breeding shorebirds. But the timing and intensity of disturbance can affect habitat suitability.

When managing grazed lands to benefit shorebirds, be aware of the influence of timing of burning on habitat provision. Areas burned between March and May in the Great Plains of Oklahoma, USA, attracted more migrating shorebirds (American Golden-Plovers, Upland Sandpipers, and Killdeers) than did unburned areas (Hovick et al., 2017). Depending on the species, over-grazing and under-grazing have the potential to render habitat unusable to some species.

In coastal Uruguay, grassland-associated shorebirds like Buff-breasted Sandpipers use grazed fields with vegetation no taller than 10 cm during austral spring and summer (Rocca and Aldabe, 2012). These fields also tend to be flat, with minimal topography, and are flooded at some time during the year. Uruguay's National Protected Areas System encourages farmers to plan cattle rotations and manage grazing intensity to ensure that intact short-grass habitat is available between October and early February, when shorebirds are present (S. Ghione, pers comm). Caution should be taken to minimize erosion and allow grazed lands the opportunity to recover from grazing pressure.

In southeast Argentina, a mix of Nearctic and Austral shorebirds use the short grass pampas at Medaland Ranch. American Golden-Plovers and Buff-breasted Sandpipers are present from August to the end of December while Tawny-throated Dotterels and Rufous-chested Dotterels use the area from May through September (Isacch and Martínez, 2003). Moderate levels of sheep grazing provide short grass habitats used by these four species (Isacch, 2001). Areas that are intensively grazed are used by a different suite of Nearctic and Austral shorebirds, including Pectoral Sandpipers and Least Seedsnipes (Isacch, 2001).

Grassland-breeding Shorebirds

For shorebirds that breed in grassland and upland habitats, review the habitat needs and requirements for the species of interest. For some breeding species, such as Long-billed Curlew or the western subspecies of Willet, large areas of short-stature, sparse grasses in proximity to wetlands or wet-meadow habitats provide ideal areas for nesting and brood-rearing (Dechant et al., 1999; Casey, 2013). Rotational grazed areas were used by Willets, and 'twice-over rotation' areas, where pasture is grazed two times within a season with two months rest in-between, were used by Marbled Godwits more than were pastures that received season-long grazing (Dechant et al., 1999;

Casey, 2013). Upland Sandpipers in the prairie habitats in Kansas, USA, foraged in grazed and burned sites with short vegetation but nested in infrequently burned sites with more vegetative structure (Sandercock et al., 2015).

See Case Study 3 for an example of using multiple strategies to benefit upland shorebirds in Cheyenne Bottoms, Kansas, USA.

Upland Sandpipers in Cheyenne Bottoms, Kansas USA. *Photo Credit:* Brad Winn

In addition, avoid actions that disturb the area such as mowing, burning, herbicide application, construction, and driving when nesting shorebirds are present. Manage vegetation, like haying and grazing, before the nesting season begins (Cochran and Anderson, 1987).

In some cases, managing shorebird habitat may include the management or protection of other animals. For example, Mountain Plovers have strong affiliations with areas disturbed by grazing American Bison (*Bison bison*) and Prairie Dog colonies (*Cynomys* spp.). Thus, protecting and improving Prairie Dog habitats will improve and increase areas available for Mountain Plovers (Skagen and Thompson, 2013).

Woodlands

The only shorebird in North America tightly associated with woodlands and woodland edges is the American Woodcock. Others species, such as Greater Yellowlegs, Lesser Yellowlegs, and Solitary Sandpiper, breed in boreal forests but are tied to associated wetlands. In the Andes of South America, several species of snipe are affiliated with forested or semi-forested communities including Imperial Snipe, Noble Snipe, and Andean Snipe.

An American Woodcock. *Photo Credit:* Maina Handmaker

HABITAT MANAGEMENT IN WOODLANDS

American Woodcock is the only shorebird species adapted to the mixed mature and early-successional forests of eastern North America. American Woodcock populations are in dramatic decline due to a loss of young forests and early successional habitats. Strategies to improve their habitats are unique among the tools used to provide habitat for shorebirds (Corr et al., 2008). American Woodcock require fertile and moist soils, shrubland, old fields, and young forests for foraging, early successional hardwood forests for nesting, and forest openings for courtship activities and roosting.

To improve nesting and brood rearing habitat, create approximately two hectare blocks of dense, regenerating hardwood saplings (Corr et al., 2008). Within 0.8 km of improved nesting habitat, foraging habitat can be provided by cutting 18 - 24 m-wide open strips that should be set back to early successional states every five years. To provide nighttime roosting areas, one 1-2 ha field for every 40 ha of habitat should be provided. Roosting fields should be mowed every 2-5 years.

Agriculture, Aquaculture, and Salt

Many shorebird species readily use working lands such as rice and crayfish agriculture, finfish ponds, shrimp ponds, and salt ponds. Upland associated shorebirds readily use sod farms and freshly turned agricultural fields in the United States during northbound migration.

HABITAT MANAGEMENT IN AGRICULTURE, AQUACULTURE, AND SALT

Agriculture and aquaculture have been driving forces for the loss of natural habitat. Wetlands have been drained or filled, mangroves cleared, and rivers diverted to make way for agricultural lands that support human communities and economies. Natural processes have been replaced by human-driven ones. Despite the conversion of these natural wetlands, working lands and waters can provide alternative habitat for shorebirds in some instances.

Managing habitat in working landscapes is often focused on providing shallow water and relatively vegetation-free areas during periods of shorebird use and minimizing disturbance. Habitat in flooded agricultural lands can be enhanced by mimicking hydrologic regimes or physical structure of natural habitats. For some crop types, such as rice fields, it is possible to improve conditions for shorebirds in many cases without affecting crop production (Elphick et al., 2010; Dias et al., 2014). Through active flooding, water-level maintenance, and well-timed drawdowns, agricultural fields can provide habitat for shorebirds as well as a variety of other waterbirds. For some types of aquaculture, like shrimp production, the scale of the threat from land conversion and the potential value of management strategies are still being studied.

The range of the Peruvian Thick-knee is restricted to coastal western South America. The species can be found in open agricultural fields. *Photo Credit:* Arne Lesterhuis

Rice and Row Crops

Studies examining management practices on agricultural lands mostly come from rice agriculture in the United States, but some identified practices can be applied to a variety of crop types, including corn, wheat, soy, and perhaps others.

The basic needs to emulate wetland habitat on farm fields during the non-growing season or out-of-production periods require that:

- » Tall or standing crop residue is lightly incorporated into the soil – this will create mudflat-like habitat when water is applied. Incorporation can be completed through disking or rolling. This process creates the potential for the open-type habitat that shorebirds prefer.
- » Water is available throughout the duration of the flooding period – this will ensure that shallow water habitat can be provided during the target period. Water can be passively collected, pumped, or gravity fed. Small berms surrounding the field will help hold water. Sandy soils will not hold water as well as clay-type soils.
- » Water can be managed – via water control structures or other means that allow for water to be removed when needed.

Multiple water depths held within one California USA rice field support a variety of waterbird species, from shorebirds to waterfowl. *Photo Credit:* Monica Iglecia

See Case Study 4 to see how conservation practitioners are working with rice farmers to improve on-farm habitat for shorebirds.

In Colombia, Asociación Calidris developed a program to promote and implement a set of standards for "shorebird friendly rice," which include eliminating the use of synthetic chemicals and fertilizers in weed and pest control, protecting the land from fire, reducing water use, preventing pollutants from entering the water supply, and prohibiting hunting on the property (Cifuentes-Sarmiento et al., 2018). They have found that shorebirds are present in the greatest numbers during the inundation, field preparation, and seedling phases of the rice-cultivation process, when water is most abundant and mud is most accessible for foraging.

Crayfish, Finfish, and Inland Freshwater Aquaculture Ponds

Finfish ponds, hatcheries, and other inland freshwater aquaculture ponds can provide shorebird habitat. Crayfish (*Procambarus* spp.) and finfish (e.g., Channel Catfish, *Ictalurus punctatus*) cultivation requires ponds or impoundments that can mimic wetland habitats. Often, these water bodies are too deep for shorebirds when they are in production; catfish ponds are typically 1 -2 m deep when in active use (Olin, 2011). In general, most shorebird use in these working lands occur when ponds are drawn down. In the United States, crayfish cultivation can occur in rotation with other cultivated crops, including rice, soybeans, or sorghum (Huner et al., 2009).

As in California rice agriculture, rice planting in the lower Mississippi Valley and Gulf Coast region of the southeastern United States occurs in the spring, providing some shallow-water open habitat for northbound shorebirds. But in contrast to California, some southeastern agriculture producers also seed the same rice fields with crayfish. During the summer months, crayfish are within their burrows and do not emerge until after the rice is harvested in the fall. Some fields are planted with soybeans or sorghum after the rice harvest. Given the flexibility of crop combinations and rotation in the southeastern United States, there is a complex and difficult-to-quantify mosaic of shorebird habitat available during both northbound and southbound migration. Even small hatchery ponds (0.4 to 4.2 ha) in Arkansas with harvest schedules that coincide with shorebird migration resulted in available mudflat habitat used by several thousand shorebirds during both northbound and southbound migration (Smith et al., 1991).

Left: Least Sandpipers use a drained catfish pond during southbound migration in Mississippi USA. *Photo Credit:* Brad Winn.
Right: Crayfish farms in Louisiana are used by shorebirds when they are flooded and drained. Holding water and timing draw-downs to align with shorebird needs can improve the availability of habitat. *Photo credit:* Monica Iglecia

Catfish impoundments in Louisiana, USA, are periodically drained for rehabilitation every 3-6 years, during which time they provide shallow-water habitat during southbound migration (Huner et al., 2009). In response to the 2010 Deepwater Horizon oil spill in the Gulf of Mexico, the United States Department of Agriculture's Natural Resources Conservation Service incentivized habitat provision on rice fields and out-of-production catfish ponds to provide alternative habitats to the oil-impacted coastal habitats. Idle catfish ponds were flooded shallowly August through September to provide habitat for southbound shorebirds. These created-wetlands had seven times more shorebirds than did catfish ponds in production, coastal wetlands, or state and federal conservation areas surveyed (Kaminski and Davis, 2014).

Actions that can be applied in catfish ponds can presumably be done in other aquaculture ponds (e.g., tilapia, trout, sturgeon) to provide shorebird habitat. Drawdowns timed to align with shorebird migration and water level management can help meet these needs.

Shrimp

Over one third of tropical and subtropical mangroves and salt flats have been developed for aquaculture, predominantly for shrimp production (Valiela et al., 2009). The top identified threats to shorebirds caused by shrimp aquaculture in Central America are 1. wetland loss through conversion of salt flats and mangroves to aquaculture production zones; 2. disturbance associated with production, including the use of gunpowder to scare off other avian species predating shrimp, thus disturbing roosting shorebirds; and 3. habitat degradation, including surface runoff into nearby estuaries and deltas, aquaculture outputs of nitrogen and other nutrient residues, and chemical use for disease and pest control (Morales et al., 2019).

Shrimp production areas are used by shorebirds in different capacities. Dikes, especially those with less than 30% cover of low vegetation, those that have been recently reworked or improved, and those not impacted by vehicle traffic, provide supra-tidal roosting habitat for resident, migrating, and nonbreeding shorebirds. Shrimp harvest can occur multiple times throughout the year. After each harvest, shrimp farms are drained for a few days. Shorebirds have been observed using the post-harvest drained and exposed pond bottoms, especially within two to three days after harvest (Navedo et al., 2016; Morales et al., 2019). Another potential period when shorebirds might use shrimp ponds occurs when ponds are being filled and stocked with post-larval shrimp. Use of ponds during the stocking and post-harvest periods depends on the degree of overlap of the shorebird annual cycle and the farm's production schedule and rotation (Morales et al., 2019). In addition, the distance from shrimp ponds to natural areas that provide additional habitat for shorebirds may influence shorebird use.

Best management practices have not yet been established for shrimp ponds but could include the following (each would require evaluation of utility):

» Prevent further conversions for shrimp aquaculture and managing existing ponds for sustainable shrimp aquaculture and shorebird habitat.

» Identify and protect known roosting and nesting dikes within a shrimp complex.

» Avoid using loud sounds, including gunpowder, to scare off avian species within a determined proximity of roosting dikes.

» Ensure vegetation-free dikes, particularly in known areas of high use. Maintenance should occur before shorebirds arrive to reduce disturbance.

» Plan for and conduct sequential harvest during periods of shorebird use to provide consistently available foraging areas (Navedo et al., 2016).

» Maintain moisture in drained post-harvest ponds to extend the period of available habitat for shorebirds (Navedo et al., 2016), as long as this does not cause unintended consequences.

Shorebird and waterbird species forage in a drained shrimp pond in Mazatlán Mexico.
Photo credit: Brad Winn

Research in Central America has identified the importance for companies to incorporate an ecosystem approach into their corporate social responsibility practices. This may include not only managing the ponds under their jurisdiction but also taking into account the associated nearby habitats that may be impacted by production, like adjacent wetlands and mudflats (I. Angarita, pers comm).

Salt

Salt and other sodium-based products (e.g., sodium sulfate) have been produced through a variety of methods around the world for centuries. A common form of salt production is solar evaporation. Through solar evaporation, saline water is collected in ponds where salt is concentrated through evaporation. This results in a salty brine that is moved to another pond where minerals can crystallize and the salt can be harvested. This process uses large, shallow ponds and high salinity water that also support large populations of brine shrimp and brine flies (*Artemia spp* and *Ephydra spp*) and result in vast areas without dense vegetation. These conditions provide shallow water and accessible food resources that can be used by nesting, migrating, and non-breeding shorebirds. As a result, shorebirds use salt production areas around the world. The Cabo Rojo salt flats of Puerto Rico, the Cargill salt ponds in Bonaire and California's San Francisco Bay, and the ECUASAL ponds in Ecuador have all been designated as WHSRN sites for their importance to shorebirds.

See Case Study 5 for an example of how to work with companies to incorporate the needs of shorebirds into salt production practices.

Management recommendations in both the San Francisco Bay and the Cabo Rojo salt flats are centered on the maintenance of ponds with varying water depths and salinities to provide habitat for a diverse set of waterbirds (Warnock et al., 2002). Shallow ponds with exposed moist sediment and water depths up to 10 cm should attract shorebird use. Recommendations for pond salinities in California are to have some ponds managed between 20-60 ppt, and some ponds managed around 140 ppt to support a diversity of waterbirds (Warnock et al., 2002). Protection and maintenance of roosting habitat is also important, which can include clearing vegetation and reducing disturbance, especially during high tide. Islands within salt ponds provide important roosting habitat, such as in the salt ponds of San Francisco Bay, and interior, undisturbed levees in the salt ponds of Ecuador provide similar benefits. In all saline environments, and especially in

Multiple shorebird species rest on the edge of a Cargill salt pond in Bonaire. P*hoto credit:* Lisa Sorenson areas where shorebirds are nesting (e.g., Snowy Plovers in San Francisco Bay salt ponds), access to freshwater may be an important factor in maintaining habitat quality and reducing the negative effects of salt stress, particularly for young shorebirds as salt glands develop (Rubega and Robinson, 1996).

Working with Farmers

Much like moist-soil management, improving habitat on farms often requires some level of active management. Yet in most agricultural settings, crop fields are the source of a farmer's livelihood. Thus, the willingness of farmers and landowners to engage in testing and implementing alternative management actions comes with some level of personal economic risk. Finding mutually advantageous scenarios that benefit wildlife and agricultural producers is vital to the acceptance and maintenance of practices that benefit shorebirds on agricultural lands.

A variety of strategies have been employed to engage farms and other privately owned lands in conservation implementation. These include: 1. government-funded incentive programs, like the Waterbird Habitat Enhancement Program developed by the National Resource Conservation Service in the United States; 2. voluntary programs managed by non-profits; 3. wildlife-friendly self- or third-party certifications that provide a premium price on crops grown in a manner compatible with wildlife; and 4. privately funded investments that incentivize implementation of compatible management practices, like The Nature Conservancy's Bird Returns program. All of the aforementioned strategies involve payments to landowners, which is rarely sustainable over the long term.

Some of the characteristics of management practices that may lead to long-term adoption by landowners after incentive payments end include those that (Dayer et al., 2018):

» Become easier to conduct over time or with practice

» Create spillover effects, like improved recreation opportunities

» Are compatible with landowner motivations, needs, and goals for their land

» Develop conservation habits

» Provide financial benefits, or do not lead to opportunity costs

» Are socially supported

Precautions

Similar to the precautions associated with managed wetlands, it is necessary to monitor water quality in these scenarios, especially because farmers' livelihoods stand to be impacted if on-farm habitat creation affects their crop production.

Managing Additional Threats

Residential and Commercial Development

Approximately 30% of the human population of the United States lives in coastal areas (Crowell et al., 2007). Residential and Commercial Development refers to threats of habitat loss and change resulting from housing and urban development and expansion, commercial and industrial areas, and the spatial footprint of tourism and recreation areas. Commercial developments like hotels and other tourism infrastructure, suburban housing, and malls, as well as industrial development including port creation and expansion, shipping, and power plants, place increasing pressures on fragile coastal systems.

Partnerships and collaborations with municipalities can help ensure that shorebirds will be taken into account during the process of new developments. There are opportunities within the built environment to manage public areas and green spaces to benefit shorebirds through understanding how the public values the areas and managing for both. For example, the Jamaica Bay Wildlife Refuge in New York City, USA, provides annual migration habitat for shorebirds that are valued by the birding public.

Management strategies to reduce the threat of habitat loss and change caused by development are varied and likely site-specific. Information-sharing and good governance foster communication and collaborative decision-making in ways that include natural resources. Where possible, manage the effects of new human structures and remnant development waste by mitigating the negative impacts of this type of habitat loss or degradation. For example, designing beach access walkways away from important shorebird habitat can direct human use to areas that will cause minimal disturbance. If roosting and nesting habitat loss is unavoidable, create artificial roost and nesting islands.

One example is the endangered Great Lakes population of Piping Plover in North America that breeds on sand spits and sparsely vegetated beaches along lake shorelines. Development for commercial, residential and recreational pursuits contribute to habitat loss, which is the most significant threat for Great Lakes breeding Piping Plovers (Wemmer et al., 2001). Great Lakes breeding populations of Piping Plover are so low that dramatic actions are required to ensure their persistence. These actions should address multiple threats and include habitat improvements such as vegetation control, predator control through lethal measures or exclosures, and even captive-rearing or translocation programs (Wemmer et al., 2001).

Natural disasters may provide unique opportunities for improving or helping to create habitat that would not otherwise exist. Hurricanes and large storms may scour and bury vegetation, or create sandbars and add sand to new areas, thereby improving habitat for shorebirds. Storms can breach islands or create new ones, increasing the amount of suitable habitat for shorebirds. While disastrous for human communities and associated infrastructure, Hurricane Sandy created new habitat on Fire Island and Westhampton Island in New York, USA, in 2012, which, coupled with coastal stabilization efforts, led directly to a more than 90 percent increase in the abundance of Piping Plover (Walker et al., 2019).

Human Intrusions and Disturbance

Human Intrusions and Disturbance refer to threats caused by humans from non-consumptive use and activities in natural areas that alter or disrupt ecological stasis. For shorebirds, these types of threats are often the results of recreational activities like beach driving, kite-surfing, and off-leash dogs that render habitats functionally unavailable to shorebirds, create ecological traps, or result in mortality. Other sources of disturbance can include activities related to shellfish aquaculture, algae harvesting, and other methods of resource use in habitats that shorebirds frequent.

> Mengak et al. (2019) define human disturbance of shorebirds as *"…a human activity that causes an individual or group of shorebirds to alter their normal behavior, leading to an additional energy expenditure by the birds. It disrupts or prevents shorebirds from effectively using important habitats and from conducting the activities of their annual cycle that would occur in the absence of humans. Productivity and survival rates may also be reduced."*

Things to consider when assessing disturbance at your site:

- Frequency of disturbance
- Type of disturbance
- Season of use by shorebirds
- Activity of shorebirds (e.g., foraging or roosting)
- Availability of food resources
- Area of disturbance and refugia

Human-caused disturbance can be equivalent to habitat loss and change because shorebirds alter their behavior or may completely abandon habitats (Gill and Sutherland, 2000; Navedo et al., 2019). Disturbance can also increase stress levels, reduce fitness, or cause site abandonment. Disturbance may affect shorebirds during foraging periods (low tide in coastal habitats) or roosting periods (high tide in coastal habitats).

The document *Guidance and Best Practices for Evaluating and Managing Human Disturbances to Migrating Shorebirds on Coastal Lands in the Northeastern United States* (Mengak et al., 2019) was developed as part of the Atlantic Flyway Shorebird Initiative and focuses on the northeastern United States during southbound migration. Though the document focuses on a specific geographic area and season, the best practices outlined can be applied to a wide range of sites to curb the effects of human disturbance on shorebirds. These best practices are summarized here with examples and suggestions to provide a broader understanding of these threats in the Americas.

TYPES OF HUMAN DISTURBANCE

The top thirteen disturbance activities from Mengak et al. (2019) are provided with examples of disturbance activities outside the scope of the report's focus on the northeastern United States. Additional types of human disturbance activities may exist that are not listed here.

Although specific management strategies can address different types of disturbance, many types of human disturbance affect shorebirds similarly. For example, dogs on beaches and various types of human recreation can displace and/or change shorebird behavior, reducing feeding or resting time. **The effects of several types of disturbance can be worsened at high tide, when shorebirds are competing for the same small amount of beach as humans.**

Left: American Oystercatchers on an undisturbed beach in Paracas Peru. *Photo Credit:* Diego Luna Quevedo
Right: Tire tracks left by vehicles driving on the beach in Mazatlán Mexico. *Photo Credit:* Monica Iglecia

1. **Beach Driving** – such as 4x4, ATV, beach buggies, off-road vehicles.
2. **Dogs** – both leashed and unleashed dogs, though probability and severity of disturbance is higher for unleashed dogs.
3. **Direct Harassment** – humans actively chasing birds.
4. **Beach Raking** – such as grooming, scraping. Many beach rakes may have similar effects on shorebirds as beach driving. Beach raking may indirectly deter shorebirds from a site by reducing or changing the composition of invertebrate prey resources in the substrate or impacting beach habitat quality (Mengak et al., 2019). In the northeastern United States, beach raking is often restricted during nesting season.
5. **Coastal Engineering** – such as beach nourishment (adding sand to combat erosion or make a beach wider, for example), artificial dune stabilization, and construction projects using heavy machinery. These can displace shorebirds and directly impact the quality and availability of habitat. Some engineering tasks occur every year (such as dune stabilization), while others are less frequent. Restrictions can regulate the timing of coastal engineering projects to not coincide with shorebird migration.
6. **General Beachgoing** – including walking, running/jogging, beachcombing, sunbathing, picnicking, ball/Frisbee playing, or similar activities.
7. **Events** – such as festivals, parties, tournaments and competitions, or fireworks that attract large groups of people. Managing disturbance from events is often focused on managing crowds of spectators to not disturb sensitive bird areas (Mengak et al., 2019).
8. **Recreational Fishing** – such as fishing, clamming, crabbing, or bait collection. Small-scale recreational activities can negatively impact shorebird foraging activity. Recreational fishing and associated activities, such as bait-digging, can lower shorebird use at a site (Townshend and O'Connor, 1993; Navedo and Masero, 2007).
9. **Motorized Watersports –** such as speedboats, jet skis, or airboats. Boating at high speeds in tidal creeks or other areas close to shorebirds may cause significant disturbance (Mengak et al., 2019). Boat landings can provide access to otherwise remote areas, opening the possibility of other types of human disturbance in sensitive shorebird habitat (Mengak et al., 2019).
10. **Commercial Fishing –** such as aquaculture, oyster racks, mariculture, Horseshoe Crab harvest, clamming, or seaweed harvest. Algae harvesting is another common practice at important shorebird wintering sites outside of the U.S., such as Chiloé Island, Chile. Mengak et al. found that many managers in the northeastern U.S. did not feel that commercial fishing/aquaculture created a significant disturbance to migrating shorebirds; however, other studies have documented lower shorebird abundance at sites with certain types of aquaculture present (Watson et al., 2017; Mengak et al., 2019). These activities often occur at or near shorebird sites, but, due to water jurisdictions in the U.S., states are often responsible for regulating commercial aquaculture or fishing operations (Mengak et al., 2019).
11. **Unmanned Aircraft –** such as drones and rocket launches. Few studies have been conducted to assess the effects of drones on shorebirds, so any recommendation should be treated as a hypothesis to be tested. On Chiloé Island, Chile, a large foraging flock of Hudsonian Godwits was observed flushing in response to a drone flying overhead, perhaps as a results of the drone casting a shadow similar to that of an avian predator (M. Iglecia, pers. obs.). Rocket launch sites near important shorebird habitats (e.g., coastal Texas and coastal French Guiana) are accompanied by vehicle traffic, tourism, and additional disturbance pressures in otherwise remote areas.
12. **Wind-powered Aircraft –** such as paragliding or kite flying. Not a common activity, but kites have been found to cause displacement and/or stress to roosting birds (Hoopes and Mark, 1992; Hatch, 1997).
13. **Non-motorized Watersports –** such as kayaking, canoeing, stand-up paddle boarding, or kite surfing. Several studies have documented shorebirds being disturbed by kitesurfing (Davenport and Davenport, 2006; Krüger, 2016) and have also found that restricting kitesurfing activity to an area far enough off shore (500m) can reduce shorebird disturbance caused by the sport.

Vehicle access to kite surfing areas in Bahia Samborombón Argentina brings large crowds to otherwise remote locations. *Photo Credit:* Monica Iglecia

ASSESSING SHOREBIRD DISTURBANCE AT A SITE

Before implementing management actions for human disturbance, managers should determine whether disturbance is negatively affecting shorebirds at their site. Transect surveys and point counts collect data about both human and shorebird use of a site, allowing comparisons of shorebird presence and abundance in different scenarios of human activity. Observations of shorebird behavior can provide insight into how human activities impact shorebird use, including which human disturbance types cause shorebirds to expend additional energy, avoid a certain habitat, or change their behavior in a way that reduces the time they are able to spend feeding or resting. While active beach activities (such as running or ball playing) have been shown to disturb shorebirds more than do passive activities (such as fishing or sunbathing), some studies have found that type of activity did not affect birds' flush frequency.

Thresholds at which shorebirds experience harmful effects from disturbance should be determined and can help design effective management actions to address human disturbance threats (Mengak et al., 2019). Disturbance thresholds vary between species, sites, and types of human activity and have not been thoroughly studied. One threshold metric is Flight Initiation Distance (FID), or the "distance at which a bird exposed to a human activity initiates escape behavior" (Livezey et al., 2016). Flight initiation can be an indicator that human activity is altering the natural behavior of the birds and can be used to determine appropriate distances for management actions, such as buffer zones. FID varies depending on species, bird age, flock size and species composition, season, number of humans present, type of human activity, and exposure frequency (Blumstein, 2003; Glover et al., 2011; Koch and Paton, 2014). One study found that mixed species flocks are less likely to flush but also less likely to return if displaced (Burger and Niles, 2014). Though FID has generally been found to be reduced when birds are actively foraging, the presence of people can reduce time spent foraging or intake rate during foraging (Thomas et al., 2003; Botto et al., 2008).

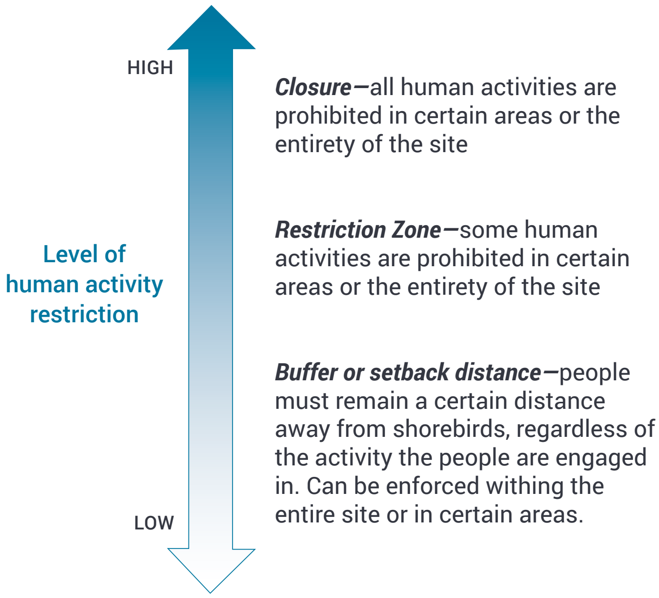
MANAGING HUMAN DISTURBANCE

(Summarized from Mengak et al., 2019)

See Case Study 6 to learn how biologists in coastal Georgia, USA, reduced the threat of human disturbance on important sand islands.

Restricting Human Activity

Methods to restrict human activity can include implementing buffer or setback distances, designating restriction zones, or full closures of specific areas. For example, symbolic fencing (e.g., a thin rope strung between temporary posts) with signage can be used effectively to protect important beach nesting areas from disturbance and is more effective than only posting signs (Ikuta and Blumstein, 2003). These same sites can benefit nesting seabirds and be refugia for migrant shorebirds if left up beyond the nesting season. Methods that restrict human activity can be challenging or controversial to implement. Tradeoffs with other management goals, perception/acceptability by the public, and lack of certainty about the impact of current human activity on shorebirds can affect implementation. Because of these challenges, it is important to choose the appropriate level of human activity restriction at a site.



A conceptual model to define management activities that regulate human activity and place them on a spectrum based on how heavily they restrict human activity. *Original source:* Mengak et al., 2019.

Other considerations for restricting human activity:

- Different species require different buffer distances, but it is recommended to use one buffer distance to reduce public confusion about the restriction being implemented (Paton et al., 2000).
- For sites used by mixed-species flocks, it has been recommended to choose the largest of the possible buffer distances to accommodate all species using the area (Koch and Paton, 2014).
- If creating restriction zones or closures, it is recommended to avoid creating too many zones to reduce confusion to beachgoers (Paton et al., 2000).
- When implementing beach closures, it is important to understand the affected audience and focus on meaningful outreach to improve compliance (Burger and Niles, 2013).
- If closures or buffers cannot be put in place, education is critical to behavior change (Koch and Paton, 2014).

Posting signs and roping off nesting areas on St Simons Island, Georgia USA helps protect nesting areas from human disturbance. While the roped area is not a true barrier for people, it provides a visual cue to delineate sensitive habitat so that beach-goers avoid areas with nesting shorebirds and seabirds. *Photo Credit:* Abby Sterling

Effective Messages and Signs

Public outreach and education are important for reducing disturbance to wildlife; however, the public is more likely to be compelled to change behavior if this new knowledge is combined with simple, actionable steps they can take to make a difference. For example, it is important to include a specific call to action, such as putting your dog on a leash or observing posted signage around roosting areas, when explaining that human disturbance can negatively impact shorebirds (Mengak et al., 2019).

It is important that messaging aligns with people's values, attitudes, and beliefs and is presented in a way that the audience understands that the issue is important. Rather than giving people too many choices, focus on a small set of behaviors that are easy and rewarding to adopt (Ardoin et al., 2013; Mengak et al., 2019).

Signs can be an effective way to encourage compliance with site rules. Signage should be designed to resonate with the site's specific user group and to strike a balance between regulatory and educational outreach. Signs with authoritative language and descriptions of fines or punishments may be effective for some groups, while signs intended to educate recreationists and promote bird-friendly human behavior might be more effective for reaching other audiences (Mengak et al., 2019).

Additional tips for effective signage, as summarized by Mengak et al., include:

» Educational signs seeking to encourage certain behaviors should be colorful and attention- getting and give a clear description of the issue and desired behavior from the public.

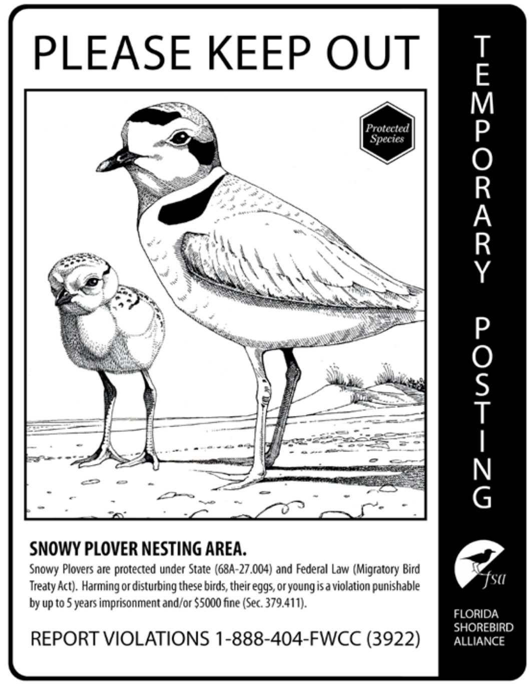
» Post signs in locations most likely to be seen – at beach entrance/access points and close to the area(s) where visitors need to be paying close attention (for example, at the edge of a restricted area or near a roost site or nesting zone.)

» Use personable, relatable language.

» Prioritize the most important messages for the top of the sign.

» Keep language simple and text as short as possible.

» Include photos, drawings, and images that are attention-grabbing, informative, and aligned with the sign's message.



Left: A variety of signs developed by children and sharing a message about shorebird conservation.
Photo Credit: Western Hemisphere Shorebird Reserve Network Executive Office.
Right: A seasonal and temporary sign with a clear message that informs visitors of nesting birds in the area.
Photo Credit: Florida Shorebird Alliance

Volunteers and Stewards

Volunteer stewards stationed at your site can greatly increase public compliance with restricted areas and buffer zones, helping reduce disturbance to shorebirds. One study found that the presence of a volunteer to educate beachgoers about birds decreased the number of people entering a protected shorebird area by nine times compared to when no steward was present (Forys, 2011).

Informational trainings for new and existing volunteers held before the shorebird season begins, coupled with specific talking points and messages to use in conversations, can increase volunteers' effectiveness communicating with beachgoers. Training sessions 1) educate volunteers about migratory shorebirds and the potential impacts of human disturbance and 2) prepare them for potential scenarios they may experience. Volunteers should be clearly recognizable, in a colorful vest or identifiable volunteer t-shirt, and located strategically at busy entrances or near restricted areas where they are able to engage the public, answer questions, and encourage compliance with posted signage (Mengak et al., 2019).

Public Access Points

Altering the way people access a beach can help concentrate human activity to a smaller area at your site. For example, most beachgoers congregate close to the beach entrance and near amenities, such as bathrooms and concession stands. Where possible, amenities and access points should be located as far as possible from key shorebird areas. Be aware of how beachgoers travel from the parking lot or other gathering points to the rest of the beach. If possible, use trails and boardwalks to discourage beachgoers from wandering into sensitive habitats, and limit the total number of these paths at the site.

Managing Beach Driving

Beach driving can displace shorebirds from feeding and roosting areas, prevent them from using certain habitats, cause direct mortality to eggs and chicks, and may compact sediments and reduce food resources. Not all species of shorebirds show the same responses to beach driving (Harrington and Drilling, 1996; Forgues, 2010), and for some species, different types of driving, such as vehicle speed or type of vehicle, may change the effect of the disturbance (Rodgers and Smith, 1997). Yet the impacts can be significant; vehicle traffic on nesting beaches can cause direct mortality of American Oystercatcher chicks and adults and decrease productivity by up to 50% (Schulte, 2012).

An American Oystercatcher chick killed by a vehicle driving on the beach. *Photo Credit:* Shiloh Schulte

The most effective way to reduce the impact of beach driving on shorebirds is to close beaches to any driving. If this is not possible, consider other management options such as:

» Reducing the total area in which driving is allowed.

» Restricting driving to less sensitive or less important habitats for shorebirds.

» Implementing low speed limit regulations in areas shared by wildlife.

» Placing seasonal restrictions on driving to reduce disturbance during key migration and nesting seasons.

A sign informing the public on Chiloé Island Chile that driving on the beach and in the dunes is prohibited, and to maintain a distance from bird congregations. *Photo Credit:* Monica Iglecia

Even sites that do not allow driving by the public might require some driving for enforcement patrols or maintenance staff. It is important to educate these drivers about best practices to reduce their disturbance to shorebirds, in addition to outreach initiatives focused on the general public. (See case study on Year Round habitat at Cape Romain National Wildlife Refuge).

Depending on the historical use and current management of a site, as well as the values and opinions of key stakeholders in the area, restricting driving on beaches can be controversial. It is important to consider these stakeholders and viewpoints in the decision-making process, which can be helpful when considering the best practices for maximizing habitat value and minimizing social conflict.

Managing Dogs

Across the Americas, dogs pose an ever-present and increasing threat of both disturbance and predation to adult and young shorebirds. In North America, the threat of dogs appears to be dominated by pets that are allowed off-leash in coastal areas. In the Caribbean and Latin America, the threat involves free-ranging dogs with and without owners. Many studies have documented dogs causing a negative impact on shorebirds. Some studies have found dogs to cause a stronger impact on shorebirds than people or vehicles, based on birds not returning to a beach after being disturbed by a dog. The presence of dogs significantly increases the probability that shorebirds will not occupy the area, causing birds to flush farther than other types of disturbance (Burger et al., 2007; Stigner et al., 2016).

Leashing dogs can reduce disturbance to shorebirds. Creating signage that appeals to dog-owners' concerns for their pet's safety (such as highlighting potential confrontations with other dogs or with people) can help persuade dog owners to leash their dogs. Managers might consider conducting education and outreach efforts specifically targeted towards dog owners and dog walkers (Mengak et al., 2019). If it is possible to provide designated areas where dogs can exercise off leash, dog owners may be more likely to comply with rules in areas where dog use is restricted. If no dogs are allowed anywhere at the site, it can be helpful to provide information about nearby dog parks at the entrance to the site, either through signage or verbal communication from staff members or volunteer beach stewards.

Free-ranging dogs cause disturbance and death to wildlife. Outreach and education to area users can help reduce this type of disturbance. *Photo Credit:* Monica Iglecia

See Case Study 8 to learn about a comprehensive approach to managing dogs on Chiloé Island, Chile.

Free-ranging dogs, especially those in packs, can be a hazard to humans in the form of attacks and reduced safety in natural spaces, as well as to shorebirds and other wildlife. For example, a variety of human disturbance activities occur in Bahía Blanca, Argentina, including, but not limited to, free-ranging dogs, mismanaged dogs with owners, and other threats like kite-surfing. Users of coastal habitats were allowing dogs to run freely and disturb birds. Through a partnership of the municipality of Daniel Cerri, the local fishing and sailing club, the Port of Bahía Blanca, the National University of the South, and the Group of Conservation and Management Studies (GEKKO), signs were designed and placed in strategic areas to notify the public that dogs off leash and other activities are not allowed (P. Petracci, pers. comm). Rules are enforced by staff of the fishing club 24 hours a day. While it has yet to be formally evaluated, observations suggest that this effort is helping to reduce disturbance from off-leash dogs and recreation activities, particularly in areas where shorebirds forage and roost.

For more literature about human disturbance see Comber et al. 2019. Atlantic Flyway Disturbance Project: Literature Review Version 1: Alphabetical.

Invasive Alien and Problematic Native Species

Invasive alien, and problematic native species have or are predicted to have negative effects on shorebirds and their habitats. Major threats within this category can be direct, such as predation of shorebird adults, eggs, and young, or indirect, such as encroachment of native and non-native plants into shorebird habitats or the all-out destruction of primary habitat, thus reducing the availability or condition of vital resources.

PREDATORS

Predators of shorebird adults, eggs, and chicks hail from a variety of taxa. Predators can include avian species like Peregrine Falcon *(Falco peregrinus)*, Herring Gull *(Larus argentatus)*, and Common Raven *(Corvus corax)*; mammals like Raccoon *(Procyon lotor)*, Red Fox *(Vulpes vulpes)*, Coyote *(Canis latrans)*, Domestic Dog *(Canis lupis familiaris)*, Feral Cat *(Felis catus)*; reptiles, including snakes and iguanas; and even invertebrates like Ghost Crabs *(Ocypode quadrata)* (Hunt et al., 2018).

Predation results in direct mortality of adult shorebirds and the loss of annual productivity when eggs or young are depredated, which can impact shorebird population dynamics. In many cases, predation is the most common cause of nest failure (Catlin et al., 2011; Ellis et al., 2015). Human actions can inadvertently increase predator abundance and even attract predators to shorebirds nests. Trees, fence posts, signs, and other structures provide perches for avian predators and should be removed or altered to prevent perching. Trash, especially food-related refuse, attracts mammalian and avian predators like Raccoon, ravens, and gulls to areas where shorebirds are nesting (e.g., beaches).

Predator control can be an effective way to improve annual reproductive success for temperate and tropical beach-nesting shorebirds. For some species, like American Oystercatcher and Snowy Plover, predator control is a necessary component of the long-term management strategy to conserve the species. One fox on an island in coastal Virginia caused near total nest failure for American Oystercatchers (~70 nests) and other nesting birds, including terns, skimmers, and plovers. Fox removal allowed nest success to rebound on the island (American Oystercatcher Working Group, 2012).

Habitat improvements can help camouflage incubating adults, chicks, and eggs, or improve habitat conditions for nesting by reducing predator access. Methods for increasing crypsis have included adding crushed oyster shells to provide beneficial cover (Riensche et al., 2015), removal of invasive or problematic vegetation (Dinsmore et al., 2014), and island creation (Ackerman et al., 2014). In the San Francisco Bay salt ponds of California, research supports locating islands in ponds within 1 km of the bay waters, constructing islands 100-200 m from a levee, and creating islands that are more linear than rounded and between 0.05 and 0.10 ha in size (50 m x 10 m) (Ackerman et al., 2014).

Guidance and Best Practices for Coordinated Predation Management to Benefit Temperate Breeding Shorebirds in the Atlantic Flyway (Hunt et al., 2018) provides best practices to guide predator management activities to benefit temperate breeding shorebird species in the Atlantic Flyway; however, these practices may be applicable at other sites. The best practices summarized here were designed to help consider and evaluate all possible options, so an appropriate combination can be selected to best suit the management needs at specific sites. For more information and to read the full document, visit the Resources section of the Atlantic Flyway Shorebird Initiative website.

Identify Target Species and Predators for Management

Determine the species to benefit from management (hereafter, target species) and identify known and potential predators at the site. Assessments of possible target species may include avian species surveys, abundance estimates, and productivity assessments to help prioritize which species would benefit most from predation management. Camera traps and telemetry, as well as interpreting tracks and signs at nest sites, can help determine whether predator species are present at a site and affecting target species.

Identify Strategies, Triggers, and Priorities for Lethal and Nonlethal Management

Once target species and their predators are identified, decide when to start and stop predation management at a site, and determine what types of triggers and thresholds warrant management action. Predator management should be a last resort, implemented only after the root cause of increased predator pressure is well understood. For example, is the predator species present (or occurring at unnaturally high densities) because of an underlying human cause such as food subsidies or a causeway connecting an island and the mainland? Can these factors be addressed rather than relying on predator management? If not, lethal and nonlethal predator control strategies can be considered. If resources are limited, managers will need to prioritize predator management with other needs.

Lethal Predator Control

Managers must decide which methods of lethal predator control might be most appropriate, feasible, and effective at their site. Techniques may include trapping, shooting, poisoning, and destroying nests and eggs (in the case of avian predators). Managers must familiarize themselves with permitting requirements and restrictions in their area, as not all lethal predator management techniques will be allowed at every site or perhaps in every country.

Nonlethal Predation Management

Nonlethal predator management may be more available to managers than are lethal methods. However, in the United States, even nonlethal techniques for controlling avian, mammalian, and other predators are regulated by local, state, and/or federal law. Managers must ensure predator management plans comply with all required permitting processes. Nonlethal predator control techniques include:

- Exclusion – such as nest enclosures, electric fencing, and predator fencing
- Visual and acoustic harassment – loud noise or visual cues that cause predatory species to flee the site, without disturbing the target species
- Chemical repellents – deterring predators from consuming nests of threatened avian species by conditioning them to develop a taste aversion
- Shock aversion – similar to chemical aversion, but instead of coating a decoy egg in a chemical repellent, uses conductive paint and a battery to wire a decoy egg to give predator a mild electric shock
- Trap and relocate – live trapping the predator(s) and relocating them as far away from the trapping site as possible

Solar powered electric fencing is used to reduce predation of American Oystercatcher nests and Least Tern colonies by mammalian predators in coastal Georgia USA. *Photo Credit:* Abby Sterling

- » Anti-perching – removing or modifying hunting perches from nearby nesting sites to make habitat less attractive to avian predators
- » Trash removal and management – removing trash left by humans so it does not provide a food source that attracts predators to an area used by target species or artificially inflates populations of predators already present at the site
- » Removal of avian predator nesting substrate – deterring avian predator species from nesting in places also used by target species

Timing of Predation Management

Careful timing can increase the success of predator control methods and reduce unintended secondary effects of predator management activities, such as the unintended increase in number of another predator. Appropriately timed implementation will be based on the phenology, ecology, and community dynamics of both the target and predatory species. For example, trapping mammalian predators before the shorebird breeding season begins might reduce disturbance to chicks, but the predator population of interest may not be active at the site until shorebird nests are present as a reliable food source, so the early trapping effort would not have the intended result of reducing predation.

Unintended secondary impacts can include altering the predator population or community dynamics. For example, removing top predators (such as Coyotes) can create an opening for smaller predators (such as Raccoons). Alternatively, a management action could cause prey switching by predators – for instance, removing colonial avian predators (such as gulls) might lead their mammalian predators to seek out shorebird nests.

Helpful data on target species includes average arrival date, average clutch initiation date, and average peak hatching date. Important information to gather about predator species includes details of their movement and dispersal, daily and seasonal activity patterns, breeding status, and availability of their preferred food resources. These ecological data require long-term monitoring studies and are often more readily available for target species than predators. If conducting a systematic research project is not an option, similar data about prey and predator interactions at nearby sites may help guide management decisions.

Community Engagement, Outreach, and Communication

Predation management can be controversial. Community engagement, outreach, and communication are important tools to clarify often misunderstood concepts about predation management and increase public support of these methods to protect at-risk species. Hunt et al. (2018) provide an extended "Predation Management Outreach Tools" resource with guidance on messaging and helpful talking points for speaking to the public about predator management. For additional insight on strategies for community engagement, please review the WHSRN Community Engagement Toolkit (WHSRN Executive Office, 2020).

Laws, Regulations, Land Access, and Permits

All relevant permitting procedures must be considered when developing a predation management program. Specific laws and regulations will differ from site to site and between countries, but regardless of project location, it takes time to secure the required permits, and ensure compliance with endangered species laws and other environmental policies. Hunt et al. (2018) provide guidance on anticipating and navigating these permitting processes when planning a predator management strategy.

Monitoring, Measuring, and Reporting Effectiveness

Regular assessment and evaluation are key to measure the success and efficiency of any management and to help adapt management actions accordingly. Predator presence, predator pressure, and productivity of the target species are metrics to help assess the effectiveness of a predator management program. Organized and consistent data collection over time will allow comparisons of the effectiveness of predation management from year to year. Hunt et al. (2018) provide Standard Operating Procedures to guide appropriate data collection protocol.

Coordination of Management and Funding Across Agencies and at Multiple Scales

Communication with other groups conducting predator management can increase a project's success. For example, managers of a state preserve in Florida, USA, identified Raccoons as a predator of beach-nesting birds at their site. By communicating with managers of the adjacent County Park and National Wildlife Refuge, they learned that theRaccoons at their preserve were part of a larger population also impacting nesting birds at these adjacent sites. Together they coordinated a Raccoon management program that led to more effective predator management at all three sites.

See Case Study 9 for predator management strategies used to benefit Snowy Plovers.

Collaborating with other sites and managers can open opportunities for funding sources and extend predation management efforts to cover a larger area or continue for a longer amount of time. Hunt et al. (2018) provide a list of primarily U.S.-based funding possibilities, as well as opportunities to connect with other managers working on predation control strategies.

MARINE INVASIVE INVERTEBRATES

Exotic invasive species influence nearly all biomes of the world, and coastal marine environments are no exception. While land managers are able to recognize and effectively control many terrestrial invasive vertebrate species that negatively affect shorebirds directly, such as free-ranging cats and feral hogs, in most cases, aquatic invasive invertebrates are beyond the management capacity of most authorities. While not considered a top-threat, we introduce the subject to create awareness among coastal managers that the invertebrate communities of intertidal wetlands could have been, or more-likely are currently being, influenced by non-native species. While there have been improvements in regulations pertaining to ballast water disposal in the United States, invasive introductions into marine and estuarine waters will be playing out for decades to come.

For more information about some of the marine invasive species potentially influencing (negatively and positively) shorebird food resources, see (Grosholz and Ruiz, 1996; Grosholz, 2002; Ray, 2005; Caldow et al., 2007; Molnar et al., 2008; Estelle and Grosholz, 2012; Epifanio, 2013).

PROBLEMATIC PLANTS

Some plant species can affect habitat quality and thwart shorebird habitat management goals. In the western United States, an invasive species of spartina (*Spartina angelica*) outcompetes native wetland vegetation, resulting in a monoculture of tall grass and the conversion of intertidal mudflats to vegetated marsh. Problematic plants, such as Phragmites (*Phragmites australis),* Purple Loosestrife *(Lythrum salicaria),* Burdock *(Arctium minus)* or Sesbania *(Sesbania punicea)* can rapidly expand and take over wetland habitats, making them largely inaccessible to most wetland-associated birds. And while some plant species, such as Cattail (*Typha latifolia*), provide important structure and cover in wetlands, they can become problematic in large stands by reducing habitat diversity and impeding use by shorebirds.

Physical treatments can help prevent, suppress, contain, or eradicate exotic invasive and problematic plant species. Mechanical methods such as mowing, digging, burning, hand pulling, and disking are techniques used, often during the growing season, to set back invasive or problematic plants. Well-timed mowing or cutting to avoid seed production and propagation can reduce the spread of problematic plants. In the Puget Sound of Washington, USA, invasive Spartina once affected more than 8,000 hectares, but through intensive chemical spraying over the course of multiple years and even hand digging persistent patches, the area of Spartina has been nearly eradicated (Hedge et al., 2003).

Chemical tools, like targeted herbicide application, can be used carefully in combination with mechanical strategies at the same site. For example, Alligator Weed (*Alternanthera philoxeroide*) is a native species to the temperate regions of South America that is increasingly problematic in the southeastern United States. It grows rapidly and chokes waterways, impacting water delivery and the efficiency of water-level management. Alligator Weed can be cut or grazed, but it is difficult to control physically because it will propagate from stem fragments or the roots. Herbicides approved for use within aquatic habitats are most commonly used to control this species.

In Central Kansas, USA, where both Cattails and Phragmites threaten the open and shallow water habitat of Cheyenne Bottoms, wetland managers use a combination of techniques to maintain ideal habitat conditions. Aerial spraying with the lowest amount of chemical required to kill the targeted plant occurs during peak growth, between July and September, and then areas are re-treated in following years as needed. When conditions are dry enough, mowing previously treated Cattails a few months after spraying can expose surviving plants, which are then targeted for spraying during the following year. Mowing helps to speed up the availability of open areas within the wetland. Another technique is to drain the area, burn the Cattails, and then disk, which exposes, dries, and kills the roots. This technique is only used for Cattails because disking Phragmites may increase growth.

See Case Study 10 to learn how managed impoundments in Louisiana make seasonal decisions based on vegetation to benefit shorebirds and waterfowl.

Phragmites is a difficult-to-manage invasive plant that can be controlled through multiple years of glyphosate application just before the plant becomes dormant when combined with mowing, cutting, trampling, and burning (Rohal et al., 2017). In Central Kansas, ground spraying before burning and disking helps set back this plant. Mechanical and chemical spraying are labor-intensive but may be an effective combination to manage problematic plants at both the large and small scale.

In Bahia de Asuncion, Paraguay, dredging and sand-removal to create an embankment for a coastal road destroyed nearly 70% of the shorebird habitat in the bay, resulting in deep freshwater areas, patches of invasive shrub habitat, and changes to the height of annual water fluctuations. During the austral summer months (October-February), large areas of the bay's shallow water and mudflats had disappeared, resulting in rapid advancement of invasive vegetation, especially Jukeri (*Mimosa pigra*), which quickly covered areas previously used by shorebirds. Guyra Paraguay and the Municipality of Asunción and the Environmental Ministry and the Ministry of Public works and Communications worked to restore priority habitat for shorebirds by building an impoundment and removing invasive vegetation. Hand-pulling and machinery were used to remove invasive vegetation. The impoundment creation and vegetation management resulted in approximately three hectares of restored habitat that was quickly used by shorebirds. While successful, the habitat in Bahia de Asunción is not fully restored, and invasive vegetation management will need to be an ongoing activity to ensure the availability of open habitat for shorebirds.

In some cases, biological controls, such as grazing animals, can be used to browse and control invasive and problematic plants.

Hunting

The threat of hunting is related to the killing or trapping of shorebirds, including deliberate and unintentional take for food or recreation, but can also include persecution or control of species considered to be pests. When Europeans colonized the Caribbean and northern South America in the mid-1600s, they brought with them a tradition of shorebird hunting. Although the practice has faded out or been restricted greatly in many jurisdictions (e.g., Canada and the United States), current information indicates that significant hunting pressure still exists in Barbados, Guadeloupe, Martinique, Brazil, French Guiana, Suriname, and Guyana (Atlantic Flyway Shorebird Initiative (AFSI) Harvest Working Group, 2020)

With the development of the AFSI Business Plan (2015), it became obvious that although modern hunting pressure on shorebirds was incompletely known, annual harvest was potentially a population-level constraint for some species or distinct populations (Watts et al., 2015). In response to this need, a working group was formed with the goal of achieving a sustainable shorebird harvest, while meeting regional cultural and subsistence needs (AFSI, 2016). Beginning in 2011, the group realized the importance of the human dimensions associated with shorebird hunting in assessing the harvest pressure and developing successful solutions for sustainability.

Management actions outlined by the AFSI Harvest Working Group include:

» Strengthen law enforcement.

» Develop harvest management tools.

» Strengthen legislation and policies.

» Develop incentives not to hunt.

» Establish and maintain no-shooting reserves.

» Improve education and communication.

See Case Study 11 to learn how shooting swamps (i.e., hunting clubs) in Barbados have transitioned to no-shooting swamps.

More information about the complex and wide range of laws and policies toward guns and hunting in the Caribbean and northern South America was a needed first step in establishing a regional approach to sustainable shorebird hunting (Watts and Turrin, 2016). For example, in Guyana there are no closed hunting seasons, bag limits, or species closures for migratory shorebirds; however, there are very restrictive gun laws. This led to the use of "shocking wires" as a hunting method (Bayney and Da Silva, 2005). In contrast, Suriname has about 30,000 active hunting licensees (New Jersey Audubon Society, 2017), and though shorebird species are protected, poaching is a widespread issue.

Understanding the uses of shorebirds by hunters and their motivations and attitudes will enable development of effective strategies for outreach and, if needed, establishment of nutritional substitutes. In some places, such as coastal Guyana, shorebirds are hunted for food or sold as bushmeat (Bayney and Da Silva, 2005; Wege et al., 2014; Moore and Andres, 2017; A. Levesque, pers. comm.). Hunters in French Guiana and Suriname usually harvest shorebirds collaterally when hunting other species (New Jersey Audubon Society, 2017; Taylor, 2017). Shorebird hunting in Barbados is primarily recreational. Escalating costs for swamp (wetland) maintenance and ammunition in Barbados, coupled with stricter gun control, are reducing the number of hunters and swamps on the island (W. Burke, pers comm; Atlantic Flyway Shorebird Initiative (AFSI) Harvest Working Group, 2020).

The shooting of two satellite-tagged Whimbrels on Guadeloupe in September 2011 catalyzed the Guadeloupe hunting federation to set bag limits, reduce hunting days, and add protections for shorebirds of conservation concern (Andres, 2017). Similarly, the Barbados Wildfowlers Association recommended previously drafted restrictions on daily and seasonal bag limits and limits on the number of hunters at one time. These recommendations were formulated cooperatively from an assessment completed by the Canadian Wildlife Service (Reed, 2012).

More recently, French Guiana has added protection for a number of shorebird species and authorized the issuance of hunting licenses (Andres, 2017). On the government agency side, the Office Français de la Biodiversité, Canadian Wildlife Service, and U.S. Fish and Wildlife Service have agreed to work cooperatively on achieving sustainable shorebird hunting in France's Overseas Departments. Building on this momentum, stakeholders from hunting federations, agencies, and non-governmental organizations met in Barbados in March 2016 and in Guadeloupe in 2019 to discuss the sustainability of shorebird hunting (BirdLife International, 2016; Laliberté et al., 2019). Engagement by a robust set of stakeholders at multiple geographic scales and organizational levels has contributed to the progress gained to date (AFSI Harvest Working Group, 2017).

Climate Change

Many of the effects of climate change have been recognized as threats to the habitats, prey, and natural systems that shorebirds rely on. The migratory nature of most shorebirds may expose them disproportionately to population-level impacts from climate change (Small-Lorenz et al., 2013). Changes in hydrological cycles (flood/drought), storm intensity and frequency, and coastal habitat losses resulting from rising sea level are just some of the challenges climate change poses for shorebirds. These stressors may result in reduced fitness and survival during migration, as well as the loss of breeding, nonbreeding, and migration habitats. Indeed, 90% of assessed North American shorebird taxa are at an increased risk of extinction exacerbated by climate change (Galbraith et al., 2014).

See Case Study 12 to learn how reducing erosion and creating habitat on an island in California is increasing resilience to sea level rise.

Ecosystem services, including storm protection, erosion control, food, and raw goods provided by wetlands and coastal estuaries globally, are valued at $31.6 trillion USD (Costanza et al., 2014). The effects of climate change on the habitats that shorebirds use will also affect human communities and economies. Further, wetlands are significant carbon sinks, especially peatlands and vegetated coastal wetlands like tidal saltmarsh. The continued loss, drying, and warming of wetlands are a future source of major carbon emissions (Moomaw et al., 2018), which will further increase the rate of climate change. Increased storm frequency and strength are threats to human infrastructure and life. Changes to drought and flood cycles threaten food systems and livelihoods. Sea level rise threatens the composition of mudflat, low-marsh, mid-marsh, and high-marsh habitat, especially in the coastal wetlands of the United States where room for marsh migration is limited by coastal development (Thorne et al., 2018).

A Sarcocornia salt marsh in the Rio Gallegos Estuary Argentina.
Photo Credit: Monica Iglecia

The root cause of the threat of climate change to shorebirds will require coordinated government action worldwide. Yet site managers can prepare for some of the impacts of a changing climate and incorporate resilience planning into their management plans.

Climate-Smart Conservation is a paradigm that seeks to improve resilience. It has been defined as "*the conservation strategies and actions that address the impacts of climate change and also other environmental threats"* (adapted from BAECCC, 2013). A variety of principles have been outlined to guide the design and application of Climate-Smart Conservation.

CLIMATE-SMART CONSERVATION

Six guiding principles of Climate-Smart Conservation are (Bay Area Ecosystems Climate Change Consortium, 2013):

1. Focus goals on future conditions.
2. Design actions in an ecosystem context by prioritizing ecosystem function and multiple species benefits within a broad geographic context.
3. Use adaptive and flexible approaches.
4. Prioritize actions based on the best available science, multiple scenarios, and multiple species.
5. Collaborate and communicate across sectors.
6. Practice the 10% rule: use 10% of each day to test out new approaches for natural resource conservation.

Four basic tenets to Climate-Smart Conservation include (Hansen et al., 2010):

1. Protect adequate and appropriate space.
2. Reduce non-climate stresses.
3. Apply adaptive management to implement and test adaption strategies.
4. Reduce the rate and extent of climate change to reduce overall risk to the conservation unit of concern.

Efforts to put Climate-Smart Conservation into practice have begun. In California, USA, high resolution data and interactive maps developed by Point Blue Conservation Science and the United States Geological Survey provide managers and coastal communities with tools they need to prepare for projected sea level rise and associated storms, flooding, and other hazards. On the Atlantic Coast of the USA, mapping and cataloguing coastal managed impoundments helps assess vulnerabilities to sea level rise. To address the threat of sea level rise and storm surges, the Delaware Division of Fish & Wildlife in Delaware, USA, is taking a multi-pronged approach by fortifying the levees of existing coastal impoundments to extend the lifespan of those impoundments and the habitat they provide today. In addition, plans to move two impoundments further inland will replace coastal impoundment habitats that will be lost in form and function by rising sea levels. The planned inland retreat of impoundments requires site selection that takes into account the overall hydrology, ability of soils to hold water, and access to freshwater sources. As the first effort of its kind, this impoundment-moving project will provide valuable lessons learned for other land managers, balancing the needs of providing habitat today while planning for a changing future.

Resilience management can help social and ecological systems maintain or regain functionality after major disturbances through 1. restoration and maintenance of current conditions, 2. accommodating change but working to return to the pre-disturbance state, 3. facilitating change through active or passive management (Powell et al., 2018).

The following strategies can help ensure that species and habitats can adapt to a changing environment (Stolley, 2010). Each of these, if applicable in your region or site, will need to be adapted according to local conditions:

» Increase resilience by reducing anthropogenic (e.g., human disturbance) and non-anthropogenic stressors (e.g., predation) that exacerbate species' abilities to respond to a changing environment (see Human Disturbance and Predation sections of this Manual for strategies to reduce these threats).

» Replicate habitats that may be lost or are under threat of change by increasing conservation ownership of important habitats or coordinating habitat management across jurisdictions.

» Mitigate effects of climate change on habitats by making modifications that will accommodate and manage flooding caused by sea level rise; ensure the availability and delivery of sediment or use prescribed fire to support accretion that keeps pace with sea level rise; or remove barriers to habitat migration. Prescribed fire stimulates plant growth, which will provide organic matter needed for accretion.

» Relocate habitats, such as managed impoundments, typically to areas at higher elevations.

» Restore habitats that are expected to be resilient to the effects of climate change.

For regional and country-specific priority actions to increase adaptation and resilience to climate change, see the Climate Action Plan for the Americas (BirdLife International and Audubon. 2017).

Pollution

Pollution, often a by-product of human development, can damage, limit, or reduce the quality of habitat or food resources and have wide-ranging implications for breeding and migratory shorebirds (Atlantic Flyway Shorebird Initiative (AFSI), 2015). Pollution can contribute to habitat loss and degradation and have sublethal and lethal impacts. Some of the most significant issues involve contaminants in food resources, contaminants caused by environmental disasters, such as oil spills, red tides, or waste-water discharge, and physical pollution of the environment.

Contaminants in Food Resources

Shorebirds are impacted by contaminants through the food chain by feeding on contaminated invertebrates. Horseshoe Crab eggs can contain contaminants including heavy metals from the environment, which can bioaccumulate in shorebirds. In Japan, water quality issues have led to significantly more contaminants documented in both eggs and early instars of Horseshoe Crabs than seen in the surrounding environment (Botton and Itow, 2009). In the Delaware Bay, USA, where shorebirds rely on Horseshoe Crab eggs during northbound migration, mercury has been found in the system at relatively low levels. However, there is a low risk of lethal effects because shorebirds only feed on Horseshoe Crab eggs for a short period of time (Burger et al., 2003).

A broad-scale study of Semipalmated Sandpipers sampled from Brazil, Suriname and New Jersey found heavy metal and metalloid contamination below lethal levels with the exception of selenium (Burger et al. 2019). Selenium, a metalloid that is used as a dietary supplement in shrimp farming has been recorded in high levels from blood samples of Semipalmated Sandpipers in Brazil, as well as those tested in Suriname and from Delaware Bay. The selenium levels found in blood samples reflect levels found in food items at these sites, and it has been proposed that the high levels of selenium in Brazil could be the result of shrimp farms. While this study looked at several different toxic metal levels in blood samples from individuals of different geographies and ages, selenium was the only metal shown to be at toxic levels; it could cause health declines in adult health, as well as increased chick mortality.

An American Avocet with an oil derrick in the background, Kansas USA. *Photo Credit:* Maina Handmaker

Environmental Contaminants

Environmental disasters, such as oil spills, introduce contaminants and pollutants into natural systems and have wide-reaching negative effects for a variety of coastal organisms. Primary concerns for oiled birds include oil ingestion, lack of buoyancy, hypo- and hyperthermia. If they survive, heavily oiled birds spend a greater proportion of their time standing or preening rather than foraging when compared to less oiled birds, thereby reducing individual fitness.

Sublethal impacts can occur even in less obviously impacted individuals. In a study of the sublethal effects to different species in the Gulf of Mexico following the Deepwater Horizon oil spill, 74% of birds captured showed trace or light oiling on their plumage. However, analysis of blood samples showed that birds with no visible signs of oiling or with light oiling experienced negative sublethal effects, including oxidative injury to erythrocytes (a type of red blood cell), decreased cell volume in blood samples, and an increase in reticulocytes (immature red blood cells). These changes in blood chemistry can lead to cascading effects that can result in lethargy and decreased availability of oxygen to muscles and metabolic processes, ultimately impacting reproductive capacity, fitness, and long-term survival (Fallon et al., 2018). Additional detrimental impacts can be caused by disturbance during beach clean-up following an oil spill, further reducing foraging time and productivity for shorebirds at impacted beaches (Andres, 1997; Burger, 1997) and accounting for sublethal effects in assessments of the overall impacts of disasters such as oil spills (Maggini et al., 2017).

Another environmental source of pollutants is sewage runoff. Untreated sewage outflows increase organic nutrients in estuary systems, which, although generally a cause for environmental health concerns, can provide food resources and increased density of invertebrates, such as polychaete worms, that benefit shorebirds (Morris et al., 2017). However, benefits to improvements in wastewater treatment are likely to outweigh any positive effects of untreated sewage outflows, as shown from a study in the Tejo estuary in Portugal (Alves et al., 2012).

Biological events, such as red tides and algal blooms, can also introduce toxins into the environment. Red tides, an annual occurrence in regions such as the Gulf Coast of Florida, USA, are caused by blooms of the dinoflagellate *Karenia brevis*, producing a family of toxins called brevetoxins, which can cause mass mortality events for marine organisms including fish, marine mammals, reptiles, and birds. During a prolonged event in 2005, deceased shorebirds were collected opportunistically from affected areas where shorebirds where observed scavenging on fish carcasses and found to have brevetoxins in sampled liver tissues. While mortality cannot be linked exclusively to the red-tide event, strong evidence exists indicating the need for awareness of potential negative impacts (van Deventer et al., 2011).

Similar to red tide, Paralytic Shellfish Poisoning Toxin (PSPT) resulting from harmful algal blooms in coastal northern California has been shown to alter feeding behavior of shorebirds. Sea mussels and sand crabs with high levels of PSPT were avoided or discarded by foraging shorebirds, indicating that individuals were able to detect and avoid lethal concentrations of toxins that resulted from harmful algal blooms (Kvitek and Bretz, 2005). Environmental toxins can change habitat quality even if they don't cause direct mortality to birds.

Shorebirds look for a place to roost at high tide but are crowded out by trash on the beach in Panama Bay Panama. *Photo Credit:* Monica Iglecia

Physical pollution

Marine debris and anthropogenic waste are ubiquitous in the environment and can cause negative impacts for shorebirds through entanglement or ingestion. Over a six-year study in coastal Texas, USA, five instances of American Oystercatcher entanglement in monofilament fishing line were documented. Confirmed mortality resulted from two cases, while one resulted in likely mortality, and the final two birds survived following intervention (Heath et al., 2017). There is evidence of plastic being ingested by American Oystercatchers in northern Brazil (Rossi et al., 2019). Both plastic pellets and manufactured plastic pieces were found in all of the collected specimens. Plastics were likely ingested either with food items or because they are similar in appearance to natural food items like bivalves. No direct mortality was attributed to the ingestion of plastic, and the majority (86%) of the plastics consumed were microplastics (< 5 mm); however, this highlights the importance of monitoring birds for negative impacts of physical environmental pollutants. Similarly, Pied Oystercatchers in Australia were found to have consumed and retained plastics in their guts (Roman et al., 2016).

Microplastics have high surface area and porosity and can absorb persistent organic pollutants, such as polychlorinated biphenyls (PCBs) and dichloro-diphenyl-trichloroethane (DDT), becoming more toxic than the environment in which they are found. A study on the Eastern Atlantic coast of Europe found microplastics, specifically microfibers, in intertidal sediment, macroinvertebrates, and shorebird fecal samples indicating that plastic pollution could be pervasive throughout the entire coastal food web where shorebirds are feeding (Lourenço et al., 2017).

Solutions for protecting habitat from pollutants and contaminants often hinge on working with local communities. Maintaining quality and aesthetics of coastal areas to promote ecotourism and environmental health can garner support for reducing pollution risk from oil spills and contaminants and encouraging proper treatment and disposal of waste. Responsible wastewater treatment provides opportunities to create or restore habitat for shorebirds. For example, in the Central Valley in California, the Davis Wetlands Project serves to provide wildlife habitat in addition to providing communities with flood control and storm water and wastewater treatment. Through careful monitoring and water-level regulation, biological processes allow plants and microorganisms to absorb excess nutrients, while simultaneously providing habitat for a variety of wildlife, including breeding and migrating shorebirds, and providing recreational opportunities for the public. This example highlights the value of working with communities, municipal decision-makers, and managers to create solutions that are wins for both wildlife and people.

Removing abandoned tires from the mudflats of Bahia Blanca Argentina.
Photo Credit: Arne Lesterhuis (left) and Pablo Petracci (right)

Building partnerships with industries and supporting regulation that limits the risk of contamination of landscapes can be critical. Additionally, community initiatives, driven through concerned constituencies and social marketing can also be effective. Audubon chapters and other groups often host beach clean-ups, such as an effort at Ormond Beach, California, USA, aimed at improving habitat prior to the start of the Snowy Plover nesting season. Community engagement strategies can be especially effective to build support for reducing both pollution and contamination risks for shorebirds.

In the wetlands of Bahía Blanca, Argentina, car and truck tires that had been illegally discarded near the estuary's coast were dragged by winds and tides into the open mudflat. These objects provided perching sites for raptors and gulls, which were negatively affecting the foraging and roosting behavior of shorebirds. Supported financially by the Port of Bahía Blanca and the local fishing and sailing club of Daniel Cerri, among others, partners hired a private boat company to remove and properly dispose of over 100 tires from the mudflats. Local biologists have observed a reduced presence of raptors and gulls in the area, and the success of this effort has inspired additional campaigns to remove tires from other subsites within the bay (Pablo Petracci, pers. comm).

Strategies to Increase Success

Supporting strategies can be applied across habitat types to increase the capacity of land managers, stakeholders, and conservationists to reduce threats for shorebirds. These topics are not discussed in-depth in this *Manual*, but we provide descriptions and resources to learn more.

See Case Study 13 for an example of a multi-pronged approach to improving habitat for shorebirds in coastal South Carolina.

Cultivating and Empowering Conservation Constituencies - Community Engagement

In almost all situations and for a variety of reasons, local communities will need to be engaged to reduce threats to shorebirds. The Community Engagement Toolkit employs the techniques of social marketing to develop an effective community engagement program and identify the best strategies to engage the community at your particular site to meet the goals of your conservation efforts (WHSRN Executive Office, 2020). Strategies for community engagement include social marketing for behavioral changes, education to build a base of supporters, volunteer programs for support of conservation actions, and advocacy to engage in decision-making processes. Another resource is RARE's *Behavior Change for Nature:* Behavioral Science Toolkit for Practitioners (Rare and The Behavioral Insights Team, 2019).

Shorebird Ecology, Habitat Management, and Conservation Workshops convene local stakeholders at important shorebird sites to increase capacity for collaboration and shorebird conservation. Cheyenne Bottoms USA. *Photo Credit:* Brad Winn

Manomet works closely with partners to deliver workshops and facilitate site-based conservation actions at important shorebird sites across the Americas. Pictured: workshop participants in Puerto Rico and Brazil.

Improving Environmental and Wildlife Protection Policies and Governance

Policies and governance at the site, local, regional, state, and national levels can impact the effectiveness of conservation and management efforts. At the local and regional levels, stakeholders at sites and in municipalities can help ensure local legislation and policies that support direct conservation actions. At the national level, policies and plans that are in alignment with international agreements and flyway-level planning can improve chances for long-term collaboration and large-scale habitat protections. Policies can improve natural infrastructure systems, fund conservation, create and restore national parks, and maintain current environmental protections. Good governance provides a framework for bringing together stakeholders and a process for decision-making and management. The WHSRN Executive Office has developed a toolkit to guide the process for improving governance at a site that includes four major principles: accountability, transparency, participation, and social justice (WHSRN Executive Office, 2019).

Relevance to Human Communities

Shorebird conservation does not occur in a vacuum. Human communities often live close to or in the areas that shorebirds require. Conservation efforts can provide other benefits, including clean air and water, improved human health, and support for local businesses (North American Bird Conservation Initiative, 2016). Taking into account the needs of local communities, businesses, and other stakeholders can vastly improve the likelihood for long-term conservation benefits. In some cases, folding in the needs of human communities and working with 'non-traditional' partners can lead to conservation benefits that would not have otherwise been possible. For example, working with local hospitals to inform communities about the public health hazards of free-ranging dogs may garner more support for managing dog populations than leading with the needs of shorebirds.

Managing Social Conflict

Conflict or perceived conflict around shorebird conservation can arise when the needs of wildlife and humans overlap or the needs of wildlife influence the activities permitted to humans, like driving on beaches. These types of conflicts can cause or increase negative attitudes about shorebirds and shorebird management and become a serious threat to wildlife conservation. Mengak et al. (2019) describe strategies for reducing social conflicts surrounding management actions; a key is ensuring a participatory process that includes the public in decision-making. An important step is conducting a stakeholder analysis to determine how a decision will affect social and natural phenomena, identify who is affected or can affect the phenomenon (i.e., stakeholders), and prioritize stakeholders to be included in the process (Mitchell et al., 1997; Mengak et al., 2019). For more information about how to conduct a stakeholder analysis see "Best Practice 2" in Mengak et al. (2019) and also Reed et al. (2009).

The needs of local communities, businesses, and stakeholders should be taken into account when planning durable conservation efforts. Fishermen and shorebirds in French Guiana. *Photo Credit:* Monica Iglecia

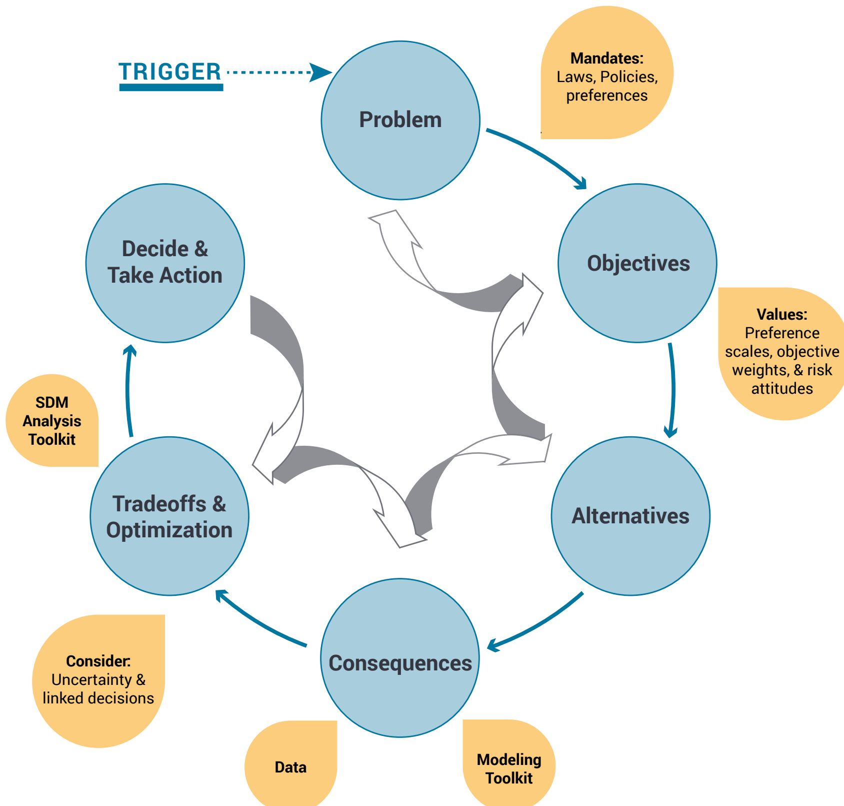
Land managers can reduce conflict by

- Paying explicit attention to the sociopolitical contexts of the management decision.
- Including the public early in a public engagement process.
- Using open, responsive communication strategies.

(Mengak et al., 2019)

Structured Decision Making

Structured Decision Making (SDM) is the formal application of decision-analysis tools to guide natural resource decisions in a way that is focused on achieving fundamental objectives and is inclusive of many stakeholders, provides transparency to increase support and understanding, allows for adaptation or adjustments to plans if new information becomes available, and considers social and political factors (Runge, 2011; Mengak et al., 2019). This process focuses on the values important to each stakeholder and the consequences to the likely outcomes if certain management actions are implemented (Gregory et al., 2012).



The PrOACT process of Structured DecisionMaking. *Original Source:* Hammond et al., 2002.

The Problem, Objectives, Alternatives, Consequences, Trade-off, and Decide (PrOACT) process can be applied to almost any shorebird-related management decision-making process.

Problem – define the problem to be addressed; identify decision-maker(s), stakeholders, other key players; and define the scope and desired outcome of the decision. This phase may include a stakeholder analysis.

Objectives – What are the management objectives? What values are most important to achieve with this decision? Some examples include maintaining shorebird populations or satisfying coastal area users.

Alternatives – The list of various specific actions that represent the realistic options available that the decision-maker(s) are choosing from.

Consequences – How would each alternative impact the objectives? This phase uses models to make predictions.

Trade-off and Decide – Choose an alternative that satisfies the most objectives (which are likely coming from different stakeholders with different values). The SDM process allows clear comparison of each alternative and its potential impact on the objectives, so trade-offs and compromises can be made to make an ultimate decision that can achieve a balance across the objectives.

For examples of the applications of structured decision making in natural resource management and species conservation, please see:

» Integrated Wetland Management for Waterfowl and Shorebirds at Mattamuskeet National Wildlife Refuge, North Carolina

» USFWS webinars about applying SDM to conservation problems

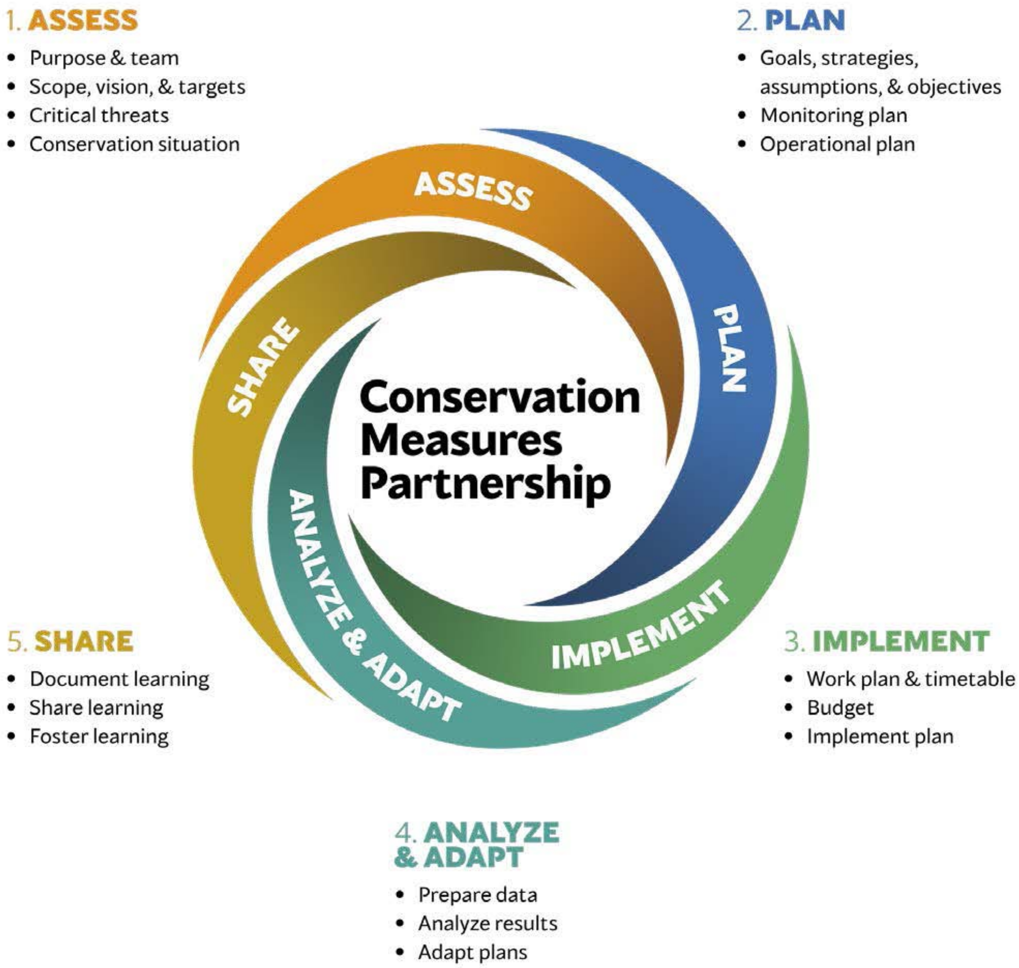
» Structured decision making as a framework for large-scale wildlife harvest management decisions

Structured Decision Making may not be the correct strategy in all situations. If there is strong disagreement among relevant stakeholders or if values of different groups are so different they are unable to agree on objectives, SDM may not be the best method. Conflict resolution or mediation techniques may be necessary to move beyond this step. A facilitator can help move the process forward and ensure that each stakeholder's views are expressed and that the whole process is documented for transparency and the ability to refer back to how decisions were made.

Open Standards for the Practice of Conservation

The Open Standards for the Practice of Conservation, or Conservation Standards is an adaptive process for logically identifying appropriate stakeholders and conservation targets, assessing the most critical threats to targets, and developing strategies that have a high likelihood of achieving positive conservation outcomes. Implementing the strategies, analyzing results, adapting plans, and documenting and sharing learning are part of the process. The Conservation Standards also provide a way to explicitly consider human wellbeing and ecosystem services in conservation planning and implementation.

The Conservation Standards have been used to address shorebird conservation at various scales, including the extent of Americas flyways (Atlantic Flyway Shorebird Initiative (AFSI), 2015; Senner et al., 2016) and one island in Chile (Delgado et al., 2010). The Conservation Standards tools are free to use and example projects are available through Miradi Share.



The Conservation Standards framework for planning is comprised of six iterative steps.
Source: https://cmp-openstandards.org/

Monitoring Shorebirds

The regular counting of shorebirds provides critical information about their abundance, distribution, and diversity. Monitoring allows tracking of short- and long- term trends and how actions at sites and across broader areas may influence populations. Monitoring data can be used to assess the status of shorebirds at the population, biogeographic population, and site level.

Monitoring can play at least three important roles in informing decision-making related to habitat management (Nichols and Williams, 2006; Lyons et al., 2008):

1. To set a baseline and assess the state of the current resource
2. To evaluate the effectiveness of particular management actions
3. To provide information needed to make additional actions or course corrections to better achieve objectives.

To prepare for shorebird monitoring efforts, increase and hone skills in shorebird identification and flock estimation.
Photo Credit: Monica Iglecia and Maina Handmaker

A Standard Monitoring Approach

The Program for Regional and International Shorebird Monitoring (PRISM) provides standards for monitoring nonbreeding shorebirds in the Western Hemisphere (Standards, PRISM, 2018). The Standards provide a unifying protocol to maximize the value of existing and emerging monitoring efforts by improving consistency and rigor across the Western Hemisphere in a scalable way that can inform management, monitor trends in shorebird populations, and answer site-specific questions while aligning with larger scale and long-term monitoring efforts. Aside from providing improved understanding of shorebird habitat use, abundance (Ross et al., 2012), and changes to populations, the Standards suggest that a key objective should be to integrate data into "iterative learning and adaptive management." For managers, an important aspect of implementing a local monitoring plan is to follow protocols consistent with other large-scale monitoring systems to ensure that data can be integrated and contribute to larger assessments.

While there are no large-scale monitoring protocol standards for breeding shorebirds, site specific protocols exist for important shorebird breeding areas, such as the Florida Fish and Wildlife Conservation Commission's Breeding Bird Protocol for Florida's Shorebirds and Seabirds.

Key components of breeding shorebird surveys include:

- Repeated surveys at routes where targeted species breed.
- Training volunteers to understand behavioral cues.
- Frequent visits to nesting sites to determine fate of nests.
- Monitoring nests and chicks throughout the season.
- Minimizing disturbance to nesting birds.

Monitoring shorebird productivity is often time-intensive, especially if managers are interested in determining daily survival rates and causes of nest failure; however, it can be an important tool to understand threats to habitats and populations.

Key components for monitoring non-breeding shorebirds (PRISM, 2018):

- Define sample units that are discrete and consistent in size, can be surveyed repeatedly over time, and can be sampled in less than 2-3 hours.
- Stratify and randomly select sample units at the appropriate inferential scale.
- During the nonbreeding season, a single count may be sufficient. More surveys are needed during migration periods.
- Determine the most appropriate tidal window, using tide heights, to ensure that shorebirds will be within 500 m of the observer and that tidal conditions are similar across surveys.
- Define a minimum amount of time to survey each unit. Survey long enough to ensure good detection rates, and incorporate a measure of detectability into protocol, if possible.
- Collect a core set of variables including: uniquely-identified and spatially-delineated sampling unit, date, local-time start, local-time end, observer identification and role (primary counter or secondary), percent of sampling unit visible, shorebird species or species group, count of shorebirds by species or species group.

Existing Large-Scale Monitoring Efforts

Multiple large-scale shorebird monitoring programs exist, including but not limited to the programs described here. In addition, regional and species-specific surveys focused on breeding and nonbreeding shorebirds also exist. Nearly all large-scale monitoring efforts rely on volunteers.

- The International Shorebird Survey (ISS) began in 1974, is coordinated by Manomet, and is conducted across the Americas. ISS consists of multiple surveys conducted annually within each northbound and southbound migration season.
- The Migratory Shorebird Project (MSP) began in 2011 and is coordinated by Point Blue Conservation Science with a focus on the Pacific Coast of the Americas with surveys conducted during the nonbreeding season.
- The Neotropical Waterbird Census (NWC) began in 1990 and is coordinated by Wetlands International. NWC surveys are conducted at the same sites twice a year, once in February and again in July, in all the countries in South America.
- The Caribbean Waterbird Census (CWC) is coordinated by BirdsCaribbean and consists of surveys conducted in the Caribbean region between January 14 and February 3 each year, but observers are encouraged to count waterbirds as often as possible throughout the year to gather additional information about migration routes and important stopover sites.
- The Integrated Waterbird Monitoring and Management program (IWMM) began in 2010 and is a USA-based protocol for the inventory and monitoring of nonbreeding waterbirds and their habitats (Loges et al., 2014). IWMM protocols were developed with impounded wetland habitats in mind but have been applied to other shorebird habitats, as well. IWMM has an online database that stores bird-use and site-condition data and has the ability to track management actions by site. In addition, the database provides several reporting functions (e.g., migration curves, species densities/hectare, diversity indices, baseline habitat conditions, etc.).

Data from coordinated monitoring efforts are used in a variety of capacities. For example, ISS data are used in State of the Birds Reports produced by The North American Bird Conservation Initiative, a tri-national committee including representatives from Canada, the United States, and Mexico. Data collected using IWMM protocol have been used to link the abundance of birds to actions at refuges and inform management at both the refuge and flyway scales. NWC data provide information to support the development of national conservation plans. Further, regional datasets, like the Coastal Shorebird Survey in Peru and Chile, provide data that have supported the creation of new protected areas and the publication of the Atlas of Peru (Program for Regional and International Monitoring (PRISM), 2018).

Estimating Shorebirds

Managers will want to think about the type of monitoring that will best fit local needs while accounting for the capacity available to conduct surveys. Monitoring intensity scales across a gradient of effort and information gained, from presence/absence to estimation to true counts. Recording the presence or absence of species does not often provide enough detail to inform management but can help with understanding seasonality of use and co-occurrence of species. More detailed methods of monitoring are necessary to understand population demographics and trends (PRISM, 2018). At the other end of the spectrum, a true count would involve counting every individual in a sample site, which can be very difficult across a large area or when high densities of individuals are present (Williams, 2002). Therefore, estimation is generally the best method when monitoring shorebirds, as it provides the level of detail necessary to calculate population trends and estimate abundance.

Alone, abundance estimates can underestimate the true number of birds using a site during migration because they don't account for movement of individuals (Collazo et al., 2002). Generally, estimates of turnover rates and stopover duration are only possible when individuals have been marked through banding or can otherwise be individually identified in a population, such as through radio telemetry (Mann et al., 2017; Howell et al., 2019). Stopover duration can be an important metric to monitor because it is closely linked to site-specific factors, such as prey abundance, weather, predation pressure (Howell et al., 2019), or habitat availability (Mann et al., 2017).

Accurately estimating the number of shorebirds in a flock can be challenging; however, through practice, the skill can be learned and honed. It is critical that data are identified as true counts versus estimates and that false precision is not generated in a dataset. Generally, estimation involves identifying a set number of birds within a flock, and then using that number as a multiplier to estimate the entire size of the flock. In a mixed species flock, counts and estimates can be done by using a species-by-species approach or, when large numbers of birds are present, by estimating percentages of different species in a flock and calculating numbers based on the total number of birds present. Resources for improving techniques can be found on the eBird website; in simulation training software, such as the Wildlife Counts program; in Manomet's webinar; and within protocols for monitoring programs such as ISS or PRISM.

Where to Report Banded/ Flagged birds

Resighting banded individuals yields information about species movements, life-span, and migration timing. In addition, resighting banded and flagged birds creates engaging stories to share with local communities and the public. The Pan American Shorebird Program standardized the marking and identification of individual shorebirds that utilize wide geographic areas within the Western Hemisphere over the course of their annual cycle. This resource includes contact information for regional coordinators, as well as details about regional banding schemes and protocols for implementing banding projects and reporting banded birds within the Western Hemisphere.

When possible, a clear photo of a flagged shorebird, like this Red Knot, can be a useful record when reporting a sighting. *Photo Credit:* Maina Handmaker

If you observe a banded, flagged, or otherwise tagged bird, try to photograph the flag or tag close enough that it is legible. Banded birds can be reported at www.bandedbirds.org and www.reportband.gov. You will need the band number, where and when the bird was sighted, the species, flag color, and positioning of flag and other bands on each leg. A good photograph will assist with this process. In the United States and Canada, the USGS Patuxent Wildlife Research Center Bird Banding Laboratory, in collaboration with the Bird Banding Office of Canada, maintains a database of all birds banded under federal permits and a website that allows for reporting of both federal and field-readable bands. (https://www.pwrc.usgs.gov/BBL/bblretrv/)

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Management Evidence

Conservation Evidence: Providing Evidence to Improve Practice. www.conservationevidence.com

Monitoring

Standards for Monitoring Nonbreeding Shorebirds in the Western Hemisphere: Program for Regional and International Shorebird Monitoring (PRISM), October 2018

Pan American Shorebird Program: Shorebird Marking Protocol, April 2016

Species Identification

The Shorebird Guide by Michael O'Brien, Richard Crossley, Kevin Karlson

Shorebirds of North America: The Photographic Guide by Dennis Paulson

Guía de los Chorlos y Playeros de la Regíon Neotropical by Pablo Canevari, Gonzalo Castro, Michel Sallaberry, Luis Germán Naranjo

Cornell Lab of Ornithology Bird Academy, Be a Better Birder: Shorebird Identification Archived Live Series

Richards, Alan. 1988. Shorebirds – A Complete Guide to Their Behavior and Migration. Gallery Books, New York City, New York.

Glossary

Austral autumn- the meteorological season from March 1- May 31 in the southern hemisphere.

Austral shorebird- a broad term for the group of shorebirds that spend their entire life cycle in the southern hemisphere. Examples include Magellanic Plover (*Pluvialnellus socialis*) and Tawny-throated Dotterel (*Oreopholus ruficollis*).

Austral spring- the meteorological season from September 1- November 30 in the southern hemisphere.

Austral summer- the meteorological season from December 1- February 28 (February 29 in a leap year) in the southern hemisphere.

Austral winter- the meteorological season from June 1- August 31 in the southern hemisphere.

Alkaline lake/ pond- wet areas dominated by clay soils with high pH (>8.5), where poor soil and intense evaporation tend to concentrate salts.

Altitudinal migration- a strategy of seasonal movement between high altitude breeding areas and lower altitude nonbreeding areas. An example is the Puna Plover (*Charadrius alticola*).

Bathymetry- underwater topography.

Boreal autumn- the meteorological season from September 1- November 30 in the northern hemisphere.

Boreal spring- the meteorological season from March 1- May 31 in the northern hemisphere.

Boreal summer- the meteorological season from May 31- August 31 in the northern hemisphere.

Boreal winter- the meteorological season from December 1- February 28 (February 29 in a leap year) in the northern hemisphere.

Brackish- water that is a mix of salt and fresh water, ranging in salinity from 0.5 to 35 parts per thousand (ppt). Source: NOAA

Charadriiformes- the order of birds that includes shorebirds, as well as skaus, jaegers, gulls, terns, skimmers and alcids. Seven of the twelve families distributed worldwide are found in North America.

Charadriidae- the family of shorebirds including lapwings and plovers, generally characterized as small- to medium-sized birds, with upright posture, large eyes, short thick bills, short necks, and medium-to long legs.

Community engagement- the application of strategies including social marketing for behavioral changes, education to build a base of supporters, volunteer programs for support of conservation actions, and advocacy to engage in decision-making processes.

Ephemeral ponds- depressional wetlands that temporarily hold water, followed by periods of dryness. They are generally isolated without a permanent inlet or outlet but may overflow during times of high water. Source: EPA

Fecundity- refers to the number of successfully raised or fledged young per year.

Fundamental Objective- the results that the decision-makers care about the most.

Fresh water- water with low or zero concentrations of salts ranging from a salinity of 0 to 0.5 parts per thousand (ppt). (NOAA)

Good governance- a framework for bringing together stakeholders, as well as a process for decision-making and management.

Human intrusions and disturbance- threats caused by humans from non-consumptive use and activities in natural areas that alter and disturb habitats.

Hyperphagia- a behavioral shift seen in migratory shorebirds exhibiting increased feeding, which results in the rapid weight gain necessary for long-distance flights.

In-situ- on-site, or locally at a specific location.

Intertidal- the area where the ocean meets the land, including abrupt rocky ledges to sloped, sandy beach. It is generally broken in four zones: the spray zone; the high intertidal zone, which floods during the highest tides but remains dry outside of those times; the middle intertidal zone, which floods during daily high tides; and the low intertidal zone, which is usually underwater except for during extreme low tide events.

Lacustrine wetlands and lakes - non-tidal shallow- and deep-water habitats that lack trees and shrubs, characterized by having less persistent or emergent vegetation (<30 %), an area larger than 8 hectares, and a low salinity (< 0.5%). This includes wetlands such as lakes. (Cowardin et al., 1979)

Means Objective- the steps necessary to achieve the fundamental objective.

Migration- a seasonal movement in response to predictable environmental changes when populations move between distinct habitats, usually between a nonbreeding area to a breeding area. (Ramenofsky, 2007).

Nearctic shorebirds- a broad term for the large group of shorebirds that migrate from southern nonbreeding ranges to northern ranges, where breeding activities occur. Examples include Sanderling (*Calidris alba*) and Red Knot (*Calidris canutus*).

Palustrine wetlands- tidal and nontidal wetlands characterized by being less than 8 hectares, having generally shallow with water that is less than 2 meters deep, having low (< 0.5%) salinity, and dominated by trees, shrubs, persistent emergent, emergent mosses or lichens. These can include marshes, swamps, or ponds (Cowardin et al., 1979).

Partial migration- is a migration strategy where a fraction of the population migrates and others do not.

Precocial- a classification for chicks that are well developed upon hatching, usually covered with downy feathers and mobile, often leaving the nest soon after hatch, following their parents and feeding themselves. All shorebird chicks are considered precocial.

Prey phenologies- the relationship between climatic conditions and various biological phenomena, in this case, the emergence or availability of insect or invertebrate food sources.

Pulse flooding- adding small amounts of water to wetland systems, typically to saturate soils.

Riverine systems- includes all wetlands and deepwater habitats contained within a channel as long as the areas are not dominated by trees, shrubs, and persistent vegetation and they do not contain saline water (>0.5%). These areas usually begin at a headwater or larger body of water, such as a lake, and terminate where the channel meets a larger body of water, such as a lake or ocean.

Saline- water with high concentrations of salt. Ocean water averages about 35 parts per thousand but hyper-saline environments, like Mono Lake in California, can exceed these levels.

Scolopacidae- the largest and most widespread family of shorebirds including sandpipers, phalaropes and their allies, generally characterized by variable body structure, with bills that range from straight, decurved, or upturned and short to long in length.

Sheet flooding- flooding wetlands with very shallow water.

Staging sites- specific locations where shorebirds prepare for long-distance flights during migration, usually gathering in large numbers, with predictable and abundant food resources necessary to meet high energetic demands.

Stopover sites- a location used by shorebirds employing hopping or skipping strategies during migration, where birds usually stay a short time to feed and rest, and then move to the next stop.

Supratidal- the region of coastal sediments that is above the highest tide line, subject only to occasional tidal overwash during extreme tides or storm events. Also called the supralittoral zone, or the spray zone.

Target species- the species that serves as a focus to guide decisions and will ultimately benefit from management actions at a given site.

Water-control structures- examples include rice trunks or flap gates; these tools allow managers to manipulate water levels in impounded habitats, sometimes relying on tidal or seasonal flow of water.

Wrack- organic material that is deposited on beaches due to wind or wave energy, and can form a line at the highest extent of the tide line, known as the wrack line. Examples include sea grass, algae and woody debris; in coastal California it can include kelp, and in the southeastern United States it can include Spartina stems. (Source: Florida Fish and Wildlife Conservation Commission)

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CASE STUDIES

CASE STUDY

Improving Grazed Shorelines for Piping Plover

Shoreline habitat on the Missouri couteau. *Photo credit: Rebecca Magnus.*

LOCATION: Alkali lakes in the Missouri Coteau, Southern Saskatchewan, Canada

AUTHOR: Rebecca Magnus, Habitat Stewardship Coordinator, Nature Saskatchewan

LAND OWNERSHIP: Mixed. The lakes and shorelines up to the annual high water line are owned by the Canadian government, but many are privately managed. Several uplands are privately owned by individuals that manage the shoreline for cattle.

Focal Habitats

» Inland Non-tidal Wetlands—Saline

Habitat is on the lakeshore of permanent alkali lakes with minimal vegetation (maximum vegetation is 20%).

Habitat Goal

The goal of the Plovers on Shore program is to maintain and enhance and improve nesting habitat along lake shorelines in the Missouri Coteau by working with private landowners throughout the region. This effort is particularly focused on habitat improvement for nesting Piping Plovers (*Charadrius melodus circumcinctus*) along the alkali lakeshores where they have historically nested. Southern Saskatchewan supports between 27 and 41 percent of the Great Plains population and 13 to 23 percent of the global population of Piping Plovers.

Species Benefitted

Piping Plover (*Charadrius melodus circumcinctus*)

Threats to Shorebirds at Site

Cattle grazing and shoreline trampling are listed threats in the federal Action Plan for the Piping Plover in Saskatchewan (Environment Canada, 2009). Cattle graze in the uplands but are able to access shorelines to drink water. Shoreline access by cattle has been found to periodically trample nests and chicks, alter breeding behavior, and/or cause pugging (dented soil made by hooves) that chicks can get caught in and die during the breeding season.

Actions Taken to Improve Habitat for Shorebirds

The Plovers on Shore program engages landowners in habitat conservation and annual monitoring of Piping Plovers. Here we describe our experience working with one particular landowner, and the actions that this landowner took along the lakeshore of one lake in the Missouri Coteau. This specific example showcases how the Plovers on Shore program works, and highlights alternative management strategies that might work for other landowners as well.

The lake in this case study contains critical habitat within the Missouri Coteau area of southern Saskatchewan, and has a shoreline that was historically used by nesting Piping Plovers. This means that there were at least two nesting pairs observed in two censuses over a 15 year window (the international breeding census occurs every five years, and began in 1991).

Enhancement efforts to reduce threats and encourage Piping Plovers to return to this lake began in 2009. The best actions for the landowner were to: 1. Use wildlife-friendly fencing (smooth top and bottom wires) to keep cattle off the shoreline and reduce trampling during the Piping Plover nesting period (April to August), and 2. To install an alternative water source for the cattle during the same period. The alternative water source used a solar powered pump to move water to an upland watering station.

These types of projects on private land are completed through a cost share agreement where the landowner and Nature Saskatchewan each pay for half the cost of materials and labor. The landowner decides placement of the fence but must ensure that the fence line is higher than the high water line on the shore (where the shoreline meets the upland). The monitoring program is voluntary in perpetuity, whereas the habitat improvement project is legally binding for 12 years.

Outcomes

As with all Plovers on Shore projects, this shoreline is monitored by the landowner annually for nesting Piping

Wildlife friendly fencing. *Photo credit: Kris Mutafov.*

Plovers. Nature Saskatchewan staff visit all participating landowners and do site checks every three to five years to ensure the project is still in place and to maintain a strong relationship with the landowner.

As of 2018 the shoreline at the site described here has recovered (pugging gone) and Piping Plovers have been observed. While the available shoreline has varied in recent years, there has been an average of two nesting pairs observed along the shoreline each year.

Advice/Precautions

This habitat enhancement project worked well for this particular landowner, allowing for sustained management and habitat improvements in subsequent years. To maintain this enhancement project, both fencing and solar pumps need regular checks and repairs.

Grazing management will vary according to the specific needs of the landowner and their operation. The fencing and alternative water site strategy worked well for this landowner because it allowed him to keep his cattle close to his home during the sensitive calving and early spring season. If the landowner has access to grazing areas further inland, an alternative strategy for an operation with similar shoreline issues could be to change the shoreline grazing period to late summer/fall. This would allow Piping Plovers to nest, fledge and migrate out of the area by the end of August without being disturbed by cattle. Fall grazing enables rainfall to soak into the ground and for shorelines to dry out before the cattle arrive, resulting in less pugging than would occur if the cattle are present during spring and summer. Many landowners in the drier mixed grassland region of southern Saskatchewan have found fall grazing to be additionally beneficial in allowing for greater forage production, heavier litter cover (undecomposed dead plant material), and greater ecological health.

Shoreline near Bengough, Saskatchewan, Canada.
Photo credit: Rebecca Magnus.

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CASE STUDY

Managing Habitat in Coastal South Carolina's Brackish Wetlands

Shorebirds feeding in a typical brackish managed tidal impoundment in May. Note the emergent smooth cordgrass in the background that can invade the open flats. *Photo credit: Jamie Dozier.*

LOCATION: Tom Yawkey Wildlife Center, South Carolina, USA

AUTHOR: Jamie Dozier, Project Leader, South Carolina Department of Natural Resources

LAND OWNERSHIP: The 9,712 hectare (24,000 acre) Tom Yawkey Wildlife Center Heritage Preserve is owned and managed by the South Carolina Department of Natural Resources in cooperation with The Yawkey Foundation.

Focal Habitats

» Managed Impoundments—Brackish

There are a variety of habitats utilized by shorebirds at Yawkey Wildlife Center Heritage Preserve (YWC) including 22.5 km (14 miles) of undeveloped beachfront. The most intensive use occurs in man-made brackish wetlands referred to as managed tidal impoundments (MTI). MTI refer to tidal wetlands that are encircled by a system of functioning dikes and have water control structures that allow the manipulation of water levels for wildlife management. Many of the diked wetlands were originally freshwater cypress swamps that were cleared of trees and enclosed by dikes in the early 1800's to grow rice. Other managed wetlands were developed in the 1930's–1960's by impounding brackish marsh for the purpose of managing them for waterfowl. In the early 1940's the Santee River system was dammed upstream for hydroelectric power which drastically changed salinity in the lower end of the river system. What were primarily fresh to slightly brackish systems became highly brackish to saline systems. Currently managed wetlands have dikes or uplands around the pond perimeters and water levels are controlled using wooden rice trunks. Wetlands are flooded and drained using tidal amplitude. Mechanical pumping of water is not common. The salinity regime ranges from 5–32 parts per thousand (ppt) with a typical range of 15-25 ppt depending on river flows and rainfall. There are 31 MTI at the YWC ranging in size from 13 to 222.5 hectares (32 to 550 acres) with most in the 60.7 hectare (150 acre) range. MTI that were former rice fields generally have level beds that allow for a more continuous water level across the entire pond. MTI that were formerly brackish marsh have a variety of elevations that create variable water depths within the same pond.

Habitat Goal

Managed tidal impoundments within YWC are intensively management for the development and maintenance of breeding, staging, and wintering habitat for waterfowl, wading birds, shorebirds, and other wetland-dependent species.

Species Benefitted

Many species of shorebirds and waterfowl using the Atlantic Flyway utilize the managed wetlands. The most abundant species of shorebirds are Semipalmated Plover (*Charadrius semipalmatus*), Semipalmated Sandpiper (*Calidris pusilla*), dowitcher (*Limnodromus spp.*), Dunlin (*Calidris alpina*), and American Avocet (*Recurvirostra americana*). As many as 24 species of shorebirds routinely utilize the MTI annually.

Threats to Shorebirds at Site

The primary threat to shorebird habitat within the MTI is invasive native and exotic vegetation that eliminates mud flats. Continued drawdowns for shorebird management during the spring and summer allows native vegetation such as smooth cordgrass (*Spartina alterniflora)*, salt-marsh bulrush (*Scirpus robustus*) and black-needle rush (*Juncus roemerianus*) to invade mud flats and form very dense stands. Common reed (*Phragmites spp.)* is an invasive exotic species in the region that also colonizes shorebird habitat. Sea level rise and increased storm velocity related to a warming climate is making management activity on the MTI, like dewatering ponds using tidal amplitude, more difficult. Management costs are high; rice trunks used for managing water levels cost $25,000.00 USD each to build and install. Most ponds have at least two water control structures and some have as many as four. The perimeter dikes must be continually maintained at a height above that of surrounding waters, especially to withstand tides that can commonly reach 2.4 m (8 ft) or more.

Storm-driven water has impacted our operations with costly results. Three years of hurricane strikes (2015, 2016, and 2017) have caused over $1 million in damage to MTI at the Tom Yawkey Wildlife Center.

Actions Taken to Improve Habitat for Shorebirds

The vast majority of brackish managed wetlands in South Carolina are manipulated for waterfowl hunting. Managed wetlands are drained to mud in late February and reflooded by mid-March. Draining to a mud bed allows the unconsolidated bottoms to firm and allows many beneficial waterfowl food plants to sprout. The water is kept at depths between 30-91 cm (12–36 inches) until late July or early August when it is drained again. The second dewatering is to reset many of the waterfowl food plants and allow a second round of plant growth. If the ponds are not drained in late summer, the waterfowl food plants might die and decompose before waterfowl arrive in the fall. Re-flooding occurs by the end of August and the ponds are kept flooded until the following February to provide wintering waterfowl habitat. This system is often reffered to as the Two Draw-Down Method and promotes vegetation such as widgeon grass (*Ruppia maritima*) and dwarf spike rush (*Eleocharis parvula*) that are heavily utilized by waterfowl. Providing wintering waterfowl habitat is a prime directive for the Tom Yawkey Wildlife Center, but we do not have waterfowl hunting.

In order to provide high quality shorebird and waterfowl habitat, a slightly altered water management regime is utilized. Past research has shown peak shorebird visitation occurs between the last week of April and first two weeks of May. In order to maximize shorebird habitat, there is no early drawdown in late-February. Instead water levels are maintained at winter depths (10–30 cm / 4–12 inches) until mid-March. The MTI are then slowly drawn down over a 4-5 week period with the goal of sheet water and mud flats in most ponds from the last week of April through the first two weeks of May. Pond drawdowns are staggered so a diversity of water levels are present at any one time. In addition, several MTI are utilized for “fast-drawdowns” where water is drained in a 3–5 day period around May 1 to create additional short term habitat.

Managed tidal impoundments are re-flooded in a staggered pattern around June 1 and then primarily managed for wintering waterfowl habitat the rest of the year. The waterfowl portion of the management cycle includes an initial flooding of 5–10 cm (2–4 in) with several inches added weekly until the desired depth of 61–76 cm (24–30 in) is reached in late August. The water is then circulated by adding water at high tide and spilling water at low tide. The circulation helps eliminate water quality issues such as turbidity, algal blooms, and low dissolved oxygen. As waterfowl begin to arrive in November the water levels are dropped to appropriate levels for optimum waterfowl usage.

This system is referred to as the Single Draw-Down Method. This method may not provide maximum waterfowl food production when compared to the Two Draw-Down System, but it does provide high quality waterfowl habitat. The MTI that have highest shorebird use in the spring are also often the ponds with highest waterfowl usage in the winter. The major difference between the two methods is the need for a deep-flooding period in the Single Draw-Down Method every 5–10 years.

The period of exposed mud in the later spring allows emergent vegetation to become established. Invasive native plant species such as smooth cordgrass and salt-marsh bulrush will begin to cover the mud flat portions of the MTI. This emergent vegetation has to be controlled by periods of continuous deep flooding (0.6–0.9m / 2–3 ft) during the growing season (March-October) or herbicide on a small scale. Depending on the elevation of an individual pond, this deep flooding may need to take place on a 5–10 year rotation. To eliminate invasives, tidal water is captured at the highest tides and held at full depth (0.6–0.9 m / 2–3 ft) for a period of 1–4 years to set back emergent vegetation. In some cases additional mechanical pumping may be used to bring water levels to a sufficient depth to kill vegetation. The pond bottoms are too muddy and unconsolidated to allow for mechanical treatments.

The exotic invasive common reed (*Phragmites australis*) can also be an issue for managers, and cannot be eliminated with flooding alone. It must be spot treated with herbicide utilizing helicopters or air boats. The herbicide treatments are most effective when applied September–October. Annual treatments are required to treat new patches and re-sprouts of previously treated areas. During these periods of deep flooding, the ponds provide very little shorebird habitat but are still utilized by waterfowl, wading birds and other wetland species.

Outcomes

When done properly, the MTI provide 24 hours of low tide-like habitat conditions for spring migratory shorebirds as well as provide waterfowl habitat. MTI that have sufficient open mud flats are preferred over adjacent natural wet-lands. Surveys routinely count 20,000–25,000 shorebirds utilizing the managed wetlands per day in mid-May.

Waterfowl in winter utilizing the same area where shorebirds were feeding in May *Photo credit: Jamie Dozier.*

Advice/Precautions

A management strategy of late spring drawdowns that provide maximum shorebird habitat availability can be accomplished while also providing waterfowl habitat in the winter. The late spring drawdowns do allow for increased emergent plants over time so a rotation for deep flooding or herbicide treatments must be expected in the management cycle. This strategy can be used to manage for waterfowl and shorebirds but is most effective if you have a suite of ponds where rotational management can be accomplished.

CASE STUDY

Grazing, Mowing and Haying for Shorebirds at Cheyenne Bottoms

Shorebirds in mowed site, notice the height of the unmowed vegetation in the background. *Photo credit: Robert Penner.*

LOCATION: Cheyenne Bottoms Preserve, Kansas, USA

AUTHOR: Robert Penner, Avian Programs Manager, The Nature Conservancy

LAND OWNERSHIP: The 3,237 hectare (8,000 acre) preserve is owned and managed by the Kansas Chapter of The Nature Conservancy.

Focal Habitats

» Uplands—grasslands

Shorebird habitat types within the Cheyenne Bottoms Preserve include ephemeral wetlands, semi-permanent wetlands, seasonally flooded wetlands, mud and alkali flats, wet meadows, shortgrass prairie, agricultural fields, and other shallow water sources such as ditches and stock ponds. Many of the shorebirds using Cheyenne Bottoms are opportunistic in their use of habitats and subsequently depend upon a large variety of wetland and habitat types. Most shorebirds use unvegetated, shallow ephemeral wetlands, semi-permanent basins, shallowly flooded mudflats and salt flats.

Habitat Goal

The Cheyenne Bottoms Preserve within the Central Flyway is working to improve the quality of habitat presently managed for shorebirds by maintaining an appropriate configuration of wetland and grassland habitats, protecting water quality and availability, and increasing and improving monitoring of shorebird populations and habitat. Furthermore, The Nature Conservancy can use the preserve to increase the awareness and understanding of grasslands and wetlands within Kansas and their importance to shorebird populations. The Nature Conservancy works to create and improve shorebird habitat types to provide a wide range of habitats to attract many shorebird species. Here, we discuss the management actions taken to improve grassland habitats.

Species Benefitted

All species of shorebirds that occur in the Central Flyway should benefit from this habitat management work. Upland species will benefit on a yearly basis, whereas the wetland species may only benefit during years of normal to above normal rainfall. Species that are more tolerant of vegetation such as Wilson's Phalaropes (*Phalaropus tricolor*) and Pectoral Sandpipers (*Calidris melanotos*) also use flooded grass, wet meadows, and agricultural fields. Small shorebirds such as White-rumped Sandpiper (*Calidris fuscicollis*), Baird's Sandpiper (*Calidris bairdii*) and Least Sandpipers (*Calidris minutilla*) use water depths of ~8 cm (3 inches) or less. Greater Yellowlegs (*Tringa melanoleuca*), Stilt Sandpipers (*Calidris himantopus*), American Avocets (*Recurvirostra americana*) and other longer-legged shorebirds use wetlands with water up to ~20 cm (8 inches). Cheyenne Bottoms also hosts species which primarily rely upon upland habitats during at least one portion of their life cycle, such as American Golden-Plover (*Pluvialis dominica*), Upland Sandpiper (*Bartramia longicauda*), Buff-breasted Sandpiper (*Calidris subruficollis*) and Killdeer (*Charadrius vociferus*). Such habitats include shortgrass prairie, abandoned agricultural fields, and grazed pastures. Visit http://wetlandscenter.fhsu.edu/bird-watching/ for a complete shorebird species list.

Threats to Shorebirds at Site

A significant challenge at Cheyenne Bottoms is the need to maintain appropriate vegetation structure on upland habitats while meeting the habitat needs of other wildlife. Other habitat management challenges, that are not described further here, include encroachment of vegetation (both native and introduced) into wetlands, complicated water issues such as securing and maintaining water rights, managing water levels to benefit invertebrates and to create dynamic hydro-periods, unpredictable precipitation patterns, increased siltation of wetlands, and lack of funding to support shorebird habitat management activities.

Actions Taken to Improve Habitat for Shorebirds

Grasslands are the most abundant habitat on the preserve, and there is an opportunity and need to manage them as spring and fall stopover habitat for shorebirds. During wet periods, the grasslands contain thousands of ephemeral wetlands, which, although small, combine to contribute a significant amount of habitat. In addition, there are several grassland dependent shorebirds that benefit from upland grassland habitats. Species such as American Golden-Plover, Buff-breasted Sandpiper, Upland Sandpiper, Long-billed Curlew (*Numenius americanus*), Baird's Sandpiper, and Killdeer benefit from short grass habitats in the spring and fall, while many other species of shorebirds benefit if those areas have standing water. Although the grasslands on the preserve can be dynamic and ephemeral in nature, they can provide important habitat if management practices are in place that target short, sparse vegetation structure during the northward migration period of mid-March through late May (northbound migration) and during the southward migration period of mid-July through mid-October (southbound migration).

Plovers in field that was mowed in the fall (October).
Photo credit: Robert Penner.

Since grazing alone may not create the ideal type of habitat to benefit migrating shorebirds, three additional large-scale practices are implemented: 1. **Haying**, 2. **Mowing**, and 3. Prescribed burning. The first two are described here.

Summer **haying** (between July 15 and September 15) creates short height vegetative structure that shorebirds use in fall, while limiting negative impact on grassland nesting birds. Summer haying provides short term habitat that is available for southbound fall migrants but is not ideal for northbound spring migrants due to regrowth occurring between haying and spring migration. The preserve currently contains about 121 hectares (300 acres) of permanent hay tracts. Tracts are managed in a Quarter Rotation system where half of each tract is hayed at a time: the north half is hayed one year, the east half the second year, and so on. This way, a quarter of the tract is hayed once a year and a second quarter is hayed two years in a row. This technique seems to favor Buff-breasted

Sandpipers during the fall and nesting Upland Sandpipers in the spring.

To provide additional high-quality stopover habitat for shorebirds, **mowing** is used as an additional tool to increase needed short grass habitat on the preserve. Mowing has the disadvantage of leaving some litter on the ground and thus may be a little less desirable for shorebirds, but this type of habitat is preferable to having tall and dense vegetation. Mowing takes place after the cattle have been removed from the pasture at the end of October. Grazing also reduces vegetation which makes mowing less time consuming. Large tracts are mowed starting in November and mowed tracts are scattered across the entire preserve. The average size of the mowed tract ranges from 2 to 10 hectares (5 to 25 acres). Each mowed tract will usually include several ephemeral wetlands and one seasonal wetland, and the process of mowing keeps the vegetation low and provides habitat accessible to shorebirds. This management technique provides mowed tracts that are attractive to shorebirds during both dry and wet periods.

Outcomes

Shorebird use of the mowed tracts increased the total number of shorebirds observed during International Shorebird Surveys. The first year of mowing resulted in an increase of 43% more shorebirds when compared to the previous high year ten years earlier. Large flocks of American Golden-Plovers have been recorded, and this species was not observed in such numbers on the preserve before mowing practices began. Other wetland and upland species have responded in a similar fashion, depending on whether the mowed sites were wet or dry. The number of nesting Upland Sandpipers has also increased.

Advice/Precautions

Prescribed burning would be preferred over mowing to create the type of habitat shorebirds prefer, but we do not have the staff capacity or the equipment. For us, mowing is an effective and worthwhile alternative to burning. Mowing can also target smaller areas more easily than burning, so we would continue to use this technique even if a prescribed burning program were established.

CASE STUDY

Enhancing Rice Agriculture in California's Central Valley

Long-billed Curlew *(Numenius americanus)* in a flooded rice field. *Photo credit: Drew Meyers.*

LOCATION: Sacramento Valley of California, USA

AUTHORS: Khara Strum, Project Manager with Audubon California, Kristin Sesser, Avian Ecologist with Point Blue Conservation Science, and Greg Golet, Applied Ecologist with The Nature Conservancy

LAND OWNERSHIP: The majority of the land is privately owned and farmed; the dominant crop is rice.

Focal Habitat

» Agriculture

Habitat Goal

To protect and enhance agricultural habitat in California's Central Valley to sustain healthy migratory shorebird populations in the Pacific Flyway in the face of changes in land use and climate.

Species Benefitted

Most shorebird species that use the inland portion of the Pacific Flyway in California rest and forage in post-harvest flooded rice fields in the Sacramento Valley (northern portion of Central Valley). The most abundant species include Dunlin (*Calidris alpina)*, Dowitchers (predominantly Long-billed; *Limnodromus scolopaceus*), Least Sandpiper (*Calidris minutilla*), Western Sandpiper (*Calidris mauri*), Greater Yellowlegs (*Tringa melanoleuca*), Killdeer (*Charadrius vociferous*), and Long-billed Curlew (*Numenius americanus*).

Threats to Shorebirds at Site

The Central Valley of California has lost over 90% of its natural wetlands. Today in the Sacramento Valley, approximately 150,000 hectares of flooded, post-harvest rice fields complement the 33,000 hectares of managed seasonal wetlands to provide a mosaic of flooded habitats for waterbirds—some of which are suitable for shorebirds given their shallow water depth and sparse vegetation. Threats to this mosaic include conversion of rice to permanent crops such as trees and vines that are not waterbird-friendly, urban expansion and development, and the availability of water for both growing rice and flooding fields after harvest, especially in times of water scarcity. Changing cultural practices of farmers may also be a threat, if for example, more choose to physically remove cut straw from their fields instead of flooding for onsite decomposition.

Actions Taken to Improve Habitat for Shorebirds

Audubon California, Point Blue Conservation Science, and The Nature Conservancy have worked directly and collaboratively with local rice farmers, the California Rice Commission, and the United States Department of Agriculture's Natural Resources Conservation Service (NRCS) to develop rice field management practices that enhance the habitat value of farms for shorebirds and other waterbirds.

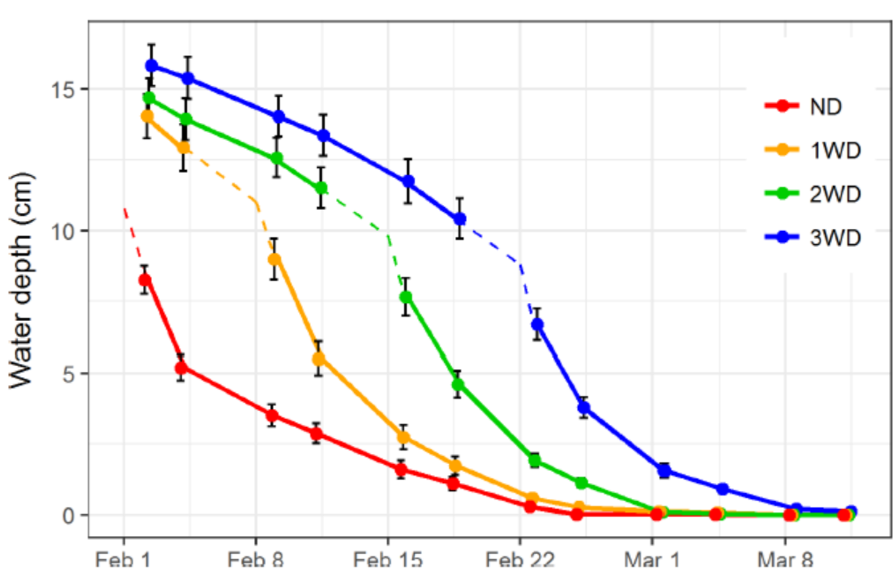
We started by identifying time periods when 1) shorebirds were moving through or using the area, 2) shorebird habitat was limited, and 3) the rice production cycle had the potential to provide improved habitat. We identified two key time periods when habitat is most limited for shorebirds, mid-July to September (during southbound migration) and March through mid-May (northbound migration).

Working with the rice growing community, we then developed and tested practices that farmers could incorporate into their operations to help alleviate habitat shortfalls for shorebirds in the Central Valley.

- **Flooding Fallow Fields during southbound migration—** Between mid-July and September, when growing rice fields are still in production (with tall, dense vegetation), we recommend flooding fallow rice fields and other compatible agricultural fields (e.g. maize or wheat) and actively managing the water drawdown over a period of 3-4 weeks. Field studies demonstrated that providing shorebird habitat during southbound migration (fall) was critically important (Golet et al. 2018), confirming the results of bioenergetic modelling which identified this season as a time of consistent habitat shortfall in the Central Valley (Dybala et al. 2017).
- **Staggered Drawdown during northbound migration—**Most rice farmers drain winter flooded rice fields at the end of January which allows fields to dry sufficiently before the farmers begin groundwork in March for planting in mid-April and May. We recommend actively flooding rice fields from November through January and then delaying the drawdown by two weeks or more and then staggering the dewatering of rice fields by 25% each week during February and March. Fields should have a starting depth of at least 10 cm (4 inches) before initiating drawdowns. This shift in the usual dewatering protocol extends the traditional flooding period and creates a mosaic of water depths that supports multiple waterbird guilds (Sesser et al. 2018).

Outcomes

These studies and other research on alternative management strategies on rice fields informed the development of the



Delayed drawdowns of flooded rice fields extends the availability of shallow water habitat and supports waterbirds. Mean water depth ± standard error for each survey occasion in each treatment over a six-week study period of the staggered drawdown of flooded rice fields during northbound migration. The known start date of each drawdown is indicated by the inflection point in each dashed line.

ND – no delay in water drawdown,
1WD – one week delay in water drawdown,
2WD – two week delay in water drawdown,
3WD – three week delay in water drawdown.

Further delaying the drawdown would create similar habitat later and support migratory shorebirds during the peak of migration. *Figure from Sesser et al. 2018.*

NRCS Waterbird Habitat Enhancement Program (WHEP), which, over eight years, has enhanced over 120,000 acres of California ricelands for waterbirds and provided over $15 million in federal Farm Bill funds to support on-the-ground conservation. This program helps to sustain production agriculture in the Sacramento Valley while simultaneously providing birds and other wildlife with flooded habitat to help offset substantial loss of wetlands over the past 150 years. **Results of field studies indicate that fields with applied habitat-enhancing practices can support up to 8 times more shorebirds than fields with traditional management (Strum et al. 2013, Sesser et al. 2018).**

Building on the success of the program developed with NRCS, The Nature Conservancy launched the BirdReturns program—applying a new funding model to similar practices. Farmers were invited to participate in a reverse auction bidding process, in which winning bids were selected based on their cost and potential to provide high quality shorebird habitat. This program is an important, dynamic complement to the NRCS program that seeks to provide habitat when and where the birds need it most (Reynolds et al. 2017). The BirdReturns program has contributed 50,000 additional acres to those provided through WHEP. Adaptive and appropriately timed (specifically between September and early October and March through early April) conservation incentive programs can effectively support large numbers of migratory shorebirds on private agricultural lands (Golet et al. 2018).

Audubon, The Nature Conservancy, and Point Blue Conservation Science also work at a policy level to ensure the longevity of these landowner incentive programs to support the implementation of bird-friendly agricultural practices. We participate in the Central Valley Joint Venture, a 20-member partnership devoted to conserving migratory birds and their habitats for the benefit of wildlife and the public, to develop habitat and population objectives for shorebirds in the Central Valley using the best available data. One outcome of our continued engagement in conservation policy is the recent passing of legislation to support a state-funded program to support winter flooding of rice fields.

Advice/Precautions

» **Flooding Fallow Fields—**Enhancing habitat in the time period between mid-July and September requires fallow rice or other crop fields, which may be available in varying quantity each year. Water availability during this time period may be limited and caution should be taken to minimize the production of mosquitos near human-populated areas.

Dunlin (*Calidris alpina*) using a field with delayed drawdown in late winter (March). *Photo credit: Monica Iglecia.*

» **Staggered Drawdown—**From an agronomic standpoint, late season rains coupled with delayed drawdowns of flooded fields have the potential to delay field preparation and planting. Additionally, water availability can be impacted by irrigation district maintenance or drought.

» **Collaboration—**Collaborations and effective communication are essential to scaling conservation outcomes. Having a strong partner in the agricultural industry, the California Rice Commission, was paramount to reaching and engaging rice growers. The relationship with NRCS, a government agency with capacity and programs to support implementation was also critical. Bringing the landowners in at the beginning of this process and including them in development of the practices themselves provided an important opportunity for building trust and cultivating relationships. All of these pieces were key to the success of this program.

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Shallow flooded rice field enrolled in The Nature Conservancy's BirdReturns program. Also shown is the tractor that was used to incorporate residual rice stubble into the soil. *Photo credit: Greg Golet.*

CASE STUDY

Compatible Management of Salt Production and Nature Conservation at Ecuasal

Phalaropes at Ecuasal. *Photo credit: Ana Agreda.*

LOCATION: Ecuasal Salt Lakes, Santa Elena Province, Ecuador

AUTHOR: Ana E. Agreda, Project Coordinator, Aves y Conservación/ BirdLife in Ecuador

LAND OWNERSHIP: Privately owned by Ecuatoriana de Sal y Productos Quimicos C.A. (Ecuasal)

Focal Habitats

» Agriculture and Aquaculture—Salt

A complex of active artificial ponds managed for salt production.

Habitat Goal

To support conservation of migratory and resident aquatic bird fauna at Ecuasal Salt Lakes and in the province of Santa Elena and promote a model of compatibility between industrial salt production and nature conservation.

Species Benefitted

Snowy Plover (*Charadrius nivosus occidentalis)*, Wilson's Plover (*Charadrius wilsonia*), Semipalmated Plover (*Charadrius semipalmatus*), American Oystercatcher (*Haematopus palliatus*), Lesser Yellowlegs (*Tringa flavipes*), Whimbrel (*Numenius phaeopus*), Semipalmated Sandpiper (*Calidris pusilla*), Western Sandpiper (*Calidris mauri*), Least Sandpiper (*Calidris minutilla*), Stilt Sandpiper (*Calidris himantopus*), Short-billed Dowitcher (*Limnodromus griseus*), Wilson's Phalarope (*Phalaropus tricolor*)

Threats to Shorebirds at Site

Threats to shorebirds at the salt production lakes of Ecuasal include but are not limited to:

- Human disturbance and lack of public knowledge of the site's importance for shorebirds.
- Degradation of surrounding habitat due to urban and industrial development, expansion and intensification of shrimp aquaculture
- Industrial and urban pollution including solid waste and residual water discharge from shrimp larvae laboratories, and contaminated runoff due to poorly managed wastewater treatment methods in nearby urban communities.

Actions Taken to Improve Habitat for Shorebirds

From 2008 to 2010, we focused on understanding the current conservation status of the salt lakes and their surroundings. For this we gathered social, economic, and ecological information that allowed us to put together the first *Conservation Plan for the Ecuasal Salt Lakes.* The Conservation Plan was funded by the salt production company Ecuasal and endorsed by Ecuador's Ministry of the Environment. The document was published in 2012 and implemented between 2012 and 2016.

Ecuasal's Conservation Plan identified strategic objectives and local political considerations to help develop effective programs. Below we highlight four parts of the Conservation Plan that have been implemented at Ecuasal to benefit shorebirds and other waterbirds.

1. **Control and Surveillance Plan.** The Conservation Plan defined the lakes' carrying capacity for tourism at 90 people per day and established guidelines for use of the area by visitors and scientists. Since 2012, Ecuasal has employed trained personnel to ensure effective control of the boundaries of the property to enforce the 90-person-per-day tourist carrying capacity and reduce human disturbance. Guards monitor the perimeter of the property to prevent public entry. Visitors must obtain a permit from Ecuasal in order to enter the salt lakes.
2. **Implementation of Buffer Zones.** We worked with the local government to support measures that prevent solid waste disposal around the perimeter of the salt lakes and to control industrial water discharge from a nearby aquaculture industry at the southern section of the lakes (Mar Bravo, Salinas).

Community engagement and outreach at Ecuasal.
Photo credit: Ana Agreda.

3. **Education and Communication.** We are improving the knowledge about the value of migratory birds among the local community and national population through bird festivals and other education and outreach efforts. In 2016, we implemented an environmental education pilot program called "Ecuasal and Migratory Birds go to Schools."
4. **Engaging Students in Research.** We have had an agreement with the local university, Universidad Peninsula de Santa Elena, since 2008, where students studying biology can participate in internships and research projects around birds at Ecuasal's salt lakes.

Outcomes

Positive impacts for shorebirds have been observed at Ecuasal. While it is still too soon to report definitive results, results from shorebird monitoring show an increase in American Oystercatchers at the site and Wilson's Phalaropes continue to use the salt lakes in large numbers. Other waterbirds are also benefiting from the implementation of the Conservation Plan - more South American Terns (*Sterna hirundinacea*) are now nesting in the area, and higher numbers of Gray-headed Gulls (*Chroicocephalus cirrocephalus*) and Gull-billed Terns (*Gelochelidon nilotica*) have been observed.

Results from the Implementation of the Conservation Plan

1. **Control and Surveillance Program.** Less than 5,000 people entered the salt lakes in 2016, mostly to fish for recreation or subsistence, or to gain access to nearby beaches and bathe with their families. The bathers are local people, coming from nearby neighborhoods and illegal camps surrounding the salt lakes. The guard staff confront trespassers, but sometimes the national police have helped explain the rules to the fishermen. Monitoring the number of visitors to the salt lakes and where they enter the property has helped improve patrolling strategies and enabled us to focus on specific high use areas.

2. **Implementation of Buffer Zones.** The salt lakes are almost completely surrounded by local communities and industries. Solid waste from surrounding shrimp larvae laboratories has been successfully reduced, with help from the Ministry of Environment to legally enforce a series of defined buffer zones that vary in length (6 – 10 kilometers) and width (5 – 10 meters).

3. **Education and Communication.** Through festivals and outreach, we have reached more than 5,000 children in the local province of Santa Elena. The majority of these people have had the opportunity to visit the salt lakes and learn about the bird life using the area, while others have experienced classroom presentations. 380 students participated in weekly in-school workshops during six months of the 2016 school year.

4. **Engaging Students in Research.** Since 2007, 498 university students, biologists, naturalist guides, and government personnel were trained to participate in monthly bird censuses. Trainings focused on techniques for bird identification, monitoring waterbird populations, and conservation. In 2011, we began an internship program with marine biology students at the local university Universidad Peninsula de Santa Elena. To date, 25 interns have completed the program and many students have continued studying birds as part of their undergraduate thesis work.

Advice/Precautions

The specific conservation actions that can be taken at each site depend on a complex web of decisions by administrators and key stakeholders. It is very important to start by gathering basic information about the site: identify the people interested in its conservation and assess the site's conservation status (including both current and potential threats). We recommend seeking support from the Western Hemisphere Shorebird Reserve Network (WHSRN) and using their available resources such as the Site Assessment Tool or a similar type of tool and then developing a Logical Framework Approach to guide this process, a process developed by the United States Agency for International Development (USAID). Currently there are other easy-to-use tools available, such as Conservation Action Planning (CAP) from the Conservation Measures Partnership, which has been a guide for initial interventions in critical biodiversity areas.

Seeking the support of key stakeholders has been one of our project's greatest strengths. Gaining the support of local authorities to implement buffer zones has been one of our biggest challenges. It is critical to involve the local community whenever possible and to effectively include them in conservation efforts

CASE STUDY

Stemming the Increase of Disturbance on Georgia's Sandbar Islands

Pelican Spit off of Sea Island in Glynn County, Georgia has moved from its original location since becoming partially protected from human disturbance in 1998. However, the state considers it the same island and protects most of it for birds. *Photo credit: Brad Winn.*

LOCATION: Georgia, Atlantic Coast, USA

AUTHOR: Brad Winn, Director of Shorebird Habitat Management, Manomet

LAND OWNERSHIP: State

Focal Habitats

- Coastal Tidal—Estuarine
- Coastal Tidal—Marine

This habitat conservation project targeted small islands that support important habitat for nesting, migrating, and wintering shorebirds and seabirds.

Habitat Goal

Reduce the disturbance of shorebirds and seabirds from recreational activities on specific ebb-tidal delta islands along the barrier coast of Georgia.

Species Benefitted

Nesting shorebirds: American Oystercatcher (*Haematopus palliatus*), Wilson's Plover (*Charadrius wilsonia*), Willet (*Tringa semipalmata*); Migrant and wintering shorebirds: Red Knot (*Calidris canutus*), Whimbrel (*Numenius phaeopus*), Marbled Godwit (*Limosa fedoa*), Long-billed Curlew (*Numenius americanus*), Piping Plover (*Charadrius melodus*), American Oystercatcher, Short-billed Dowitcher (*Limnodromus griseus*), Dunlin (*Calidris alpina*), Sanderling (*Calidris alba*), Black-bellied Plover (*Pluvialis squatarola*), Semipalmated Plover (*Charadrius semipalmata*), Western Sandpiper (*Calidris mauri*), Semipalmated Sandpiper (*Calidris pusilla*), Least Sandpiper (*Calidris minutilla*). Also, nesting seabirds including Royal Tern (*Thalasseus maximus*), Gull-billed Tern (*Gelochelidon nilotica*), Sandwich Tern (*Thalasseus sandvicensis*), Least Tern (*Sternula antillarum*), Black-Skimmer (*Rynchops niger*), and Brown Pelican (*Pelecanus occidentalis*) benefited from the management actions described below.

Threats to Shorebirds at Site

Detrimental levels of disturbance from increasing recreational use of sites by the boating public.

Actions Taken to Improve Habitat for Shorebirds

Small sandbar islands of the southeastern coast of the United States are rare, and Georgia is not an exception. Sandbar islands make up less than 1% of the state's beaches, yet they are highly valuable habitat for a wide assemblage of coastal birds. The values of these small sandbar islands involve a combination of physical and biological features rarely provided by other beach areas including 1) a dry-sand portion that persists above the normal tidal range, used for nesting and roosting by beach-obligate birds, 2) extensive intertidal flats and shoals that are full of shorebird food resources, 3) isolation from most land-based predators, and 4) areas with limited or no vegetation (such as dune grasses), providing an open 360 degree view for easy detection of incoming avian predators.

In the late 1990's, the remote aspect of these sand islands in Georgia changed as the growing human population on the coast "discovered" and began to access some of them regularly, leading to elevated recreational activities ranging from daytime beach use to overnight camping. As public use increased, disturbance became so frequent that some habitat became functionally unavailable to birds. Beach-nesting birds using islands closest to urban areas like Savannah and St. Simons Island were most sensitive to this rise in public access. Pet dogs exacerbated disturbance and predation impacts to nests, chicks, and migrant shorebird flocks, particularly during daytime high tides when roosting habitat was limited.

Independently, a local fishing guide, a local eco-tour nature guide, and a coastal boating outfitter approached the state of Georgia's Department of Natural Resources (GADNR) with concerns that increased use by the boating public was threatening an important draw for their clients and local visitors: the ability to see and experience large

Marbled Godwit and other wintering shorebirds brace the winter winds and storm-driven overwash on Georgia's Barrier coast. *Photo credit: Brad Winn.*

numbers of coastal birds. They interpreted the loss of key breeding and resting sites for local seabird and shorebird populations as a detriment to the overall experience of their clients, and potentially a long-term economic loss for their nature-dependent tourism businesses. Staff of the Wildlife Resources Division of the Georgia Department of Natural Resources determined that five small sand islands on the 160 kilometer coast were in jeopardy of losing their biological integrity due to overuse by the public. The islands included Williamson (Chatham County), St. Catherines Island Bar (Liberty County), Little Egg Island Bar (McIntosh County), Pelican Spit (Glynn County), and Satilla River Marsh Island (Camden County).

A two-year process, led by state biologists, began by developing site profiles for each of the islands. The profiles included a compilation of all known species-specific bird use data, known physical history of sand accretion and stability, and through island by island visits, helped provide an understanding of user group interests. Nine individuals representing diverse stakeholder groups from the five coastal counties were selected for a panel, which included a conservation organization, a sport fishing club, a boat manufacturer, a biologist from a federal agency, a community doctor, a marina owner, a retired maintenance technician, a small business owner, and a tourist industry representative. The nine individuals were volunteers on behalf of local constituencies interested in the outcome of any management related regulations that might be developed.

These individual coastal community representatives were tasked with familiarizing themselves with all of the issues related to the islands through a process led by state biologists. Their assignment, with no deadline, was to write recommendations for the management of each of the sandbar islands and submit those recommendations as a report to the Commissioner of the Georgia Department of Natural Resources. This task had no deadline to allow the representatives to take their time to learn about all aspects of these issues and to reach a consensus on their recommendations. Their report, when accepted by the commissioner, would be used as the base for any regulatory actions taken by the state to manage the islands.

The recommendations developed by the stakeholder panel included:

1. **A GADNR biologist should oversee the management of the islands**, monitor bird populations, and monitor public compliance.
2. **Complete year-round closure** of the three most biologically important islands to any public access.
3. **Limited public access** allowed on specific areas of two of the islands, with the remainder of those two islands protected for nesting birds.
4. **No pets allowed** on any of the five islands at any time.

Outcomes

Following the recommendations of the stakeholder panel and two executive orders from the Governor of Georgia, state authorities wrote the legally binding "Bird Island Rule" which became a state regulation when passed by the Board of the Department of Natural Resources in 1998. This regulation was more restrictive than the original proposal written by state biologists, and was a significant achievement toward maintaining the biological integrity of Georgia's Coast by limiting disturbance to specific sensitive habitats. The following paragraphs reflect on the long-term outcomes of the legal parameters of the Bird Island Rule (hereafter BIR):

1. **A GADNR biologist to oversee the management of the islands—**A full-time biologist was hired and continues to oversee the management of the islands, monitor

Little Egg Island Bar at the mouth of the Altamaha River. Twenty years after the Bird Island Rule went into effect in 1998, this sandbar island is still considered one of the single most important sites for birds on the coast of the southeastern United States. *Photo credit: Brad Winn.*

bird populations, and monitor public compliance. The biologist became and continues to be an advocate for the continued protection and monitoring of the islands. Community engagement and outreach efforts led by the biologist further educate the public about the BIR. A brochure was created for distribution in marinas and eco-tour outlets. A poster was also developed to hang in kiosks and be available as outreach material for school groups. Both the poster and brochures were well received by coastal businesses and the beach-using public. Large signs that are legible from a distance were placed on islands to tell visitors of the rules of conduct. Symbolic fencing is placed each year around high-use shorebird areas.

2. **Complete year-round closure—**This action was taken on the three islands experiencing lower levels of human use (St. Catherines Island Bar, Little Egg Island Bar, and Satilla Marsh Island), and arguably had the greatest value to coastal birds. All three islands have maintained their values for colonial nesting seabirds, multiple pairs of nesting shorebirds, and stopover migrants – and the two ebb-tidal sandbars continued to support impressive numbers of wintering coastal birds each year. Periodic but rare enforcement of the regulations was necessary to maintain compliance when island closures were ignored, but the BIR successfully prevented a regular pattern of public use from establishing on any of the three islands.

3. **Limited public access—**The two islands that allowed some level of public access under the BIR were less successful from the shorebird/seabird conservation perspective. The south end of Williamson Island was left open to the public, and in the late 1990s was a favorite destination for Savannah boaters. The north end of the island was also publically accessible and under the BIR was left open for less frequent boater access. The middle of this linear island was used by three pairs of American Oystercatchers, five to ten pairs of Wilson's Plovers, and small numbers of Least Terns. The dry-sand portion of the middle of the island was closed with the exception of north-south walking access, and the wet sand beach of the intertidal zone was also left open for walking. Due to the popularity of this beach to the public, the state's original proposal to completely close Williamson Island built significant resentment and anger, rapidly escalating to a media-driven fervor that

Little Egg Island Bar in the mouth of the Altamaha River, Georgia has all of the elements of superb shorebird habitat, including dry sand areas for large numbers of birds to roost, an extensive wrap-around waterline, gently sloping sediments, and large tidal change that uncovers huge areas of river mud and sand as the tide goes out. Here, Red Knots forage for tiny clams in the shallow water. *Photo credit: Brad Winn.*

caused the state to reconsider the entire protection plan for any of the islands. In hindsight, Williamson Island should not have been included at all in the proposal for conservation action based on lower biological value, and its popularity with recreationists.

4. **No pets allowed on any of the five islands—**Other than Williamson Island near Savannah, which had become a destination for boaters to bring dogs, there was generally good compliance with this no-pet stipulation. Over time, this restriction may have been the single most important aspect of this coastal conservation initiative. The GADNR biologist's engagement with the public at the sand spit islands during peak boating times on weekends in early summer was instrumental in explaining the value of the no-pets clause of the BIR. A regular contingent of visitors used Pelican Spit in the year following the passage of the rule and learned from the GADNR biologist about the habitat value of the island to birds. These boaters and beach goers became protective of the beach-nesting birds in the center of the island, and policed themselves as well as new people coming to the island to keep dogs off, and prevented anyone walking near any of the nests of Black Skimmers, Gull-billed Terns, Least Terns, American Oystercatchers, and Wilson's Plovers.

Advice/Precautions

Understanding the full spectrum of political, legal, biological, social, and cultural ramifications of regulating coastal habitat for the protection of birds is paramount to achieving a successful outcome. It is critically important to strategically select relevant stakeholders to foster local support well in advance of regulatory discussions. In the process of developing the BIR, the support of people whose businesses were dependent on the abundance of wildlife and the health of barrier island habitats was very important to persuade local politicians to support proposed regulations. Creating a well-planned media campaign to disseminate accurate information to the public well ahead of any regulatory decisions or implementation will help increase public support and adoption of eventual conservation proposals to reduce disturbance.

Due to the dynamic nature of barrier coasts, especially those made up of sand and mud like in Georgia, regulations that protect specific parts of a sandbar island need to have the flexibility to move and change with the island over time. The BIR intentionally lacked specific coordinates describing which areas were closed and open to the public, which has allowed coastal managers to use biological and habitat clues to adjust protected areas as islands change and migrate. For example, Pelican Spit disappeared entirely when adjacent sand was dredged to renourish the eroding beach on nearby Sea Island. Within a year of sand removal from the borrow pit and its relocation to Sea Island, Pelican Spit essentially slipped into the dredged hole. Subsequently, the island reemerged just to the south, and quickly became a valuable bird site all over again. The flexibility built into the BIR made it possible for Pelican Spit to remain protected by the State, even in its new location.

CASE STUDY

Managing Kitesurfing at Laguna de Rocha and Laguna Garzón

Aerial image of Laguna Garzón. Nautical sports are permitted within the zone bounded by the two red lines. Note the circular bridge bisecting the nautical zone. *Image source: Google Earth.*

LOCATION: Laguna de Rocha and Laguna Garzón Protected Areas, Provinces: Maldonado and Rocha, Uruguay

AUTHORS: Soledad Ghione, Sebastian Horta and Hector Caymaris, Sistema Nacional de Áreas Protegidas de Uruguay

LAND OWNERSHIP: National Protected Areas

Focal Habitats

- Coastal Tidal Wetlands—Estuarine
- Coastal Tidal Wetlands—Marine

Coastal lagoon with intermittent connectivity to the ocean, including sand dunes, beach, and ephemeral sand bars, mudflats, coastal grasslands, flooded marsh, wetlands, and relict forest.

Habitat Goal

Reduce disturbance to allow natural restoration of coastal habitat conditions of sandy beach, mudflats, and naturally flooded wetlands.

Species Benefitted

Buff-breasted Sandpiper (*Calidris subruficollis*), White-rumped Sandpiper (*Calidris fuscicollis*), Rufous-chested Dotterel (*Charadrius modestus*), and American Golden Plover (*Pluvialis dominica)* are the most common species at Laguna de Rocha (Alfaro and Clara 2007). In Laguna Garzón, shorebirds are less abundant, but American Golden Plover and White-rumped Sandpiper are well represented.

Threats to Shorebirds at Site

The main threats at these sites are disturbance and habitat loss caused by unregulated watersports, urban development, tourism, and overgrazing by cattle. In this case study, we discuss management actions to reduce human disturbance caused by coastal recreation, specifically driving on beaches and kitesurfing.

Actions Taken to Improve Habitat for Shorebirds

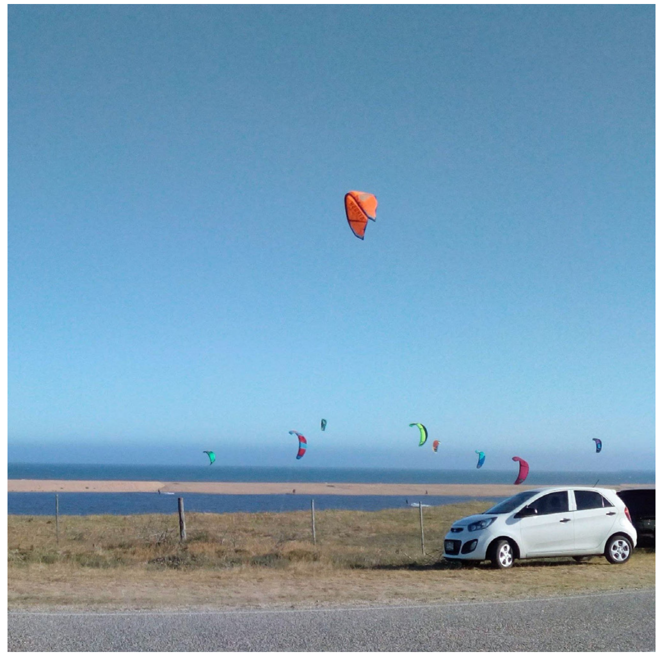
Both Laguna de Rocha and Laguna Garzón are part of the National Protected Area System in Uruguay; Laguna de Rocha has been protected since 2010 and Laguna Garzón became a protected area in 2014. These highly productive intertidal areas have intermittent connectivity with the ocean and are part of a larger coastal lagoon system stretching from Uruguay to the north of Brazil. Both Laguna de Rocha and Laguna Garzón have been recognized as Important Bird Areas by Birdlife International. Laguna de Rocha is a Western Hemisphere Shorebird Reserve Network Site of Regional Importance.

» **Vehicle Control:** To reduce vehicle disturbance in both coastal lagoons, the National Protected Areas System has been working to implement and enforce Law N° 16.736, which forbids vehicle use of any kind in beach areas. The law was created in 1996 but had not been enforced within the protected areas. By enforcing this law, protected area staff are able to control the presence of vehicles on the beaches and remove them if necessary. Signs were installed throughout the coastal areas to indicate that it is forbidden to drive on the beach.

» **Kitesurfing Management:** There are high levels of use by kitesurfers at both lagoons.

Laguna de Rocha is a Paisaje Protegido (Protected Landscape) in the National System of Protected Areas of Uruguay and is the country's third Ramsar Site. The local government supports efforts to reduce the threat of kitesurfing to birds. The site has an approved management plan, which helps enforce regulation of recreational activities. Independent kitesurfing is only allowed within a designated 50m x 50m area of the lagoon, and kitesurfing schools are no longer allowed in the area. Independent kitesurfers must register with park rangers, who relay the rule that they can only practice kitesurfing within the designated 50m x 50m area in the lagoon.

Laguna Garzón does not yet have an approved management plan, and many kitesurfing schools used to operate in the area without regulation. When the lagoon was designated as a Protected Area in 2014, the site became subject to Uruguay's National Environmental Impact



Kitesurfers at Laguna Garzón. *Photo credit: Soledad Ghione*

Regulation, which requires all activities within a protected area to obtain environmental authorization. Kitesurfing schools are now required to obtain this authorization to operate at Laguna Garzón. Each school must provide a detailed report describing the physical extent of their activities in the water and on the beach, including space used for parking, bathrooms, tents for shade, and advertising. Within the water, schools may only operate within a zone designated by the authorization, and they are no longer allowed to operate near bird foraging and roosting sites. Schools must also provide information to protected area staff about their hours of operation and number of students at any given time.

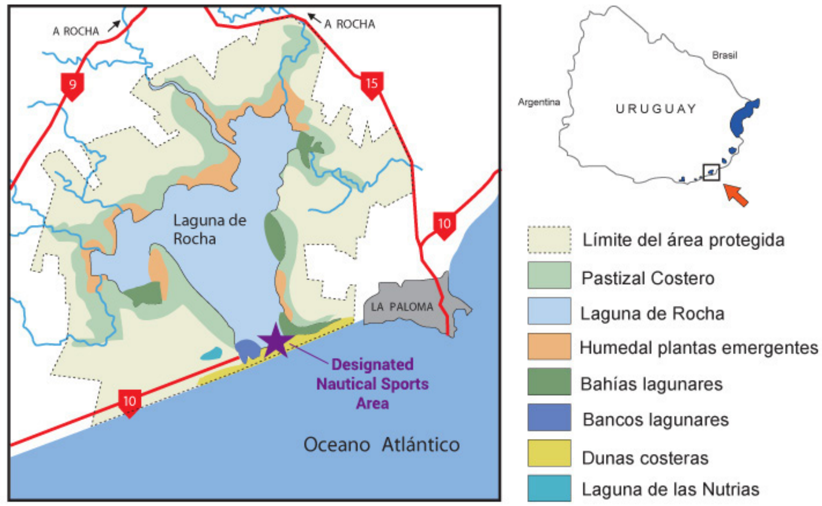
Outcomes

» **Vehicle controls:** The Ministry of the Environment began enforcement of the vehicle controls at Laguna de Rocha in 2010 and at Laguna Garzón in 2016. In 2017, 27 fines were issued to violators of the no-vehicles on beaches policy, and subsequent decreases have been observed in the number of vehicles on the sand bars and in coastal sand dune areas.

» **Kitesurfing Management:** At *Laguna de Rocha*, the 50m x 50m kitesurfing area has led to a decrease in the presence of kitesurfers and, consequently, a decrease in vehicles in coastal dune areas. While kitesurfers resisted the new regulations when they were implemented in 2016, they were embraced by local ecotourism groups and nature enthusiasts that support tourism and nature-based recreation such as bird watching and kayaking. Today, members of the local community are working together to reduce kitesurfing at Laguna de Rocha because of the disturbance it causes to roosting and foraging shorebirds.

At *Laguna Garzón*, it is still too soon to report definitive results, but we are optimistic that the threat reduction efforts are causing positive change. There are multiple walk-in access points to the prime kitesurfing location at this site, making it challenging for protected area staff to regulate the sport. In addition, the original raft ferry system to access the lagoon was replaced by the Laguna Garzón Bridge in 2015. Although a significant improvement from the previous mode of transportation, this circular bridge has not only increased access to the lagoon, but has heightened human activity in the region overall. Furthermore, park staff are only able to regulate kite surfing schools, not individual kitesurfers, until a management plan is in place. Efforts to develop and approve a management plan for the site are underway.

At this time, capacity limits the ability to conduct regular bird surveys at either lagoon. However, protected area staff have observed that shorebirds are able to utilize the area when fewer or no kitesurfers are present.



The designated kitesurfing area established in Laguna de Rocha.
Figure source: MVOTMA 2016.

Advice/Precautions

Creativity is an important tool for those working in habitat management at sites where user groups are made up of individuals with different interests. Find creative solutions, sometimes within existing frameworks, such as a lack of enforcement of existing laws, and use these tools to support conservation efforts.

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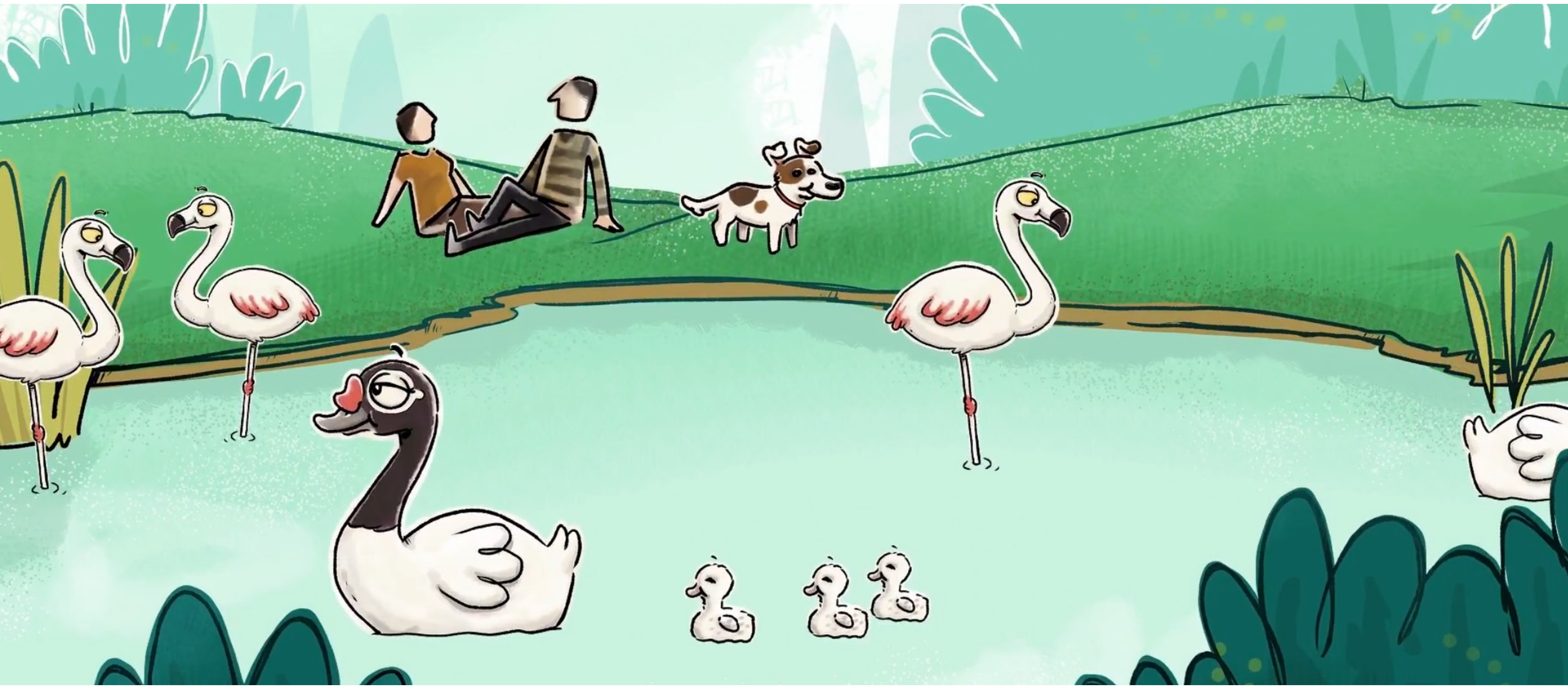
CASE STUDY

Managing dogs on Chiloé Island, Chile



"Plan de control de mascotas en zonas rurales de Chiloé 01." YouTube, uploaded by OBSCHILOECECPAN, 16 May 2018, https://youtu.be/aeieO-EFG1Y.

LOCATION: Chiloé Island, Chile

AUTHOR: Catalina Parragué Migone, Veterinarian, Centro de Estudio y Conservación del Patrimonio Natural

LAND OWNERSHIP: Public

Focal Habitats

» Coastal Tidal Wetlands

Habitat Goal

To protect the island's wetlands which are the nonbreeding home to 27% of the global population of Hudsonian Godwit and significant numbers of Whimbrel. To reduce threats to wildlife by changing local community management of dogs.

Species Benefitted

Hudsonian Godwit (*Limosa haemastica*), Whimbrel (*Numenius phaeopus*), Black-necked Swan (*Cygnus melancoryphus*), Chilean Flamingo (*Phoenicopterus chilensis*), Rufous-chested Dotterel (*Charadrius modestus*), rayador (*Rynchops niger cinerascens*), Pudú (*Pudu puda*), Darwin's Fox (*Lycalopex fulvipes*), and other migratory and resident species.

Threats to Shorebirds at Site

The mismanagement of pets, specifically dogs, on the island pose a significant threat to native wildlife. Most dogs have owners but the animals are free to roam. Municipalities on the island are challenged by the abandonment of dogs in wetlands and fields.

Free roaming and abandoned dogs disturb shorebirds at roosting and foraging sites, potentially affecting their ability to gain weight in preparation for migration. There have been cases when dogs depredate birds directly. Other threats to shorebirds exist including but not limited to driving on beaches, filling of wetlands, and waste from aquaculture.

Actions Taken to Improve Habitat for Shorebirds

Through the implementation of a public outreach campaign, an education program for children, and by providing free dog sterilization, the Centro de Estudio y Conservación del Patrimonio Natural (CECPAN) has been working to reduce the threat of dogs at two important wetland sites on Chiloé Island, Caullín and Pullao. These needed actions were included in the Conservation Plan for Migratory Shorebirds of Chiloé, developed by the WHSRN Executive Office, Manomet Inc. and local partners with support from the Packard Foundation.

Outcomes

Via workshops to more than 300 children and adults, CECPAN is working with and educating communities to responsibly manage dogs. Through this effort more than 500 handouts and calendars that include specific recommended actions have been developed and distributed. Actions include keeping dogs on a leash, keeping dogs within fenced areas at home, and the need to sterilize pets. The calendars provide a year round reminder of these strategies.

Working with local children and a theater group, CECPAN created four short radio clips and three animated videos that share stories and strategies for managing dogs and how to participate in the free dog sterilization program. The sterilization program was also promoted directly in focal communities through door to door information sharing. Through this effort, 93 dogs have been sterilized.

Outreach materials provide guidance for responsible pet ownership.

Advice/Precautions

This has been a successful effort, but CECPAN notes actions that could be taken to further increase impact. For example, travelling with a dog to a specific location for sterilization may be a limiting factor. A sterilization van that visits communities and provides this service may be expensive but more effective. In general, sterilization of dogs is not popular but working with local children has helped this idea gain traction in local communities. Reaching out to even more members of the community through workshops and developing a brochure with specific information about the benefits of dog sterilization may help gain wider adoption of this practice.

Another useful strategy that has not yet been implemented could include providing fencing materials to community members that have pets and live near important wetlands. Construction materials could be provided in exchange for a signed commitment to participate in sterilization efforts and to keep animals (both livestock and pets) safe and secure on their property.

Video Links

VIDEOS ABOUT RESPONSIBLE PET OWNERSHIP (IN SPANISH)

https://www.youtube.com/watch?v=aeieO-EFG1Y&t=4s

https://www.youtube.com/watch?v=_myrBwvvBw4&t=2s

https://www.youtube.com/watch?v=hRd9KCp-flQ

VIDEO ABOUT PROTECTING DUNES AND BEACHES (IN SPANISH)

https://www.youtube.com/watch?v=HEAZ_BNJYas

Outreach materials included calendars with suggested actions for responsible pet management to benefit wildlife.

CASE STUDY

Predator Management to Benefit Snowy Plovers

Newly hatched Snowy Plover brood in oyster shells of habitat restoration area. *Photo Credit: EJ Feucht*

LOCATION: Pacific coast of the United States (Washington, Oregon, and California)

AUTHOR: Mark A. Colwell, Professor, Wildlife Department, Humboldt State University

LAND OWNERSHIP: Federal, state, and county ownership; some private lands.

Focal Habitats

- Coastal Tidal Wetlands—Marine
- Coastal Tidal Wetlands—Estuarine
- Inland Non-tidal Wetlands—Riverine
- Agriculture and Aquaculture—Salt ponds

Including ocean-fronting beaches, dredge spoil habitats, salt ponds, and riverine gravel bars.

Habitat Goal

Improved vital rates (especially productivity) of breeding Snowy Plovers.

Species Benefitted

Pacific coast population of the Western Snowy Plover (*Charadrius nivosus nivosus*); threatened status under U.S. Endangered Species Act.

Threats to Shorebirds at Site

Predation of eggs and chicks by native (e.g., corvids) and invasive (e.g., *Vulpes vulpes*) predators.

Actions Taken to Improve Habitat for Shorebirds

Across the range of the listed population of the Snowy Plover, predation of eggs and chicks is the single most important factor compromising reproductive success, population growth, and recovery. Managers have used lethal and non-lethal methods to reduce predation, with the aim of increasing productivity. One criterion for delisting the species requires greater than or equal to 1.0 fledged chicks per male for 5 years.

Accordingly, an array of non-lethal and lethal methods has been used to address threats posed by predators, especially Common Ravens (*Corvus corax*). This intelligent omnivore has expanded its range and population in human-altered landscapes where food is abundant. Ravens incidentally consume plover eggs and chicks during normal foraging for other food items.

Several types of predator management exist:

1. **Habitat Management.** Habitat modification can enhance the crypsis of eggs and chicks, or increase the detection of predators by plovers. Along the Pacific coast, introduced European beachgrass (*Ammophila arenaria*) has altered the extent and quality of habitats favored by plovers for breeding. Plovers favor open viewscapes to detect predators early and leave the nest or chicks hidden by cryptic habitat features, but *Ammophila* occurs in dense stands that preclude this nesting behavior. Prior to the breeding season, spraying with herbicide or removing *Ammophila* mechanically restores the "openness" of habitats favored by plovers, with the result that plovers often nest in restored areas. Adding natural debris (e.g., oyster shells) to habitats increases crypsis afforded eggs and chicks.
2. **Managing Humans.** Humans may unknowingly provide attractants (e.g., food) to corvids and, hence, increase the likelihood of corvids depredating plover eggs and chicks. Educational signage where plovers breed is often used to decrease the likelihood that humans may leave attractants (e.g., food, trash) that draw scavengers to areas hosting nests and broods. Restricting access via roped fencing may also keep humans at a distance (>50-100 m) that minimizes disturbance of incubating or brooding adults, which may attract predators.

Depredated Snowy Plover clutch with Common Raven tracks at the nest cup. *Photo credit: EJ Feucht.*

3. **Non-lethal and lethal management of predators.** Non-lethal and lethal methods can reduce the abundance or alter the behaviors of predators. Diverse approaches have been used to manage the behavior and populations of predators. The non-lethal methods include:
   - exclosures (of varying design) that protect eggs but don't address the issue of whether the same egg predators also prey on nidifugous chicks
   - scare tactics or effigies of ravens that alter corvid behavior and abundance near breeding plovers; this effect is often localized
   - conditioned taste aversion using chemicals (e.g., carbachol) injected into eggs painted to mimic plover's, with the notion that individual predators will learn to avoid eating eggs
   - trap/hold/translocate predators that have a strong negative effect on a local population; this requires targeting "offending" individuals
   - lethal methods (e.g., poison, trap, shoot) that humanely kill offending predators and/or reduce their local abundance, with concomitant reduction in egg or chick predation and, therefore, increased productivity.
4. **Captive propagation.** The captive propagation of plovers is the only direct way to bolster plover population size via increased productivity; it is, however, expensive and labor intensive. This requires a nearby facility and expertise to rear young, as well as a location to

release juveniles in the presence of conspecifics, which increases their survival probability.

Approaches 1 through 3 increase plover productivity through means objectives in that the management of habitat, humans, and predators is linked to an increase in per capita reproductive success, which drives population growth.

Outcomes

Predator management varies greatly across the plover's range.

1. **Habitat management.** Habitat restoration, including addition of shells, attracted breeding plovers, and enhanced their reproductive success, especially in areas where Common Raven activity is low, or lethal and non-lethal predator management methods are also used (Dinsmore et al. 2014, 2017).
2. **Managing humans.** In Southern California, restricted access to beaches and education provided by docents produced breeding activity at a site hosting wintering plovers (Lafferty et al. 2006).
3. **Non-lethal and lethal management of predators.**
   - Exclosures offer short-term increases in hatching success but don't necessarily increase fledging success if the same predators of eggs prey on chicks. Exclosures may occasionally result in elevated mortality of incubating adults, which should result in immediate cessation of use.
   - Scare tactics reduce Common Raven activity in a very limited area; intelligent predators may learn that effigies are harmless (Peterson and Colwell 2014).
   - Conditioned taste aversion reduces egg predation in localized settings for short intervals by specific individuals, which best facilitates success when territorial pairs ward off conspecifics (Brinkman et al. 2018). Using this method to reduce predation on chicks is untested.
   - Trap/hold/translocate may be effective with especially problematic predators, but it requires targeting the offending predator and a facility to hold the individual until plovers finish breeding. Translocated predators likely return quickly to their home range.
   - Where lethal methods have been practiced results are mixed. A combination of lethal and non-lethal methods has increased productivity in the northern extent of the plover's Pacific coast range, with one nearby population (northern California) showing a steady increase owing to immigration (Colwell et al. 2017). Alternatively, where non-lethal or no management is practiced, productivity often remains well below the delisting criterion of 1.0 fledged chicks per male over 5 years.
4. **Captive propagation.** When eggs are readily available (i.e., from abandoned clutches), captive rearing may increase plover productivity (Newmann et al. 2013).

Advice/Precautions

Locally abundant predators may render other management practices (i.e., restoration) ineffective. Managers should employ a well-organized protocol of indexing predator activity, documenting causes of reproductive failure, and monitoring per capita reproductive success of plovers to enable adaptive management. Despite evidence that 1) predators compromise population growth and 2) management can reverse negative impacts of predators on plover productivity, the decision to proceed with lethal methods of control may be hindered by public opinion as expressed in diverse ethical perspectives.

1. **Habitat management.** Plovers respond to removal of Ammophila by nesting in restored habitats, and productivity may be enhanced by the spread of oyster shells that provides increased clutter that enhances crypsis of eggs and chicks. Continued hand pulling of re-sprouted Ammophila may be necessary for years after initial removal.
2. **Managing humans.** Changing the behavior of humans through education is time consuming and challenging, and most productive with children. Restricting access to plover breeding areas may cause resentment and run counter to the educational objective of encouraging valuation of plovers. Enforcement of localized closures is often necessary to effect a reduction in human disturbance of plovers.
3. **Non-lethal and lethal management of predators.** The approach to predator control should weigh logistics/costs, effectiveness of method, and ethical considerations such as the degree of suffering imposed on predators. Humane lethal methods that target "offending" individuals should be undertaken after non-lethal methods are explored.
4. **Captive propagation.** This approach requires a rearing facility, expertise, and social environment to release juveniles with conspecifics such that their survival probabilities are increased. Results are improved when

soft release occurs such that juveniles integrate into non-breeding flocks and benefit (i.e., reduced predation; enhanced foraging) from association with conspecifics.

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CASE STUDY

Managing Impoundments for Multiple Species at the Sherburne Wildlife Management Area

Stilt Sandpipers and Black-necked Stilts on margins with duck forage growing in background. *Photo credit: Jason Olszak.*

LOCATION: Sherburne Wildlife Management Area, Iberville Parish, Louisiana, USA.

AUTHOR: Jason Olszak, Wetland Bird Specialist, Louisiana Department of Wildlife and Fisheries

LAND OWNERSHIP: Impoundments are owned by the U.S. Army Corps of Engineers and managed by the Louisiana Department of Wildlife & Fisheries.

Focal Habitats

» Managed Impoundments—Fresh

Habitat Goal

To improve forage production for wintering waterfowl, while implementing management actions that simultaneously create habitat for migrating shorebirds (July through November).

Species Benefitted

Black-necked Stilt (*Himantopus mexicanus*), Least Sandpiper (*Calidris minutilla*), Lesser Yellowlegs (*Tringa flavipes*), Greater Yellowlegs (*Tringa melanoleuca*), Pectoral Sandpiper (*Calidris melanotos*), Wilson's Snipe (*Gallinago delicate*), Spotted Sandpiper (*Actitis macularius*), Stilt Sandpiper (*Calidris himantopus*), Killdeer (*Charadrius vociferus*), Long-billed Dowitcher (*Limnodromus scolopaceus*). These species are common and locally abundant when sufficient habitat conditions and timing coincide with shorebird migration. No threatened or species of high conservation concern are targeted because few individuals of those species pass through.

Threats to Shorebirds at Site

Habitat for common southbound shorebirds is limited in the Lower Mississippi Alluvial Valley (MAV) for two main reasons; 1) Shallow surface water is limited in summer and, 2) where it does occur, these wetlands are often dominated by dense vegetation. The first southbound shorebirds arrive in Louisiana in late July and new birds continue arriving until November. Turnover rates are high, approximately 10 days for Pectoral Sandpipers (*Calidris melanotos*) and 4 to 7 days for Least Sandpipers (*Calidris minutilla*), and suitable habitat is short-lived (Lehnen and Krementz 2005, Lehnen and Krementz 2007).

Encroachment of open areas within impoundments by robust, noxious vegetation and deliberate production of annual grasses and sedges for wintering waterfowl forage reduce the availability of open, shallow-water shorebird habitat. In the southern MAV, impoundments are generally passively managed by winter flooding to depths between 15 – 46 cm (6 – 18 inches) followed by drawing down water in the spring or summer. Over time, this results in the establishment of dominant stands of perennial emergent vegetation including genera *Zizaniopsis, Alternanthera,* and perennial *Polygonum*, and woody vegetation such as *Cephalanthus, Salix,* and *Triadica*. Consequently, the amount and quality of habitat is degraded and both waterfowl and shorebird use declines. However, actions that reduce undesirable annual competition and set back perennial dominance to a state of primary succession (i.e. bare dirt), increase the productivity of beneficial annual plants. These actions also help create ideal shorebird habitat.

Actions Taken to Improve Habitat for Shorebirds

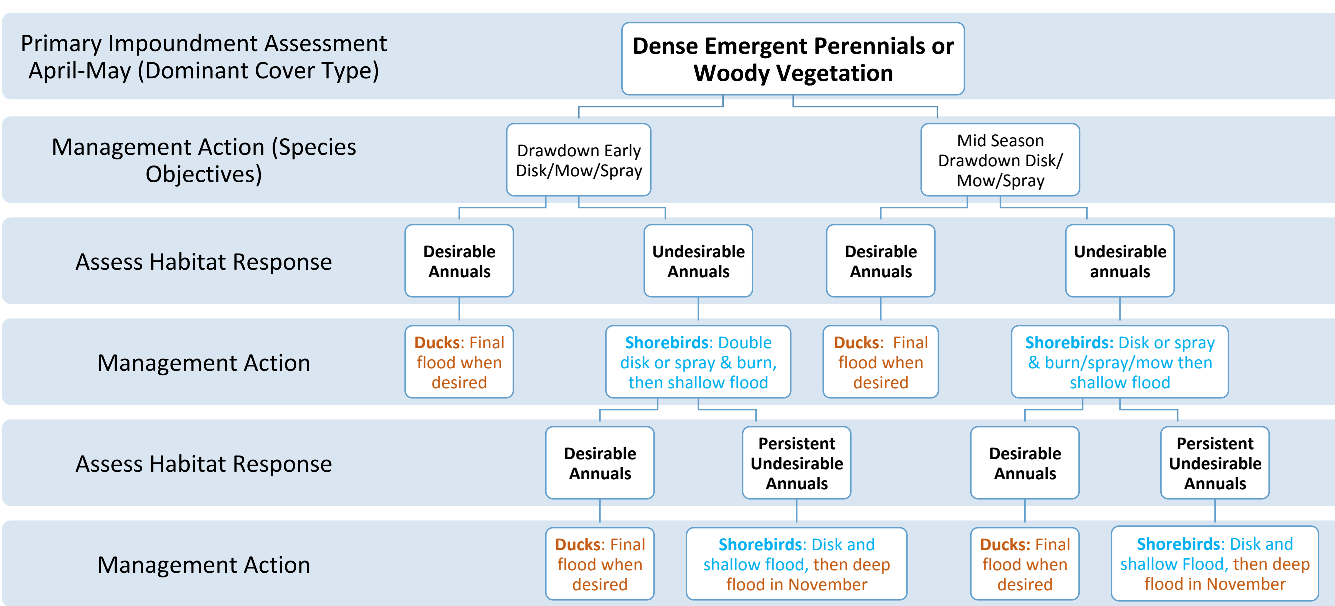
To better track and inform management activity at Sherburne WMA, a dichotomous decision strategy is used. Through recurrent assessment and adaptive response, this key serves as a guide to choose management actions that increase the impoundments' carrying capacity for waterfowl while also creating habitat for southbound shorebirds.

Before growth commences in the spring, while impoundments retain water from the previous winter, individual units are assessed for their upcoming fall waterfowl habitat potential. Initial impoundment conditions are classified into two categories: **vegetated** and **open water**.

STRATEGY 1

Impoundments **vegetated** with substantial perennial herbaceous or woody cover are scheduled for active management, which includes vegetation management and/or soil disturbance. Wetland units may be dewatered any time before July to ensure dry enough conditions for machinery. Vegetation density determines the initial treatment. Especially tall and dense stands get an herbicide treatment, and perhaps a burn before being mowed or disked. Less dense stands require only mowing or herbicide alone. Disking, if necessary, would be the final step. The addition of shallow water (preferably by precipitation) then promotes growth of annual moist-soil tolerant plants. If accomplished later than July the resulting mudflat is useable for roughly about ten days by southbound migrating shorebirds until rapid vegetative growth degrades

Example of Generalized Dichotomous Decision Strategy 1



its suitability. If preferred waterfowl forage plants dominate the response, continued growth is permitted, and the impoundment is fully flooded in late-October or early-November for the arrival of wintering waterfowl. However, because vegetative response is often unpredictable, regular monitoring is necessary after disking so that action can be taken if non-desirable plants dominate. In this case, the impoundment can be drained again, and the young growth can be mowed and/or disked before being shallowly re-flooded. If water cannot be removed promptly, aerial application of herbicide is used to kill unwanted vegetation. These actions result in additional time for exploitation by a later arriving cohort of shorebirds.

STRATEGY 2

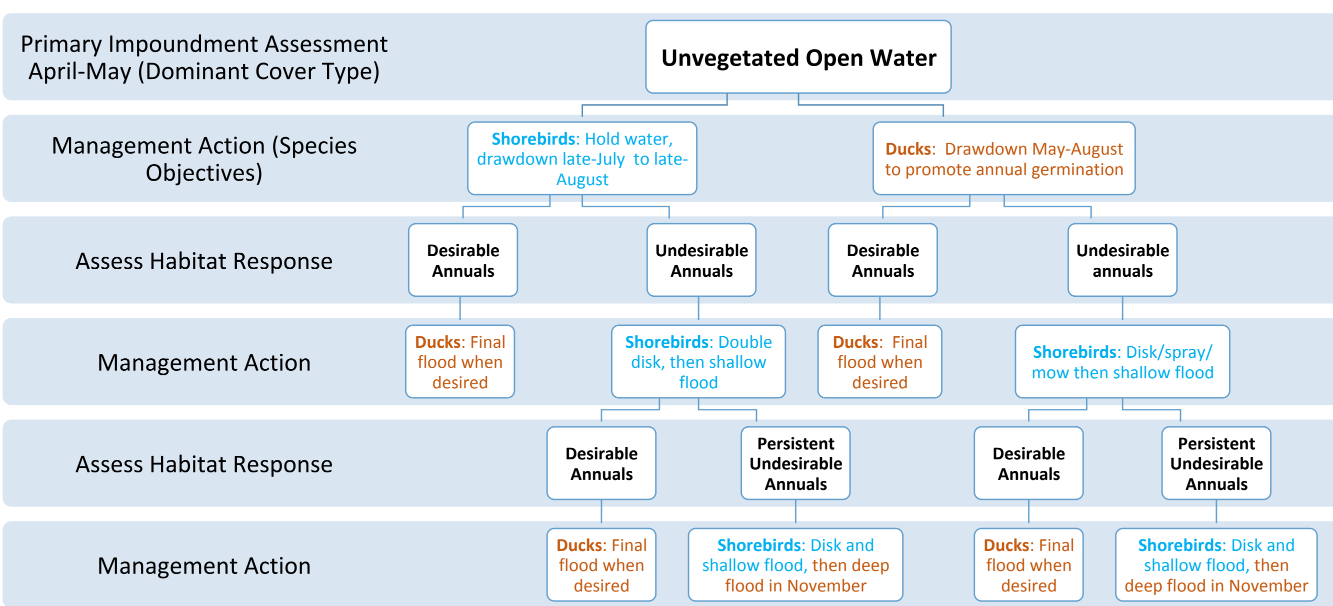
If impoundments are dominated by **open water** during spring assessment, no initial soil disturbance is necessary. This passive management strategy is employed initially, allowing dewatering to be delayed until mid to late-July or even August. Additional benefits of summer drawdown as opposed to adding water to a disked field include a higher abundance of benthic invertebrates. Late spring and early summer water provides the opportunity for recreational crawfishing, concentrates prey for nesting wading birds, and impedes encroachment of woody vegetation. Upon drawdown, mudflats materialize in early August and annual vegetation begins to flourish in this early successional state. Regular monitoring then determines whether active management is required. As with the vegetated category, plant species favorable to wintering waterfowl are left to grow to maturity but impoundments dominated by undesirable vegetation are treated chemically or mechanically to set back succession -- creating more shorebird habitat during later migratory periods in August or September.

Vegetative response to soil manipulation can include non-desirable annuals that must be identified and removed regularly. *Photo credit: Jason Olszak.*

Outcomes

Active moist-soil management is an inherently costly endeavor, but the costs of annual management are less than the costs of reclamation once dense emergent or

Example of Generalized Dichotomous Decision Strategy 2



Costs of common wetland management actions based on 2018 Louisiana Environmental Quality Incentives Program (USA) rate estimates. Annual active management costs less than periodic reclamation activities. Note that expenses are in $USD.

Activity	Cost/Acre	Cost/Hectare	Management Activity
Mow	$34.84	$86.09	Active Management
Prescribed Burn	$35.30	$87.23	Active Management
Disk	$35.95	$88.83	Active Management
Clear shrub; mechanical chopper/ cutter	$41.61	$102.82	Reclamation
Herbicide; Broadcast application	$45.10	$111.44	Active Management
Herbicide; Aerial application	$99.27	$245.30	Active Management
Herbicide; Shrubs - Cut and Squirt	$203.55	$502.98	Reclamation
Dozer; clear and pile	$417.93	$1,032.73	Reclamation
Remove brush and trees <15.24 cm (6 in)	$1,048.05	$2,589.78	Reclamation
Remove brush and trees >15.24 cm (6 in)	$2,055.52	$5,079.29	Reclamation

woody vegetation dominate an impoundment. Aside from regularly producing poor stands of waterfowl forage, passively managed units often result in small, spotty mudflat areas surrounded by tall, thick vegetation. In these conditions, shorebird use at Sherburne WMA was often low in number and species richness. Moving from passive to active management achieved both goals: it produced greater quality waterfowl forage and created mudflat habitat for migrating shorebirds July through November.

Advice/Precautions

Shorebird habitat is maximized when entire units are treated. However, spot treatment can be carried out when sizeable patches of undesirable vegetation exists within an impoundment dominated by preferred vegetation.

Because the growing season in southern Louisiana persists from March to October, the creation of moist-soil conditions for plant germination can take place as late as September and still produce a mature stand of annual grasses and sedges. This provides the opportunity to manipulate soil during peak shorebird migration, though species affected will differ depending on the timing.

There are a variety of reasons why best planned management actions don't always result in desired effects. If either strategy (or lack of any management) results in a unit dominated by unwanted vegetation in October, rather than letting these plants mature and add seed to the soil for subsequent years, it should be mowed or disked, then shallowly flooded for late shorebird migrants and early migrating waterfowl that use open, shallow water such as teal, Northern Pintails (*Anas acuta*), and Northern Shovelers (*Anas clypeata*). Since the existing vegetation had little value as waterfowl forage there is no net loss to primary waterfowl objectives and the impoundment would follow Strategy 2 the following spring.

Oftentimes, preferred grasses germinate together with unwanted broad leaf annuals such as *Xanthium strumarium* and *Sesbania herbacea*. Rather than mechanical disturbance, a broadleaf herbicide can be applied to release the desirable grasses from competition.

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Passively managed impoundments are invaded by woody vegetation rapidly. *Photo credit: Jason Olszak.*

CASE STUDY

Ensuring No-shooting Swamps in Barbados

View of managed impoundments on Barbados. *Photo credit: Eric Reed*

LOCATION: Swamps on Barbados

AUTHOR: Brad Andres, Atlantic Flyway Shorebird Initiative Harvest Working Group Co-Chair, U.S. Fish and Wildlife Service (based largely on Wege et al. 2014)

LAND OWNERSHIP: Privately owned by paying members

Focal Habitats

» Managed Impoundments—Fresh

Both shooting and no-shooting swamps provide habitat in diked impoundments that are mechanically prepared and flooded to provide shallow water that attracts southbound migrating shorebirds. For example, at Woodbourne Shorebird Refuge, preparation of shorebird feeding areas involves scraping vegetation (when it is dry enough to do this by tractor) from the previous season. Vegetation is sprayed with herbicide and manure is applied before 15 July. Vegetation removal followed by spraying uses less herbicide and reduces the fire hazard from dry, dead vegetation. Banks between the various ponds are mowed every month; these short-grass banks are favored by American Golden-Plover (*Pluvialis dominica*). Management of Woodbourne differs from the other swamps because they apply mulch and manure in the feeding areas to increase densities of macro-invertebrates which leads to high density use by shorebirds. The ponds are all stocked with fish. One pond is kept with deep water to maintain a fish population from which the other ponds are restocked each year as soon as water levels are high enough to sustain them. The fish eat the larvae of *Aedes aegypti* mosquitos, the vector for dengue fever, which the Ministry of Health checks for on a regular basis.

Habitat Goal

Providing shooting-free reserves in areas where shorebird harvest occurs is a viable strategy to reduce mortality. The objective is to ensure no-shooting swamps, such as the Woodbourne Shorebird Refuge, that are consistently maintained to benefit shorebirds and to increase the number of no-shooting reserves on the island. Beyond fee-title acquisitions, easements, leases or designations, there is a critical need to support the long-term maintenance of reserves.

Species Benefitted

Six species have consistently comprised the majority of the shorebird harvest on Barbados: Lesser Yellowlegs (*Tringa flavipes*, 54-67% of the harvest), Pectoral Sandpiper (*Calidris melanotos*, 11-23%), Stilt Sandpiper (*Calidris himantopus*, 6-8%), Short-billed Dowitcher (*Limnodromus griseus*, 4-11%), Greater Yellowlegs (*Tringa melanoleuca*, 3-7%), and American Golden-Plover (1-6%). These species, and an additional 12 species (some present in small numbers), would benefit from additional no-shooting reserves, including Black-bellied Plover (*Pluvialis squatarola*), Semipalmated Plover (*Chadrius semipalmatus*), Spotted Sandpiper (*Actitis macularius*), Solitary Sandpiper (*Tringa solitaria*), Ruddy Turnstone (*Arenaria interpres*), Red Knot (*Calidris canutus*), Semipalmated Sandpiper (*Calidris pusilla*), Western Sandpiper (*Calidris mauri*), Least Sandpiper (*Calidris minutilla*), White-rumped Sandpiper (*Calidris fuscicollis*), Long-billed Dowitcher (*Limnodromus scolopaceus*), Wilson's Snipe (*Gallinago delicata*).

Threats to Shorebirds at Site

Shorebird hunting began soon after Barbados was colonized by the British in 1627 and was mainly an opportunistic harvest of large shorebirds (such as Eskimo Curlew and Upland Sandpiper) stopping over in the wet depressions of harvested or fallow sugar cane fields. The 1800s saw the structured development of shorebird hunting in Barbados through the establishment of shooting swamps where diked impoundments were actively managed to attract migrating shorebirds. At its peak, Barbados supported at least 20 active shooting swamps, each with 5-10 active hunters. In the 1960s and 70s, harvest averaged about 15-20,000 individuals and exceeded 40,000 shorebirds in one year. More recently (2001-2009), harvest ranged from 19,000 to 30,000 shorebirds for all active shooting swamps.

Habitat provided at the Woodbourne Shorebird Refuge.
Photo credit: David Wege.

Actions Taken to Improve Habitat for Shorebirds

In 1981, the Barbados Wildfowlers Association (BWFA) was established by a founding group of about 40 hunters, and in 2014 the membership was about 80 individuals. Prior to 2010, the BWFA had begun to proactively set bag limits on certain shorebirds species, In 2010, the Association agreed to release shorebird harvest information to outside sources for the first time. After an objective analysis of hunting data conducted by the Canadian Wildlife Service, the BWFA passed a series of resolutions to voluntarily regulate shorebird hunting, starting in 2012. Although not binding to all shooting swamp members, these recommendations included:

- limiting gross annual harvest on the island to 22,500 birds
- allowing no more than 2,500 birds shot per swamp each year
- shooting no more than 300 birds in a given day per swamp
- limiting the Lesser Yellowlegs harvest per swamp to 1,250 birds annually
- restricting the shooting of American Golden-Plovers to 100 birds in any swamp on any given day
- no use of extension magazines

» restricting the number of hunters to three at one time. These recommendations were based on the premise that there were 10 active shooting swamps on the island.

In 2009, the Woodbourne shooting swamp shifted management to a no-shooting reserve and became the Woodbourne Shorebird Refuge. In 2015, the owners of the Congo Road Swamp banned hunting and continued to maintain water levels, providing a second no-shooting reserve on the island.

Outcomes

Shooting swamps have declined due to rising costs of maintaining wetland habitats, increased gun possession restrictions, decreasing interest in hunting by the younger generation, and a desire to provide no-shooting reserves. Eight shooting swamps were active in 2013 and six were active in 2016. Because of the reduced number of shooting swamps, adherence to the recommendations of the BFWA, and some uncontrollable events such as weather, ammunition cost, and gun policy, the shorebird harvest trend this decade (between 2010 and 2020) is approximately 40–63% of the harvest of the last decade.

Advice/Precautions

In a landscape now mainly devoid of natural wetlands, the artificially-maintained and managed network of shooting swamps on Barbados provides habitat for many non-target waterbirds for at least part of the year, with some swamps being maintained to provide year-round habitat. The shooting swamps represent important components of the island's wetland network, but they exist solely as a result of shooting-specific management actions. Cost for the maintenance of no-shooting reserves will continue to be a challenge into the future. Without the ability to pump water, the vagaries of weather can reduce the ability to provide consistent shorebird foraging habitat. Demands for other uses of scarce water resources will compete with shorebird and waterbird conservation uses.

The collaborative, non-confrontational approach between conservationists and local hunters has started to demonstrate its potential for significant returns in the survival prospects of shorebirds. Additional refuges for shorebirds and the establishment and adherence to bag limits on species of concern will ensure that Barbados earns a reputation as a haven for passage shorebirds rather than be discredited with notoriety as one of the places where shorebirds are shot. Towards this end, some of the hunters must be commended for starting to release data to BirdLife International for analysis by the Canadian Wildlife Service. This signals a most welcomed locally driven change from unexamined resource consumption to data-informed resource conservation. In the long term, this transparent alliance will benefit all. Not least, the magnificent flights of shorebirds.

LITERATURE CITED

Wege. D.C., W. Burke and E.T. Reed. 2014. Migratory shorebirds in Barbados: hunting, management and conservation. BirdLife International, Unpublished report submitted to U.S. Fish and Wildlife Service, Migratory Bird Program, Falls Church, Virginia, USA.

CASE STUDY

Aramburu Island Enhancement Project

Least sandpipers (*Calidris minutilla*). *Photo credit: Joey Negreann*

LOCATION: Aramburu Island, Richardson Bay, CA, USA

AUTHORS: Julia Kelly, PhD and Danielle Montijo, National Audubon Society

LAND OWNERSHIP: Marin County, California

Focal Habitats

» Coastal Tidal Wetlands—Estuarine

» Coastal Tidal Wetlands—Marine

The enhancement project has protected and improved tidal mudflat and marsh habitat, a freshwater vernal pool, sand and gravel beaches, oyster reef habitat, high tidal marsh, seasonal wetlands, and coastal grasslands in the northern part of California's San Francisco Bay.

Habitat Goal

The main goals of the Aramburu Island Enhancement Project are to reduce erosion of the nearly 7 hectare (17 acre) island's eastern shoreline, create wetland and terrestrial habitat to support a range of target species and natural communities, and to provide a platform for enhancing resilience to sea level rise. For birds, the project's target species included shorebirds, waterfowl, and wading birds.

Reducing erosion of the island's eastern shoreline will improve habitat in the long term and help enhance the island's resilience to sea level rise. Instead of using traditional "hard" methods (i.e., using rock rip-rap to armor shoreline), the Aramburu Island Enhancement Project used "soft" engineering methods to fix erosion, by establishing healthy tidal marsh vegetation and using large woody debris.

The Aramburu Island Enhancement Project has also created a number of new wetland and terrestrial habitats and improved pre-existing habitats. The project enhanced tidal mudflats and marshes, haul out areas for harbor seals, and habitat for rare salt marsh plants. A variety of habitats once prevalent in Richardson Bay, including sand and gravel beaches, high tidal marsh, seasonal wetlands, and coastal grasslands were successfully re-established.

Species Benefitted

The project has benefitted a variety of shorebirds that use the island for resting, foraging, and nesting, including the Black bellied Plover (*Pluvialis squatarola*), Semipalmated Plover (*Charadrius semipalmatus*), Killdeer (*Charadrius vociferus*), Black Oystercatcher (*Haematopus bachmani*), Black-necked Stilt *(Himantopus mexicanus*), American Avocet (*Recurvirostra americana*), Greater Yellowlegs (*Tringa melanoleuca*), Spotted Sandpiper (*Actitis macularius*), Long-billed Curlew (*Numenius americanus*), Marbled Godwit (*Limosa fedoa*), Willet (*Tringa semipalmata*), Ruddy Turnstone (*Arenaria interpres*), Black Turnstone (*Arenaria melanocephala*), Sanderling (*Calidris alba*), Dunlin (*Calidris alpina*), Least Sandpiper (*Calidris minutilla*), Western Sandpiper (*Calidris mauri*), Long-billed Dowitcher (*Limnodromus scolopaceus*), Short-billed Dowitcher (*Limnodromus griseus*), Red-necked Phalarope (*Phalaropus lobatus*), and Wilson's Snipe (*Gallinago delicata*).

Threats to Shorebirds at Site

Before the enhancement project took place, the island's shoreline had been eroded and there was no transition from mudflat to upland habitat. Shorebirds lacked foraging options during high tide when the mudflats became inundated and inaccessible. The island essentially lacked an intertidal zone, the habitat that species like Black Oystercatchers require. Prior to implementation of the enhancement project, Aramburu had been largely overrun with non-native, invasive plants that provided poor habitat and food resources. The island was threatened by projected moderate sea-level rise and erosion of the island's margins.

Actions Taken to Improve Habitat for Shorebirds

The island's eastern shore originally had an abrupt, unstable divide between uplands and intertidal habitats, which had no significant resilience to storm wave impacts and sea level rise and did not provide adequate foraging or high-tide roosting habitat for shorebirds. Phase 1 of construction lasted 5 weeks between August and September 2011 and Phase 2 was completed during fall of 2012. A gentle ramp-like backshore profile was created that used coarse beach sediment and micro-groins to maximize potential buffering of wave erosion by beaches, increase residence time of beach materials, and improve foraging and roosting habitat functions for shorebirds. Micro-groins were constructed out of natural, soft material including eucalyptus logs and rocks embedded in the mud. This transformed the island from a wave-reflecting to wave-dissipating profile, providing the foundation for native vegetation and intertidal habitats associated with the renovated shoreline. These modifications are expected to allow the island habitats to adapt to forecasted sea level rise. This new un-vegetated linear substrate provides attractive supratidal roost habitat for shorebirds when they are flooded off mudflats at high tide.

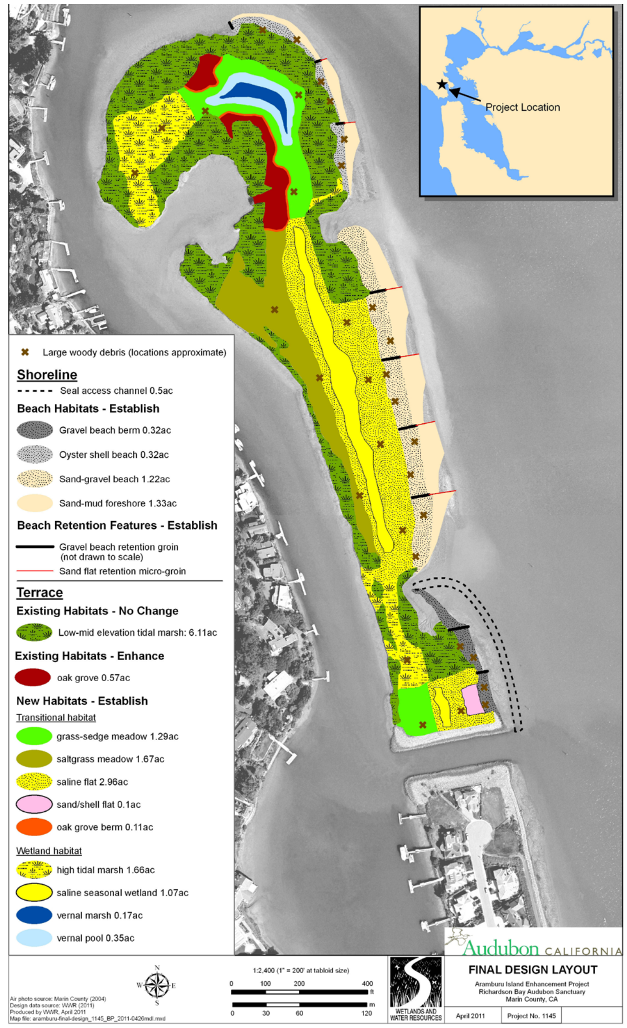
Micro-groins on Aramburu Island. *Photo credit: Julia Kelly.*

Large woody debris (LWD) was placed in various locations along the shoreline. This provides perching and roosting habitat for herons and egrets, and also provides habitat structure for aquatic plants, invertebrates, and fish when submerged. Rock micro-groins were installed to provide hard substrate for sessile marine invertebrates such as native oysters and mussels, which serve as prey for some shorebirds. Habitats on the island terrace including seasonal wetlands, salt pans, and transitional grassland areas were also enhanced to provide additional foraging, roosting, and nesting habitats for shorebirds, as well as ducks and wading birds.

Outcomes

Enhancement activities have created nearly 7 hectares (17 acres) of new habitat and significantly reduced non-native vegetation coverage on the island. Beach creation on the San Francisco Bay has resulted in enhanced shorebird habitat, and evolution of new shorebird habitats, including breeding habitat. Prior to restoration activity, non-native vegetation accounted for 75% of the island's vegetation community, but now covers less than 5% of its expected zone of colonization. The new beach and low-angle shore transformed the island from a wave-reflecting to wave-dissipating profile, promoting gradual beach development rather than progressive erosion. These modifications are expected to allow the island habitats to adapt to forecasted sea level rise for the coming decades with a succession of valuable transitional intermediate habitats, rather than the progressive erosion of the island and the limited habitat value to priority wildlife species that would have remained.

Since 2013, thousands of shorebirds have been observed foraging, resting, and roosting on the island. A drastic increase in resting and foraging behavior on the new beach suggests that the new shoreline is providing high-quality habitat. In 2014, Aramburu became 1 of only 4 known successful nesting sites for Black Oystercatchers within the San Francisco Bay. Black-necked Stilts and Killdeer have also hatched successful nests on Aramburu. The average abundance of birds on Aramburu at both high and low tides has increased, according to bird survey data.



Aramburu project design map

Advice/Precautions

To ensure longevity of enhanced, newly installed beaches, installed log groins need to be completed with interwoven dense branches to be effective impediments to longshore drift of sand and shell in the beach-face. Log groins should be carefully placed to ensure closely spaced stable pockets of beach accretion. Mixed beaches are more resilient than predominantly sand and shell beaches in settings with high potential longshore drift. Using soft shoreline stabilization techniques such as boulders and micro-groins allows bay beaches to self-construct, reduces erosion rates, and provides functional transitional habitats. Due to budget limitations, we are not able to perform annual upkeep on the shoreline, but we have found it effective to focus on continuing native plant restoration at the site.

CASE STUDY

Year-round Habitat at Cape Romain National Wildlife Refuge

Northbound shorebirds at the Cape Romain National Wildlife Refuge. *Photo Credit: Sarah Dawsey.*

LOCATION: Cape Romain National Wildlife Refuge, South Carolina, USA

AUTHOR: Sarah Dawsey, Refuge Manager, US Fish and Wildlife Service

LAND OWNERSHIP: Public, Federal Government

Habitat Types

- Coastal Tidal Wetlands—Estuarine
- Coastal Tidal Wetlands—Marine

Stretching for 22 miles along the coast of South Carolina, the Cape Romain National Wildlife Refuge includes barrier islands, long sandy beaches, dense maritime forest, fresh and brackish impoundments, emergent salt marsh, oyster bars, and mud flats.

Species Benefitted

American Oystercatcher (*Haematopus palliatus*), Sanderling (*Calidris alba*), Ruddy Turnstone (*Arenaria interpres*), Black-bellied Plover (*Pluvialis squatarola*), Dunlin (*Calidris alpina*), Short-billed Dowitcher (*Limnodromus griseus*), Western Sandpiper (*Calidris mauri*), Willet (*Tringa semipalmata*), Semipalmated Plover (*Charadrius semipalmatus*), Least Sandpiper (*Calidris minutilla*), Red Knot (*Calidris canutus*), Piping Plover (*Charadrius melodus*), Marbled Godwit (*Limosa fedoa*), Wilson's Plover (*Charadrius wilsonia*), Whimbrel (*Numenius phaeopus*), Long-billed Curlew (Numenius americanus), Spotted Sandpiper (*Actitis macularius*), Greater Yellowlegs (*Tringa melanoleuca*), Lesser Yellowlegs (*Tringa flavipes*), Pectoral Sandpiper (*Calidris melanotos*), Stilt Sandpiper (*Calidris himantopus*).

Habitat Goal

Provide year-round habitat for foraging, resting, roosting, and nesting shorebirds and seabirds.

Threats to Shorebirds at Site

Human disturbance, predation, declining horseshoe crab populations, and loss of habitat from sea level rise are some of the top threats to shorebirds at the refuge.

Actions Taken to Improve Habitat for Shorebirds

The refuge has a management plan in place and uses multiple strategies to reduce threats and improve habitats for shorebirds. We address the following threats with the associated strategies.

1. **Human Disturbance—**Finding a balance between providing public access and protecting wildlife is a priority. The refuge is only accessible by boat, so a contracted concessionaire service provides access to many areas in the refuge. The general public, schools, and the private business contracted to transport people to the barrier islands in the refuge are informed about bird use of the region. We have recently started training volunteers to be bird stewards that are stationed at the boat landings or at the nesting colonies to improve awareness and education.

   Two barrier islands, one with the highest density of nesting birds and one other, are closed and no boat landing is allowed on these islands from February 15 to September 15 to protect nesting and migrating birds. On other barrier islands, areas used less frequently by shorebirds are open for walking and other recreation, but the ends of islands and other sensitive areas are closed during the nesting season. We also encourage increased law enforcement efforts to deter illegal dogs and human disturbance.

   All-Terrain Vehicles (ATVs) are used by staff and volunteers to monitor sea turtle nesting. To reduce disturbance to nesting shorebirds and/or potential shorebird chick mortality, the refuge implements best management practices developed by the South Carolina Department of Natural Resources (SCDNR) for ATV use during the shorebird nesting season. These practices include but are not limited to:

   » Drive the ATV as low on the beach as possible. Do not drive above the daily wrack line.

   » Maximum speed should not exceed 10 miles per hour to allow time to observe and avoid adults and young.

   » Do not drive over objects such as wrack, sticks, limbs, grasses, large shells, boards, bottles, cans, or other objects where a chick could be hiding.

   » Do not drive around the ends of islands where bird nesting is typically concentrated and turtle nesting is typically low. Stop prior to the end and send an experienced individual on foot with binoculars to identify any turtle activity. If a turtle nest is observed, retrieve any sample needed quickly to reduce the duration of disturbance to birds.

   » Sections of the beach with the highest concentrations of nesting American Oystercatchers and Wilson's Plovers should be identified at the beginning and end with a highly visible post or other marker. The speed limit in this area should not exceed 5-10 miles per hour and extra care should be taken to avoid chicks and adults.

   » Identify shorebird nest sites with bright colored flags. Place flags 274 meters (300 yards) before and after nest sites to avoid flushing incubating birds. Estimate hatch dates of shorebird nests to increase awareness of the presence of roaming chicks.

2. **Predator Management—**Predator abundance is reduced through trapping. Most common predators trapped are raccoon, mink, and coyote if needed. Trapping generally occurs outside of the bird nesting season to prevent accidental capture of birds. This works well for raccoon, but mink are more transient and it is more effective to trap them closer to the bird nesting season. This is also true for coyote as they are difficult to catch; waiting until they are focused on a particular area and prey will increase the likelihood of successfully catching them.

3. **Horseshoe Crab Population—**To protect vital shorebird food resource supplies, the refuge has worked with the SCDNR since 2015 to enforce restrictions on horseshoe crab harvest in high shorebird use areas. However, this is a complex issue. The water and water bottoms in the refuge are owned by the State. The refuge has a lease on the water areas with the exception of finfish, shellfish and other salt water species. This makes the refuge unable to manage the horseshoe crab harvest directly.

4. **Monitoring—**Comprehensive surveys of birds and their use of the refuge are conducted annually.

5. **Sea-Level Rise—**The refuge is currently looking into ways to improve resilience to sea level rise through thin layer sediment deposition on marshes, oyster restoration,

and habitat creation for nesting birds -- but is not yet implementing these actively.

Outcomes

We have found that this suite of management actions has created undisturbed areas in the refuge for shorebirds to forage, rest, and nest. Many management strategies have been in place for decades, such as the prohibition of dogs (not described here) and seasonal island closure. Enforcement of all regulations and rules on the refuge has come under pressure as growing nearby human populations and visitation to the refuge has increased. Sufficient staff capacity to enforce regulations has been a limiting factor.

1. **Human Disturbance—**Working with the contracted concessionaire is an opportunity to educate visitors before they arrive to the refuge's barrier islands. We are working more closely with the contracted concessionaire to educate the general public as they transport them to Bulls Island and lighthouses within the refuge. We have also been adding more informational signage for the public throughout the refuge to increase awareness about wildlife and their habitat needs. Recent efforts have included information about the impacts of disturbance into the environmental education curriculum. We are seeing an increase in visitor knowledge regarding the nesting birds on the refuge. While the voluntary bird steward program has just begun (2019), we think it will be very successful over time.
2. **Predator Management—**We have been trapping mammalian predators of eggs and chicks annually for seven years, which has helped to increase productivity of nesting shorebirds on some of the islands.
3. **Horseshoe Crab Population—**State permitted horseshoe crab harvesting was stopped in areas of highest shorebird use in 2015. This practice leaves more horseshoe crab eggs for shorebirds to forage on, and also reduces disturbance from the harvesting activity.
4. **Monitoring—**Through monitoring, we are seeing an increase in the successful nesting of shorebirds, and some increases for the colonial seabirds. Despite management efforts, there are things that we cannot manage for such as sea level rise and the subsequent increase of nest loss.

Refuge signs inform area users about seasonal island closures. *Photo credit: Sarah Dawsey.*

Advice/Precautions:

Almost everything done for conservation, with the exception of environmental education, can be interpreted as controversial in some way. Predator removal can be extra sensitive. It is vital to have an institutionally approved plan, and to keep it as internal as possible. Find allies in State partners to help implement and support needed management. Combining limited resources between regional partners can yield successful outcomes.

APPENDICES

Appendix 1. Flyway, country, and regional shorebirds plans

FLYWAY PLAN	PLAN TITLE	LINK
Atlantic Flyway	Atlantic Flyway Shorebird Initiative- A Business Plan	http://atlanticflywayshorebirds.org/documents/AFSI_Business_Plan_11_2017.pdf
Pacific Americas Flyway	Pacific Americas Shorebird Conservation Strategy	https://www.fws.gov/migratorybirds/pdf/management/PASCS_final_medres_dec2016.pdf
COUNTRY PLAN	**PLAN TITLE**	**LINK**
Brazil	Migratory Shorebird Brazilian Conservation Plan	http://www.icmbio.gov.br/portal/images/stories/docs-plano-de-acao/pan-aves-limicolas-migratorias/matriz-planejamento-aves-limicolas-versao-ingles.pdf
Canada	Canadian Shorebird Conservation Plan	https://waterbirds.org/wp-content/uploads/CW69-15-5-2000-eng.pdf
Colombia	Conservation Plan for the Shorebirds of Colombia	http://calidris.org.co/wp-content/uploads/2010/10/plan_aves_playeras_colombia.pdf
Ecuador	Plan de Conservacion Para Aves Playeras en Ecuador	http://avesconservacion.org/web/wp-content/uploads/2018/05/Plan-de-Conservaci%C3%B3n-para-Aves-Playeras-en-Ecuador-1.pdf
Mexico	Strategy for the Conservation and Management of Shorebirds and their Habitats in Mexico	NA
United States	United States Shorebird Conservation Plan	http://www.shorebirdplan.org/plan-and-council/
REGIONAL PLANS	**PLAN TITLE**	**LINK**
Alaska, USA	Alaska Shorebird Conservation Plan	https://www.fws.gov/alaska/mbsp/mbm/shorebirds/pdf/ascp_nov2008.pdf
North Pacific Rainforest, Canada	Bird Conservation Strategy for Bird Conservation Region 5: Northern Pacific Rainforest	https://www.ec.gc.ca/mbc-com/DF49C9A5-E2A7-466F-B06C-2DF69B0E0664/BCR-5-PYR-FINAL-Feb-2013.pdf
Puget Sound, USA	Nearshore Birds in Puget Sound	http://www.pugetsoundnearshore.org./technical_papers/shorebirds.pdf
Northern Pacific Coast, USA	Northern Pacific Coast Regional Shorebird Management Plan	http://www.shorebirdplan.org/wp-content/uploads/2013/01/NPACIFIC4.pdf
Southern Pacific Coast, USA	Southern Pacific Shorebird Conservation Plan	http://www.prbo.org/cms/docs/wetlands/SPSCPlan_010904.pdf
Northwest Mexico, Mexico	Shorebird Recovery Project in Northwest México	https://www.manomet.org/wp-content/uploads/old-files/Northwest%20Mexico%20Shorebird%20Recovery%20Plan_2009.pdf
Patagonia, Chile and Argentina	Recovery Plan for Shorebirds in Patagonia	https://www.manomet.org/wp-content/uploads/old-files/Patagonia%20Shorebird%20Recovery%20Plan_May2012.pdf
Panamá Bay	Conservation Plan for the Wetlands of Panamá Bay	NA
Ecuasal, Ecuador	Conservation Plan and Tourism Capacity Study for the Artificial Salt Lakes of Ecuasal, Santa Elena Province, Ecuador	NA
Chiloé, Chile	Conservation Plan for Migratory Shorebirds in Chiloé	NA

Appendix 2. Priority shorebird species listed in Migratory Bird Joint Venture Plans

MIGRATORY BIRD JOINT VENTURE	WEBSITE	PLANS AND PRIORITY LISTS THAT INCLUDE SHOREBIRDS	Black-necked Stilt *Himantopus mexicanus*	American Avocet *Recurvirostra americana*	American Oystercatcher *Haematopus palliatus*	Black Oystercatcher *Haematopus bachmani*	Black-bellied Plover *Pluvialis squatarola*	American Golden-Plover *Pluvialis dominica*	Pacific Golden-Plover *Pluvialis fulva*	Snowy Plover *Charadrius nivosus*	Wilson's Plover *Charadrius wilsonia*	Semipalmated Plover *Charadrius semipalmatus*	Piping Plover *Charadrius melodus*	Killdeer *Charadrius vociferus*	Mountain Plover *Charadrius montanus*	Upland Sandpiper *Bartramia longicauda*	Eskimo Curlew *Numenius borealis*	Whimbrel *Numenius phaeopus*	Long-billed Curlew *Numenius americanus*	Hudsonian Godwit *Limosa haemastica*	Marbled Godwit *Limosa fedoa*	Ruddy Turnstone *Arenaria interpres*	Black Turnstone *Arenaria melanocephala*	Red Knot *Calidris canutus*	Surfbird *Calidris virgata*	Stilt Sandpiper *Calidris himantopus*
Appalachian Mountains Joint Venture	http://amjv.org/index.php/	https://amjv.org/wp-content/uploads/2018/09/AMJV-Priority-Species.pdf										x				x										x
Atlantic Coast Joint Venture	http://acjv.org/	-																								
Canadian Intermountain Joint Venture	http://cijv.ca/	http://nabci.net/wp-content/uploads/CIJV-Implementation-Plan-2010_FINAL.pdf		x																						
Central Hardwoods Joint Venture	http://www.chjv.org/	-																								
Central Valley Joint Venture	http://www.centralvalleyjointventure.org/	https://www.centralvalleyjointventure.org//assets/pdf/CVJV_fnl.pdf	x	x						x				x	x											
East Gulf Coastal Plain Joint Venture	http://www.egcpjv.org/	http://www.egcpjv.org/pdf/FinalImplementation-PlanMay112010.pdf		x	x					x	x		x			x		x			x			x		x
Gulf Coast Joint Venture	http://www.gcjv.org/	http://www.gcjv.org/docs/GCJV%20Priority%20Shorebirds%20Fall%20Habitat%20Objectives%20Combined_vers4.0.doc								x	x								x	x						x
Intermountain West Joint Venture	https://iwjv.org/	https://iwjv.org/resource/2013-implementation-plan-chapter-5-shorebirds	x	x						x					x	x			x							
Lower Mississippi Valley Joint Venture	http://www.lmvjv.org/	https://www.lmvjv.org/shorebird-plan						x						x			x									
Northern Great Plains Joint Venture	http://ngpjv.org/	https://ngpjv.org/conserving-habitat/birds-intermountain-west/shorebirds/		x									x		x	x			x		x					
Oaks and Prairies Joint Venture	https://www.opjv.org/	https://docs.wixstatic.com/ugd/6af720_d088f-08b11eb467eaa5490556eda148c.pdf													x	x										
Pacific Birds Habitat Joint Venture	http://www.pacificbirds.org/	-																								
Playa Lakes Joint Venture	http://pljv.org/	-																								
Prairie Habitat Joint Venture	https://www.phjv.ca/	https://www.phjv.ca/wp-content/uploads/2017/10/Prairie-Canada-Shorebird-Conservation-Plan.pdf	x	x									x			x			x	x	x					x
Prairie Pothole Joint Venture	http://ppjv.org/	http://ppjv.org/assets/pdf/PPJV_2017_ImplPlan_Sec3.pdf		x									x	x	x	x			x		x					
Rainwater Basin Joint Venture	http://rwbjv.org/	http://rwbjv.org/wp-content/uploads/2012/02/Rainwater-Basin-Joint-Venture-Shorebird-Plan-2013.pdf		x			x					x				x				x						x
Rio Grande Joint Venture	http://www.rgjv.org/	https://www.birdconservancy.org/wp-content/uploads/2014/06/ChihuahuanDesertGrasslandBirdPlan2012v1.0.pdf																								
San Francisco Bay Joint Venture	http://www.sfbayjv.org/	http://www.sfbayjv.org/pdfs/strategy/Restoring_The_Estuary_Full.pdf																								
Sonoran Joint Venture	http://sonoranjv.org/	http://sonoranjv.org/downloads/SJV_StratPlan_1.0.pdf																								
Upper Mississippi River and Great Lakes Region Joint Venture	http://www.uppermissgreatlakesjv.org/	http://umgljv.org/docs/UMRGLR_JV_Shorebird-HCS.pdf						x					x	x		x										

Appendix 2. Priority shorebird species listed in Migratory Bird Joint Venture Plans (cont.)

MIGRATORY BIRD JOINT VENTURE	WEBSITE	PLANS AND PRIORITY LISTS THAT INCLUDE SHOREBIRDS	Sanderling *Calidris alba*	Dunlin *Calidris alpina*	Rock Sandpiper *Calidris ptilocnemis*	Purple Sandpiper *Calidris maritima*	Baird's Sandpiper *Calidris bairdii*	Least Sandpiper *Calidris minutilla*	White-rumped Sandpiper *Calidris fuscicollis*	Buff-breasted Sandpiper *Calidris subruficollis*	Pectoral Sandpiper *Calidris melanotos*	Semipalmated Sandpiper *Calidris pusilla*	Western Sandpiper *Calidris mauri*	Short-billed Dowitcher *Limnodromus griseus*	Long-billed Dowitcher *Limnodromus scolopaceus*	Wilson's Snipe *Gallinago delicata*	American Woodcock *Scolopax minor*	Spotted Sandpiper *Actitis macularius*	Solitary Sandpiper *Tringa solitaria*	Wandering Tattler *Tringa incana*	Greater Yellowlegs *Tringa melanoleuca*	Willet *Tringa semipalmata*	Lesser Yellowlegs *Tringa flavipes*	Wilson's Phalarope *Phalaropus tricolor*	Red-necked Phalarope *Phalaropus lobatus*	Red Phalarope *Phalaropus fulicarius*
Appalachian Mountains Joint Venture	http://amjv.org/index.php/	https://amjv.org/wp-content/uploads/2018/09/AMJV-Priority-Species.pdf		x				x		x		x	x				x	x	x		x		x			
Atlantic Coast Joint Venture	http://acjv.org/	-																								
Canadian Intermountain Joint Venture	http://cijv.ca/	http://nabci.net/wp-content/uploads/CIJV-Implementation-Plan-2010_FINAL.pdf	x											x										x	x	
Central Hardwoods Joint Venture	http://www.chjv.org/	-															x									
Central Valley Joint Venture	http://www.centralvalleyjointventure.org/	https://www.centralvalleyjointventure.org//assets/pdf/CVJV_fnl.pdf																								
East Gulf Coastal Plain Joint Venture	http://www.egcpjv.org/	http://www.egcpjv.org/pdf/FinalImplementationPlanMay112010.pdf	x							x		x	x			x	x		x							
Gulf Coast Joint Venture	http://www.gcjv.org/	http://www.gcjv.org/docs/GCJV%20Priority%20Shorebirds%20Fall%20Habitat%20Objectives%20Combined_vers4.0.doc								x			x	x												
Intermountain West Joint Venture	https://iwjv.org/	https://iwjv.org/resource/2013-implementation-plan-chapter-5-shorebirds																						x		
Lower Mississippi Valley Joint Venture	http://www.lmvjv.org/	https://www.lmvjv.org/shorebird-plan						x			x	x			x	x	x				x		x			
Northern Great Plains Joint Venture	http://ngpjv.org/	https://ngpjv.org/conserving-habitat/birds-intermountain-west/shorebirds/																				x		x		
Oaks and Prairies Joint Venture	https://www.opjv.org/	https://docs.wixstatic.com/ugd/6af720_d088f-08b11eb467eaa5490556eda148c.pdf																								
Pacific Birds Habitat Joint Venture	http://www.pacificbirds.org/	-																								
Playa Lakes Joint Venture	http://pljv.org/	-																								
Prairie Habitat Joint Venture	https://www.phjv.ca/	https://www.phjv.ca/wp-content/uploads/2017/10/Prairie-Canada-Shorebird-Conservation-Plan.pdf	x				x		x	x	x	x										x	x	x	x	
Prairie Pothole Joint Venture	http://ppjv.org/	http://ppjv.org/assets/pdf/PPJV_2017_ImplPlan_Sec3.pdf																				x		x		
Rainwater Basin Joint Venture	http://rwbjv.org/	http://rwbjv.org/wp-content/uploads/2012/02/Rainwater-Basin-Joint-Venture-Shorebird-Plan-2013.pdf					x		x	x	x	x	x		x			x			x	x	x	x		
Rio Grande Joint Venture	http://www.rgjv.org/	https://www.birdconservancy.org/wp-content/uploads/2014/06/ChihuahuanDesertGrasslandBirdPlan2012v1.0.pdf																								
San Francisco Bay Joint Venture	http://www.sfbayjv.org/	http://www.sfbayjv.org/pdfs/strategy/Restoring_The_Estuary_Full.pdf																								
Sonoran Joint Venture	http://sonoranjv.org/	http://sonoranjv.org/downloads/SJV_StratPlan_1.0.pdf																								
Upper Mississippi River and Great Lakes Region Joint Venture	http://www.uppermissgreatlakesjv.org/	http://umgljv.org/docs/UMRGLR_JV_Shorebird-HCS.pdf	x	x										x		x	x							x		

Appendix 3. Priority shorebird species listed in State Wildlife Action Plans in the United States

STATE	WILDLIFE ACTION PLAN TITLE	Black-necked Stilt *Himantopus mexicanus*	American Avocet *Recurvirostra americana*	American Oystercatcher *Haematopus palliatus*	Black Oystercatcher *Haematopus bachmani*	Black-bellied Plover *Pluvialis squatarola*	American Golden-Plover *Pluvialis dominica*	Pacific Golden-Plover *Pluvialis fulva*	Snowy Plover *Charadrius nivosus*	Wilson's Plover *Charadrius wilsonia*	Semipalmated Plover *Charadrius semipalmatus*	Piping Plover *Charadrius melodus*	Killdeer *Charadrius vociferus*	Mountain Plover *Charadrius montanus*	Upland Sandpiper *Bartramia longicauda*	Eskimo Curlew *Numenius borealis*	Whimbrel *Numenius phaeopus*	Bristle -thighed Curlew *Numenius tahitiensis*	Long-billed Curlew *Numenius americanus*	Hudsonian Godwit *Limosa haemastica*	Marbled Godwit *Limosa fedoa*	Bar-tailed Godwit *Limosa lapponica baueri*	Ruddy Turnstone *Arenaria interpres*	Black Turnstone *Arenaria melanocephala*	Red Knot *Calidris canutus*
Alabama	Alabama Wildlife Action Plan			x					x	x		x													x
Alaska	Alaska Wildlife Action Plan				x		x	x					x		x		x	x		x	x	x		x	x
Arizona	Arizona's State Wildlife Action Plan								x					x											
Arkansas	Arkansas Wildlife Action Plan					x	x					x											x		
California	California State Wildlife Action Plan				x				x					x	x								x	x	x
Colorado	Colorado State Wildlife Action Plan								x			x		x	x				x						
Connecticut	Connecticut Wildlife Action Plan			x								x			x								x		
District of Columbia	District of Columbia Wildlife Action Plan																								
Delaware	Delaware Wildlife Action Plan 2015-2025	x	x	x		x	x					x			x		x			x	x		x		x
Florida	Florida´s State Wildlife Action Plan		x	x		x	x		x	x		x			x		x		x		x		x		x
Georgia	Georgia State Wildlife Action Plan	x		x						x		x					x								x
Hawai	Hawai'i's State Wildlife Action Plan	x						x										x					x		
Idaho	Idaho State Wildlife Action Plan																		x						
Illinois	Illinois State Wildlife Action Plan						x					x			x										
Indiana	Indiana State Wildlife Action Plan						x					x			x								x		x
Iowa	Iowa Wildlife Action Plan					x	x					x			x		x		x	x	x		x		x
Kansas	Kansas Wildlife Action Plan	x	x			x	x		x			x		x	x				x	x	x				
Kentucky	Kentucky Wildlife Action Plan	x					x					x			x										
Louisiana	Louisiana Wildlife Action Plan			x					x	x		x			x				x	x	x				x
Maine	Maine´s Wildlife Action Plan			x		x						x			x		x						x		x
Maryland	Maryland State Wildlife Action Plan			x		x				x		x			x		x						x		x
Massachusetts	Massachusetts State Wildlife Action Plan			x								x			x	x	x						x		x
Michigan	Michigan's Wildlife Action Plan											x													x
Minnesota	Minnesota Wildlife Action Plan											x			x					x	x				x
Mississippi	Mississippi State Wildlife Action Plan			x					x	x		x									x				x
Missouri	Missouri State Wildlife Action Plan														x										

Appendix 3. Priority shorebird species listed in State Wildlife Action Plans in the United States (cont.)

STATE	WILDLIFE ACTION PLAN TITLE	Black-necked Stilt *Himantopus mexicanus*	American Avocet *Recurvirostra americana*	American Oystercatcher *Haematopus palliatus*	Black Oystercatcher *Haematopus bachmani*	Black-bellied Plover *Pluvialis squatarola*	American Golden-Plover *Pluvialis dominica*	Pacific Golden-Plover *Pluvialis fulva*	Snowy Plover *Charadrius nivosus*	Wilson's Plover *Charadrius wilsonia*	Semipalmated Plover *Charadrius semipalmatus*	Piping Plover *Charadrius melodus*	Killdeer *Charadrius vociferus*	Mountain Plover *Charadrius montanus*	Upland Sandpiper *Bartramia longicauda*	Eskimo Curlew *Numenius borealis*	Whimbrel *Numenius phaeopus*	Bristle -thighed Curlew *Numenius tahitiensis*	Long-billed Curlew *Numenius americanus*	Hudsonian Godwit *Limosa haemastica*	Marbled Godwit *Limosa fedoa*	Bar-tailed Godwit *Limosa lapponica baueri*	Ruddy Turnstone *Arenaria interpres*	Black Turnstone *Arenaria melanocephala*	Red Knot *Calidris canutus*
Montana	Montana's State Wildlife Action Plan											x		x											
Nebraska	Nebraska State Wildlife Action Plan	x							x			x		x					x						
Nevada	Nevada Wildlife Action Plan		x						x										x						
New Hampshire	New Hampshire Wildlife Action Plan											x			x		x						x		x
New Jersey	New Jersey's Wildlife Action Plan			x		x	x					x	x		x		x			x	x		x		x
New Mexico	New Mexico State Wildlife Action Plan								x					x					x						
New York	New York State Wildlife Action Plan											x			x		x								x
North Carolina	North Carolina's Wildlife Action Plan		x	x		x				x		x					x				x		x		x
North Dakota	North Dakota State Wildlife Action Plan		x									x			x				x		x				x
Ohio	Ohia State Wildlife Action Plan														x										
Oklahoma	Oklahoma State Wildlife Action Plan						x		x			x		x	x				x	x					x
Oregon	Oregon Conservation Strategy	x			x				x						x				x						
Pennsylvania	Pennsylvania Wildlife Action Plan											x			x										x
Puerto Rico	Puerto Rico State Wildlife Action Plan			x					x	x		x													x
Rhode Island	Rhode Island Wildlife Action Plan			x		x					x	x											x		x
South Carolina	South Carolina State Wildlife Action Plan		x	x		x	x			x	x	x			x		x		x		x		x		x
South Dakota	South Dakota Wildlife Action Plan											x							x		x				
Tennessee	Tennessee's 2015 State Wildlife Action Plan						x		x	x		x			x		x			x	x				x
Texas	Texas Conservation Action Plan			x			x		x	x		x		x					x	x					x
Utah	Utah Wildlife Action Plan								x																
Vermont	Vermont's Wildlife Action Plan														x										
Virginia	Virginia Wildlife Action Plan			x		x				x		x					x				x				x
Washington	Washington State Wildlife Action Plan								x						x						x				x
West Virginia	West Virginia State Wildlife Action Plan														x										
Wisconsin	Wisconsin Wildlife Action Plan	x										x			x										x
Wyoming	Wyoming State Wildlife Action Plan								x						x				x						

Appendix 3. Priority shorebird species listed in State Wildlife Action Plans in the United States (cont.)

STATE	WILDLIFE ACTION PLAN TITLE	Surfbird *Calidris virgata*	Sanderling *Calidris alba*	Dunlin *Calidris alpina*	Rock Sandpiper *Calidris ptilocnemis*	Purple Sandpiper *Calidris maritima*	Baird's Sandpiper *Calidris bairdii*	Least Sandpiper *Calidris minutilla*	White-rumped Sandpiper *Calidris fuscicollis*	Buff-breasted Sandpiper *Calidris subruficollis*	Pectoral Sandpiper *Calidris melanotos*	Semipalmated Sandpiper *Calidris pusilla*	Western Sandpiper *Calidris mauri*	Short-billed Dowitcher *Limnodromus griseus*	Long-billed Dowitcher *Limnodromus scolopaceus*	Wilson's Snipe *Gallinago delicata*	American Woodcock *Scolopax minor*	Spotted Sandpiper *Actitis macularius*	Solitary Sandpiper *Tringa solitaria*	Wandering Tattler *Tringa incana*	Greater Yellowlegs *Tringa melanoleuca*	Willet *Tringa semipalmata*	Lesser Yellowlegs *Tringa flavipes*	Wilson's Phalarope *Phalaropus tricolor*	Red-necked Phalarope *Phalaropus lobatus*	Red Phalarope *Phalaropus fulicarius*
Alabama	Alabama Wildlife Action Plan																									
Alaska	Alaska Wildlife Action Plan	x	x	x	x					x	x	x	x	x	x			x	x	x			x			x
Arizona	Arizona's State Wildlife Action Plan																									
Arkansas	Arkansas Wildlife Action Plan		x	x						x				x			x									
California	California State Wildlife Action Plan	x	x																	x						
Colorado	Colorado State Wildlife Action Plan																									
Connecticut	Connecticut Wildlife Action Plan		x									x					x					x				
District of Columbia	District of Columbia Wildlife Action Plan															x	x						x			
Delaware	Delaware Wildlife Action Plan 2015-2025		x	x		x			x	x	x	x		x		x	x	x	x		x	x	x	x		
Florida	Florida´s State Wildlife Action Plan		x	x					x	x	x	x	x	x	x		x		x			x	x	x		
Georgia	Georgia State Wildlife Action Plan																									
Hawai	Hawai'i's State Wildlife Action Plan		x																	x						
Idaho	Idaho State Wildlife Action Plan																									
Illinois	Illinois State Wildlife Action Plan															x	x				x			x		
Indiana	Indiana State Wildlife Action Plan									x				x					x		x			x		
Iowa	Iowa Wildlife Action Plan		x						x	x	x	x		x	x	x	x						x	x		
Kansas	Kansas Wildlife Action Plan						x	x	x	x	x	x			x						x		x	x		
Kentucky	Kentucky Wildlife Action Plan		x	x						x		x	x		x	x	x	x	x				x	x		
Louisiana	Louisiana Wildlife Action Plan			x						x				x			x									
Maine	Maine´s Wildlife Action Plan		x	x		x		x				x		x			x		x		x	x	x		x	x
Maryland	Maryland State Wildlife Action Plan		x									x		x			x	x			x	x	x		x	x
Massachusetts	Massachusetts State Wildlife Action Plan		x			x						x		x		x	x					x			x	x
Michigan	Michigan's Wildlife Action Plan																							x		
Minnesota	Minnesota Wildlife Action Plan											x		x			x				x			x		
Mississippi	Mississippi State Wildlife Action Plan			x									x				x									
Missouri	Missouri State Wildlife Action Plan																									

Appendix 3. Priority shorebird species listed in State Wildlife Action Plans in the United States (cont.)

STATE	WILDLIFE ACTION PLAN TITLE	Surfbird *Calidris virgata*	Sanderling *Calidris alba*	Dunlin *Calidris alpina*	Rock Sandpiper *Calidris ptilocnemis*	Purple Sandpiper *Calidris maritima*	Baird's Sandpiper *Calidris bairdii*	Least Sandpiper *Calidris minutilla*	White-rumped Sandpiper *Calidris fuscicollis*	Buff-breasted Sandpiper *Calidris subruficollis*	Pectoral Sandpiper *Calidris melanotos*	Semipalmated Sandpiper *Calidris pusilla*	Western Sandpiper *Calidris mauri*	Short-billed Dowitcher *Limnodromus griseus*	Long-billed Dowitcher *Limnodromus scolopaceus*	Wilson's Snipe *Gallinago delicata*	American Woodcock *Scolopax minor*	Spotted Sandpiper *Actitis macularius*	Solitary Sandpiper *Tringa solitaria*	Wandering Tattler *Tringa incana*	Greater Yellowlegs *Tringa melanoleuca*	Willet *Tringa semipalmata*	Lesser Yellowlegs *Tringa flavipes*	Wilson's Phalarope *Phalaropus tricolor*	Red-necked Phalarope *Phalaropus lobatus*	Red Phalarope *Phalaropus fulicarius*
Montana	Montana's State Wildlife Action Plan																									
Nebraska	Nebraska State Wildlife Action Plan									x																
Nevada	Nevada Wildlife Action Plan												x		x									x	x	
New Hampshire	New Hampshire Wildlife Action Plan		x			x											x					x				
New Jersey	New Jersey's Wildlife Action Plan		x	x		x		x	x			x		x			x	x	x		x	x	x	x		
New Mexico	New Mexico State Wildlife Action Plan																									
New York	New York State Wildlife Action Plan									x		x		x												
North Carolina	North Carolina's Wildlife Action Plan		x			x						x										x				
North Dakota	North Dakota State Wildlife Action Plan																					x		x		
Ohio	Ohia State Wildlife Action Plan																x							x		
Oklahoma	Oklahoma State Wildlife Action Plan									x			x				x		x					x		
Oregon	Oregon Conservation Strategy				x																					
Pennsylvania	Pennsylvania Wildlife Action Plan															x	x	x								
Puerto Rico	Puerto Rico State Wildlife Action Plan																					x				
Rhode Island	Rhode Island Wildlife Action Plan		x	x		x		x	x			x		x		x	x	x			x	x				
South Carolina	South Carolina State Wildlife Action Plan		x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x			
South Dakota	South Dakota Wildlife Action Plan																					x		x		
Tennessee	Tennessee's 2015 State Wildlife Action Plan									x		x	x				x									
Texas	Texas Conservation Action Plan									x			x				x									
Utah	Utah Wildlife Action Plan																									
Vermont	Vermont's Wildlife Action Plan																x						x			
Virginia	Virginia Wildlife Action Plan		x	x		x								x			x					x				
Washington	Washington State Wildlife Action Plan				x																					
West Virginia	West Virginia State Wildlife Action Plan															x	x	x								
Wisconsin	Wisconsin Wildlife Action Plan																x							x		
Wyoming	Wyoming State Wildlife Action Plan																									

Appendix 4. Shorebird species of the Americas, grouped by guild, primary habitat, principle foraging habitats, and foraging techniques

Primary Habitat is a basic description of the most commonly associated habitats that shorebirds are associated with, including Freshwater, Saltwater, and Upland areas.

Shorebird Guilds were defined by Harrington (2007). Harrington's definitions were used to group remaining shorebird species in the Americas not previously defined. Some species use more than one guild; for the purposes of this categorization, shorebird species are grouped into the habitat guild they use most frequently. Grouping includes a combination of the habitat elements of preferred water depth and vegetation type.

- Coastal - Sandy Intertidal: Species that are most frequently found in oceanfront habitats on sandy beaches or nearby sandy intertidal habitats.
- Coastal - Rocky Intertidal: Species that are most frequently found in oceanfront habitats on rocky beaches or rocky coastlines.
- Upland: Species that frequent short-or tall-grass habitats.
- Coastal/ Upland: Species that frequent both coastal and upland habitats regularly.
- Mud: Species that commonly use unconsolidated muddy or sandy substrates at tidal and non-tidal sites. Most species prefer open, sparsely vegetated flats.
- Wading: Species that mostly forage by wading in water. Some forage in the water column while others forage on the bottom surface or by probing into muddy bottom. Some wading shorebirds use both marine and nonmarine habitats, some prefer either marine or nonmarine, some primarily use marine habitats.

Foraging Guilds characterize the variety of foraging techniques that shorebirds use in aquatic and terrestrial habitats. How shorebirds forage can influence management strategies like the targeted production of food resources or choice of sediments to use in restorations. Shorebirds glean, probe, pry, and sweep as they forage for prey items (Helmers 1992, Colwell 2010).

- Gleaners - visual feeders that pick or glean for food from the surface.
- Probers - tactile feeders that probe the substrate for prey items.
- Sweepers - use their bill to sweep for food in the water column.
- Priers - use their bill to pry open mollusks or other prey items.

Appendix 4. Shorebird species of the Americas, grouped by guild, primary habitat, principle foraging habitats, and foraging techniques (cont.)

Data sources: Johnsgard 1981; Burger and Olla 1984; Hayman et al., 1991; Fjeldså and Krabbe 1990; Helmers 1992; Stotz et al. 1996; Colwell 2010; Birds of the World.

Scientific Name	Common Name	Primary Habitat	Principle Foraging Habitat	Terrestrial or Aquatic Forager	Foraging Guild
COASTAL					
Chionis albus	Snowy Sheathbill	Saltwater	Sandy Beach, Rocky Beach	Terrestrial/Aquatic	gleaner
COASTAL - ROCKY INTERTIDAL					
Arenaria interpres	Ruddy Turnstone	Saltwater	Rocky Beach	Terrestrial/Aquatic	Gleaner/Prober
Arenaria melanocephala	Black Turnstone	Saltwater	Rocky Beach	Terrestrial/Aquatic	Gleaner/Prober
Calidris maritima	Purple Sandpiper	Saltwater	Rocky Beach	Terrestrial/Aquatic	Gleaner/Prober
Calidris ptilocnemis	Rock Sandpiper	Saltwater	Rocky Beach	Terrestrial/Aquatic	Gleaner/Prober
Calidris virgata	Surfbird	Saltwater	Rocky Beach	Terrestrial/Aquatic	Gleaner/Prober
Haematopus ater	Blackish Oystercatcher	Saltwater	Rocky Beach	Aquatic	Prober/Prier
Haematopus bachmani	Black Oystercatcher	Saltwater	Rocky Beach	Aquatic	Prober/Prier
Tringa incana	Wandering Tattler	Saltwater	Rocky Beach	Aquatic	Gleaner
COASTAL - SANDY INTERTIDAL					
Calidris canutus	Red Knot	Saltwater	Sandy Beach	Aquatic	Prober/Gleaner
Calidris alba	Sanderling	Saltwater	Sandy Beach	Aquatic	Prober/Gleaner
Charadrius melodus	Piping Plover	Freshwater/ Saltwater	Sandy Beach	Terrestrial/Aquatic	Gleaner
Charadrius nivosus	Snowy Plover	Saltwater	Sandy Beach, Salt Flats	Terrestrial/Aquatic	Gleaner
Charadrius wilsonia	Wilson's Plover	Saltwater	Sandy Beach	Terrestrial/Aquatic	Gleaner
Haematopus palliatus	American Oystercatcher	Saltwater	Sandy Beach	Aquatic	Prober/Prier
COASTAL / UPLAND					
Charadrius modestus	Rufous-chested Dotterel	Freshwater/ Saltwater/ Upland	Grassland, Sandy Beach, Mud	Terrestrial/Aquatic	Prober/Gleaner
Haematopus leucopodus	Magellanic Oystercatcher	Saltwater/ Freshwater	Sandy Beach, Lake	Aquatic	Prober/Prier

Appendix 4. Shorebird species of the Americas, grouped by guild, primary habitat, principle foraging habitats, and foraging techniques (cont.)

MUD					
Scientific Name	Common Name	Primary Habitat	Principle Foraging Habitat	Terrestrial or Aquatic Forager	Foraging Guild
Actitis macularius	Spotted Sandpiper	Freshwater	Mud	Terrestrial/Aquatic	Gleaner/Prober
Calidris fuscicollis	White-rumped Sandpiper	Freshwater/ Saltwater	Flooded	Aquatic	Prober/Gleaner
Calidris minutilla	Least Sandpiper	Freshwater/ Saltwater	Mud	Aquatic	Prober/Gleaner
Calidris pusilla	Semipalmated Sandpiper	Freshwater/ Saltwater	Mud	Aquatic	Prober/Gleaner
Charadrius alticola	Puna Plover	Freshwater/ Saltwater	Lakes, Ponds	Terrestrial/Aquatic	Gleaner
Charadrius collaris	Collared Plover	Freshwater/ Saltwater	Sandy Beach, River Beach, Mud	Terrestrial/Aquatic	Gleaner
Charadrius falklandicus	Two-banded Plover	Freshwater/ Saltwater	Lake, Pond, Sandy Beach, Rocky Beach, Mud	Terrestrial/Aquatic	Gleaner
Charadrius semipalmatus	Semipalmated Plover	Freshwater/ Saltwater	Mud	Terrestrial/Aquatic	Gleaner
Hoploxypterus cayanus	Pied Lapwing	Freshwater/ Saltwater	River Beach	Terrestrial/Aquatic	Gleaner/Prober
Numenius phaeopus	Whimbrel	Freshwater/ Saltwater/ Upland	Mud, Grassland	Terrestrial/Aquatic	Gleaner/Prober
Numenius tahitiensis	Bristle-thighed Curlew	Freshwater/ Saltwater	Mud, Grassland	Terrestrial/Aquatic	Gleaner/Prober
Pluvialis squatarola	Black-bellied Plover	Freshwater/ Saltwater	Mud	Terrestrial/Aquatic	Gleaner
Pluvianellus socialis	Magellanic Plover	Freshwater/ Saltwater	Lake, Pond	Terrestrial/Aquatic	Gleaner/Prober

UPLAND					
Scientific Name	Common Name	Primary Habitat	Principle Foraging Habitat	Terrestrial or Aquatic Forager	Foraging Guild
Attagis gayi	Rufous-bellied Seedsnipe	Upland	Grassland- Puna, Bog	Terrestrial	Gleaner
Attagis malouinus	White-bellied Seedsnipe	Upland	Grassland, Bog	Terrestrial	Gleaner
Bartramia longicauda	Upland Sandpiper	Upland	Grassland	Aquatic/Terrestrial	Gleaner
Burhinus bistriatus	Double-striped Thick-knee	Upland	Grassland- wet, scrub	Terrestrial	Gleaner
Burhinus superciliaris	Peruvian Thick-knee	Upland	Grassland - wet, scrub	Terrestrial	Gleaner
Calidris bairdii	Baird's Sandpiper	Freshwater/ Saltwater	Grassland	Aquatic	Prober/Gleaner

Appendix 4. Shorebird species of the Americas, grouped by guild, primary habitat, principle foraging habitats, and foraging techniques (cont.)

UPLAND					
Scientific Name	Common Name	Primary Habitat	Principle Foraging Habitat	Terrestrial or Aquatic Forager	Foraging Guild
Calidris subruficollis	Buff-breasted Sandpiper	Upland	Grassland	Aquatic	Gleaner
Charadrius montanus	Mountain Plover	Upland	Grassland	Terrestrial/Aquatic	Gleaner
Charadrius vociferus	Killdeer	Freshwater/ Saltwater	Grassland, Marsh, River Beach	Terrestrial/Aquatic	Gleaner
Gallinago imperialis	Imperial Snipe	Upland/Freshwater	Forest, Bog	Terrestrial	Prober/Gleaner
Gallinago jamesoni	Andean Snipe	Upland/Freshwater	Grassland- Paramo, Bog	Terrestrial/Aquatic	Prober/Gleaner
Gallinago nobilis	Noble Snipe	Upland/Freshwater	Grassland- Paramo, Bog	Terrestrial/Aquatic	Prober/Gleaner
Gallinago paraguaiae	South American Snipe	Freshwater	Marsh, Grassland	Terrestrial/Aquatic	Prober/Gleaner
Gallinago stricklandii	Fuegian Snipe	Upland/Freshwater	Grassland - Paramo, Bog	Terrestrial/Aquatic	Prober/Gleaner
Gallinago undulata	Giant Snipe	Upland	Grassland- wet, Bog	Terrestrial/Aquatic	Prober/Gleaner
Numenius americanus	Long-billed Curlew	Freshwater/ Saltwater/ Upland	Grassland	Terrestrial/Aquatic	Prober/Gleaner
Oreopholus ruficollis	Tawny-throated Dotterel	Upland	Heathland, Grassland	Terrestrial	Gleaner
Phegornis mitchellii	Diademed Sandpiper-Plover	Upland/Freshwater	Grassland- Puna, Bog	Terrestrial/Aquatic	Prober
Pluvialis dominica	American Golden-Plover	Upland	Grassland	Terrestrial/Aquatic	Gleaner
Pluvialis fulva	Pacific Golden-Plover	Upland	Grassland, Marsh, Mud	Terrestrial/Aquatic	Gleaner
Scolopax minor	American Woodcock	Upland	Saturated Soil, Grassland	Terrestrial	Prober
Thinocorus orbignyianus	Grey-breasted Seedsnipe	Upland	Grassland- Puna	Terrestrial	Gleaner
Thinocorus rumicivorus	Least Seedsnipe	Upland	Grassland	Terrestrial	Gleaner
Vanellus chilensis	Southern Lapwing	Upland	Grassland, River Beach	Terrestrial	Gleaner/Prober
Vanellus resplendens	Andean Lapwing	Upland	Grassland, Marsh	Terrestrial	Gleaner/Prober

Appendix 4. Shorebird species of the Americas, grouped by guild, primary habitat, principle foraging habitats, and foraging techniques (cont.)

WADING					
Scientific Name	Common Name	Primary Habitat	Principle Foraging Habitat	Terrestrial or Aquatic Forager	Foraging Guild
Calidris himantopus	Stilt Sandpiper	Freshwater	Flooded	Aquatic	Prober/Gleaner
Calidris alpina	Dunlin	Freshwater/ Saltwater	Mud	Aquatic	Prober/Gleaner
Calidris mauri	Western Sandpiper	Saltwater	Mud	Aquatic	Prober/Gleaner
Calidris melanotos	Pectoral Sandpiper	Saltwater	Flooded	Aquatic	Prober/Gleaner
Gallinago andina	Puna Snipe	Freshwater	Marsh, Bog	Terrestrial/Aquatic	Prober/Gleaner
Gallinago delicata	Wilson's Snipe	Freshwater	Marsh	Aquatic	Prober/Gleaner
Himantopus mexicanus	Black-necked Stilt	Freshwater/ Saltwater	Flooded	Aquatic	Gleaner/Sweeper
Jacana jacana	Wattled Jacana	Freshwater	Flooded	Aquatic	Gleaner
Jacana spinosa	Northern jacana	Freshwater	Flooded	Aquatic	Gleaner
Limnodromus griseus	Short-billed Dowitcher	Freshwater/ Saltwater	Flooded	Aquatic	Prober/Gleaner
Limnodromus scolopaceus	Long-billed Dowitcher	Freshwater/ Saltwater	Flooded	Aquatic	Prober/Gleaner
Limosa lapponica	Bar-tailed Godwit	Freshwater/ Saltwater	Flooded	Aquatic	Prober
Limosa fedoa	Marbled Godwit	Freshwater/ Saltwater	Flooded	Aquatic	Prober
Limosa haemastica	Hudsonian Godwit	Freshwater/ Saltwater	Flooded	Aquatic	Prober
Nycticryphes semicollaris	South American Painted-snipe	Freshwater/ Upland	Marsh, Grassland	Aquatic	Gleaner/Prober
Phalaropus fulicarius	Red Phalarope	Saltwater	Open Ocean	Aquatic/Pelagic	Gleaner
Phalaropus lobatus	Red-necked Phalarope	Saltwater	Open Ocean	Aquatic/Pelagic	Gleaner
Phalaropus tricolor	Wilson's Phalarope	Freshwater/ Saltwater	Open Water, Flooded	Aquatic	Gleaner
Recurvirostra americana	American Avocet	Freshwater/ Saltwater	Flooded	Aquatic	Gleaner/Sweeper
Recurvirostra andina	Andean Avocet	Saltwater/ Upland	Flooded	Aquatic	Gleaner/Sweeper
Tringa flavipes	Lesser Yellowlegs	Freshwater/ Saltwater	Flooded	Aquatic	Gleaner
Tringa melanoleuca	Greater Yellowlegs	Freshwater/ Saltwater	Flooded	Aquatic	Gleaner
Tringa semipalmata	Willet	Freshwater/ Saltwater	Mud, Marsh, Sandy Beach	Aquatic	Gleaner
Tringa solitaria	Solitary Sandpiper	Freshwater	Flooded	Aquatic	Gleaner

Appendix 5. Size, water depth associations, vegetation height and density for nonbreeding shorebird species in the Americas

Data sources: Johnsgard 1981; Burger and Olla 1984; Hayman et al., 1991; Fjeldså and Krabbe 1990; Helmers 1992; Stotz et al. 1996; Colwell 2010; Birds of the World. Size class based on body length defined by Skagen and Knopf 1993.

S = small (≤ 190mm), M = medium (195 – 350mm), L = large (>350mm).

SCIENTIFIC NAME	ENGLISH NAME	SIZE	WATER DEPTH (CM)	VEGETATION HEIGHT	VEGETATION DENSITY
Actitis macularius	Spotted Sandpiper	S	Dry - 5cm	None/Short	Sparse
Arenaria interpres	Ruddy Turnstone	M	Dry - 5cm	None/Short	Sparse
Arenaria melanocephala	Black Turnstone	M	Dry - 5cm	None/Short	Sparse
Attagis gayi	Rufous-bellied Seedsnipe	M	Dry	Short/Medium	Sparse/Moderate
Attagis malouinus	White-bellied Seedsnipe	M	Dry	None/Short/Medium	Sparse/Moderate
Bartramia longicauda	Upland Sandpiper	L	Dry	None/Short	Sparse
Burhinus bistriatus	Double-striped Thick-knee	L	Dry	Short/Medium	Moderate/Dense
Burhinus superciliaris	Peruvian Thick-knee	L	Dry	None/Short/Medium	Moderate/Dense
Calidris alba	Sanderling	S	Saturated - 5cm	None/Short	Sparse
Calidris alpina	Dunlin	S	Saturated - 12cm	None/Short	Sparse
Calidris bairdii	Baird's Sandpiper	S	Saturated - 5cm	None/Short	Sparse
Calidris canutus	Red Knot	M	Saturated - 12cm	None/Short	Sparse
Calidris fuscicollis	White-rumped Sandpiper	S	Saturated - 5cm	None/Short	Sparse
Calidris himantopus	Stilt Sandpiper	M	Saturated - 12cm	None/Short	Sparse
Calidris maritima	Purple Sandpiper	S	Dry - 5cm	None/Short	Sparse
Calidris mauri	Western Sandpiper	S	Saturated - 5cm	None/Short	Sparse
Calidris melanotos	Pectoral Sandpiper	S	Saturated - 12cm	None/Short	Sparse
Calidris minutilla	Least Sandpiper	S	Saturated - 5cm	None/Short	Sparse
Calidris ptilocnemis	Rock Sandpiper	S	Dry - 5cm	None/Short	Sparse
Calidris pusilla	Semipalmated Sandpiper	S	Saturated - 5cm	None/Short	Sparse
Calidris subruficollis	Buff-breasted Sandpiper	S	Saturated - 12cm	None/Short	Sparse
Calidris virgata	Surfbird	M	Dry - 5cm	None/Short	Sparse
Charadrius alticola	Puna Plover	S	Dry - 5cm	None/Short	Sparse
Charadrius collaris	Collared Plover	S	Dry - 5cm	None/Short	Sparse
Charadrius falklandicus	Two-banded Plover	S	Dry - 5cm	None/Short	Sparse
Charadrius melodus	Piping Plover	S	Dry - 5cm	None/Short	Sparse

Appendix 5. Size, water depth associations, vegetation height and density for nonbreeding shorebird species in the Americas (cont.)

SCIENTIFIC NAME	ENGLISH NAME	SIZE	WATER DEPTH (CM)	VEGETATION HEIGHT	VEGETATION DENSITY
Charadrius modestus	Rufous-chested Dotterel	S	Saturated - 5cm	Short/Medium	Sparse
Charadrius montanus	Mountain Plover	S	Dry - 5cm	None/Short	Sparse
Charadrius nivosus	Snowy Plover	S	Dry - 5cm	None/Short	Sparse
Charadrius semipalmatus	Semipalmated Plover	S	Dry - 5cm	None/Short	Sparse
Charadrius vociferus	Killdeer	S	Dry - 5cm	None/Short	Sparse
Charadrius wilsonia	Wilson's Plover	S	Dry - 5cm	None/Short	Sparse
Chionis albus	Snowy Sheathbill	L	Saturated - 5cm	None	None
Gallinago andina	Puna Snipe	M	Dry - 5cm	Short/Medium	Moderate/Dense
Gallinago delicata	Wilson's Snipe	L	Saturated - 12cm	Medium/Tall	Moderate/Dense
Gallinago imperialis	Imperial Snipe	L	Dry - 5cm	Medium/Tall	Moderate/Dense
Gallinago jamesoni	Andean Snipe	L	Dry - 5cm	Medium/Tall	Moderate/Dense
Gallinago nobilis	Noble Snipe	L	Dry - 5cm	Medium/Tall	Moderate/Dense
Gallinago paraguaiae	South American Snipe	L	Dry - 5cm	Short/Medium	Moderate/Dense
Gallinago stricklandii	Fuegian Snipe	L	Dry - 5cm	Medium/Tall	Moderate/Dense
Gallinago undulata	Giant Snipe	L	Dry - 5cm	Medium/Tall	Moderate/Dense
Haematopus ater	Blackish Oystercatcher	L	NA	None/Short	Sparse
Haematopus bachmani	Black Oystercatcher	L	NA	None/Short	Sparse
Haematopus palliatus	American Oystercatcher	L	NA	None/Short	Sparse
Haematopus leucopodus	Magellanic Oystercatcher	L	NA	None/Short	Sparse
Himantopus mexicanus	Black-necked Stilt	L	8-20 cm	None/Short	Sparse
Hoploxypterus cayanus	Pied Lapwing	M	Saturated - 5cm	None/Short	None/Sparse
Jacana jacana	Wattled Jacana	M	Saturated - 5cm	None/Short	Sparse/Moderate (floating)
Jacana spinosa	Northern jacana	M	Saturated - 5cm	None/Short	Sparse/Moderate (floating)
Limnodromus griseus	Short-billed Dowitcher	L	Saturated - 12cm	None/Short	Sparse
Limnodromus scolopaceus	Long-billed Dowitcher	L	Saturated - 12cm	None/Short	Sparse
Limosa fedoa	Marbled Godwit	L	Saturated - 16cm	Short/Medium	Sparse/Moderate
Limosa haemastica	Hudsonian Godwit	L	Saturated - 16cm	Short/Medium	Sparse/Moderate
Numenius tahitiensis	Bristle-thighed Curlew	L	Dry - 16cm	Short/Medium	Moderate/Dense

Appendix 5. Size, water depth associations, vegetation height and density for nonbreeding shorebird species in the Americas (cont.)

SCIENTIFIC NAME	ENGLISH NAME	SIZE	WATER DEPTH (CM)	VEGETATION HEIGHT	VEGETATION DENSITY
Numenius americanus	Long-billed Curlew	L	Dry - 16cm	Short/Medium	Moderate/Dense
Numenius phaeopus	Whimbrel	L	Dry - 16cm	Short/Medium	Moderate/Dense
Numenius tahitiensis	Bristle-thighed Curlew	L	Dry - 16cm	Short/Medium	Moderate/Dense
Nycticryphes semicollaris	South American Painted-snipe	M	7-15cm	Short/Medium	Sparse/Moderate
Oreopholus ruficollis	Tawny-throated Dotterel	M	Dry- saturated	None/Short	Sparse
Phalaropus fulicarius	Red Phalarope	S	6cm - open water	None/Short	Sparse/Moderate
Phalaropus lobatus	Red-necked Phalarope	S	6cm - open water	None/Short	Sparse/Moderate
Phalaropus tricolor	Wilson's Phalarope	S	6cm - open water	None/Short	Sparse/Moderate
Phegornis mitchellii	Diademed Sandpiper-Plover	M	Dry - 5cm	Short	Sparse/Moderate
Pluvialis dominica	American Golden-Plover	M	Dry - 5cm	None/Short	Sparse
Pluvialis fulva	Pacific Golden-Plover	M	Dry - 5cm	None/Short	Sparse
Pluvialis squatarola	Black-bellied Plover	M	Dry - 5cm	None/Short	Sparse
Pluvianellus socialis	Magellanic Plover	M	Saturated - 5cm	None/Short	Sparse
Recurvirostra americana	American Avocet	L	8-20cm	None/Short	Sparse
Recurvirostra andina	Andean Avocet	L	8-20cm	None/Short	Sparse
Scolopax minor	American Woodcock	L	Dry- saturated	Short /Forest	Moderate/Dense
Thinocorus orbignyianus	Grey-breasted Seedsnipe	M	Dry	Short/Medium	Sparse/Moderate
Thinocorus rumicivorus	Least Seedsnipe	S	Dry	Short/Medium	Sparse/Moderate
Tringa flavipes	Lesser Yellowlegs	M	2 - 12cm	Short/Medium	Sparse/Moderate
Tringa incana	Wandering Tattler	M	Dry - 5cm	None/Short	Sparse
Tringa melanoleuca	Greater Yellowlegs	L	2 - 12cm	Short/Medium	Sparse/Moderate
Tringa semipalmata	Willet	L	2 - 12cm	Short/Medium	Sparse/Moderate
Tringa solitaria	Solitary Sandpiper	M	2 - 12cm	Short/Medium	Sparse/Moderate
Vanellus chilensis	Southern Lapwing	L	Dry - 5cm	Short/Medium	Sparse/Moderate
Vanellus resplendens	Andean Lapwing	L	Dry - 5cm	Short/Medium	Sparse/Moderate

Appendix 6. Nesting characteristics in non-Arctic or sub-Arctic habitats

Primary ecosystem, principle breeding habitat, nesting site substrate, vegetation height and density, nesting behavior, and altitude are derived from Helmers 1992; Birds of the World; O'Brien et al., 2006.

BREED IN NORTH AND/OR CENTRAL AMERICA							
Scientific name	English name	Primary Ecosystem	Principle Breeding Habitat	Nesting Substrate	Nesting - Vegetation Height	Nesting - Vegetation Density	Nesting Behavior
Actitis macularius	Spotted Sandpiper	Freshwater	Beach/ Upland	Open/ Sand/ Rocky	None	Sparse	Solitary
Bartramia longicauda	Upland Sandpiper	-	Grassland	Closed/ Vegetated	Medium/ Tall	Dense	Solitary/ Semicolonial
Charadrius melodus	Piping Plover	Alkaline/ Saltwater	Beach/ Peninsula	Open/ Salt Flats/ Sand/ Gravel	None	Sparse	Semicolonial
Charadrius montanus	Mountain Plover	-	Pasture/ Prairie	Open/ Vegetated	Short	Sparse	Semicolonial
Gallinago delicata	Wilson's Snipe	Freshwater	Upland/ Meadow – wet	Closed/ Vegetated	Medium	Dense	Solitary
Haematopus bachmani	Black Oystercatcher	Saltwater	Beach	Sand/ Gravel	None	None/Sparse	Semicolonial
Jacana spinosa	Northern jacana	Freshwater	Wetlands	Open/ Floating Vegetation	Short/Medium	Sparse/ Moderate	Polyandrous
Limosa fedoa	Marbled Godwit	Freshwater/ Saltwater	Upland	Open/ Vegetated	Medium	Moderate	Solitary
Numenius americanus	Long-billed Curlew	Freshwater	Upland/ Pasture	Open/ Vegetated	Short	Moderate	Solitary
Phalaropus tricolor	Wilson's Phalarope	Freshwater	Upland/ Meadow- wet	Closed/ Vegetated	Medium	Moderate	Solitary
Recurvirostra americana	American Avocet	Alkaline/ Saltwater/ Freshwater	Beach/ Peninsula	Open/ Exposed Soil	Short	Sparse	Semicolonial
Scolopax minor	American Woodcock	-	Forest – young	Open/ Forested/ Vegetated	Short	Moderate	Polygynous
Tringa melanoleuca	Greater Yellowlegs	-	Bog/ Forest	Open/ Forested	Short/Medium/ Tall	Moderate	Solitary
Tringa semipalmata	Willet	Freshwater/ Saltwater	Upland/ Prairie (interior); Upland/ Salt-marsh (coastal)	Open/ Vegetated	Medium	Short/ Moderate	Solitary
Tringa solitaria	Solitary Sandpiper	Freshwater	Forest	Forested	Tall	Moderate/ Dense	Solitary

Appendix 6. Nesting characteristics in non-Arctic or sub-Arctic habitats (cont.)

BREED IN NORTH, CENTRAL, AND SOUTH AMERICA							
Scientific name	English name	Primary Ecosystem	Principle Breeding Habitat	Nesting Substrate	Nesting - Vegetation Height	Nesting - Vegetation Density	Nesting Behavior
Burhinus bistriatus	Double-striped Thick-knee	Upland	Grassland/ Pasture	Open/ Vegetated	Short/Medium	Sparse/ Moderate	Solitary
Charadrius collaris	Collared Plover	Freshwater/ Saltwater	Beach	Open/ Vegetated/ Sand	None/ Short	None/Sparse	Semicolonial
Charadrius nivosus	Snowy Plover	Alkaline/ Saltwater	Beach/ Upland	Open/ Salt Flats/ Gravel/ Sand/ Exposed Soil	None	Sparse	Semicolonial
Charadrius vociferus	Killdeer	Freshwater/ Saltwater	Upland/ Beach	Open/ Exposed Soil/ Rocky	None/Short	Sparse	Solitary
Charadrius wilsonia	Wilson's Plover	Saltwater	Beach/ Saltmarsh	Open/ Sand	Short	Sparse	Solitary
Haematopus ater	Blackish Oystercatcher	Saltwater	Beach	Sand/ Gravel	None	None/Sparse	Semicolonial
Haematopus palliatus	American Oystercatcher	Saltwater	Beach/ Saltmarsh	Open/ Sand/ Exposed Soil	Sone	Sparse	Semicolonial
Himantopus mexicanus	Black-necked Stilt	Freshwater/ Saltwater	Beach/ Peninsula (in-terior); Island/ Open Flats/ Saltmarsh (coastal)	Open/ Vegetated	Short	Sparse	Semicolonial
Jacana jacana	Wattled Jacana	Freshwater	Wetlands	Open/ Floating Vegetation	Short/Medium (floating)	Sparse/ Moder-ate (floating)	Polyandrous

BREED IN SOUTH AMERICA								
Scientific name	English name	Primary Ecosystem	Principle Breeding Habitat	Nesting Substrate	Nesting - Vegetation Height	Nesting - Vegetation Density	Nesting Behavior	Altitude (m)
Attagis gayi	Rufous-bellied Seedsnipe	Upland	Slope - barren	Open/ Vegetated	None/Short	Sparse/ Moderate	Solitary	1000-5500
Attagis malouinus	White-bellied Seedsnipe	Upland	Slope - barren	Open/ Vegetated	None/Short	Sparse	Solitary	650-2000
Burhinus superciliaris	Peruvian Thick-knee	-	Slope/ Grassland - dry	Open/ Vegetated	None/Short	Sparse/ Moderate	Solitary	-
Charadrius alticola	Puna Plover	Freshwater/ Saltwater	High plateau	Open/ Vegetated	Short	Sparse	Solitary	2400-5000

Appendix 6. Nesting characteristics in non-Arctic or sub-Arctic habitats (cont.)

BREED IN SOUTH AMERICA								
Scientific name	English name	Primary Ecosystem	Principle Breeding Habitat	Nesting Substrate	Nesting - Vegetation Height	Nesting - Vegetation Density	Nesting Behavior	Altitude (m)
Charadrius falklandicus	Two-banded Plover	Freshwater/ Saltwater	Beach/ Grassland	Open/ Vegetated	None/Short	None/ Sparse	Solitary	-
Charadrius modestus	Rufous-chested Dotterel	Freshwater/ Saltwater	Grassland/ Upland	Open/ Vegetated/ Rocky	Short/ Medium	Sparse/ Moderate	Solitary	-
Gallinago andina	Puna Snipe	Upland/ Freshwater	Marsh/ Puna	Open/ Vegetated	Medium	Dense	Solitary	2000-5000
Gallinago imperialis	Imperial Snipe	Upland	Humid Treeline	Closed/ Vegetated	Medium/ High	Dense	Solitary	2745-3800
Gallinago jamesoni	Andean Snipe	Upland/ Freshwater	Slope - grassy	Open/ Vegetated	Short/ Medium	Sparse/ Dense	Solitary	2100-3800
Gallinago nobilis	Noble Snipe	Upland	Wetland - grassy	Closed/ Vegetated	Short/ Medium	Sparse/ Dense	Solitary	2500-3900
Gallinago paraguaiae	South American Snipe	Upland/ Freshwater	Wetland - grassy	Closed/ Vegetated	Medium/High	Dense	Solitary	-
Gallinago stricklandii	Fuegian Snipe	Freshwater	Wetland - grassy	Closed/ Vegetated	Short	Sparse	Solitary	-
Gallinago undulata	Giant Snipe	Upland/ Freshwater	Wetland - grassy	Closed/ Vegetated	Medium/High	Moderate/ Dense	Solitary	-
Haematopus leucopodus	Magellanic Oystercatcher	Freshwater/ Saltwater	Beach/ Upland	Open/ Sand	None/Short	Sparse	Semicolonial	-
Hoploxyp-terus cayanus	Pied Lapwing	Freshwater	River Beach/ Sandbanks	Open/ Sand	None	None	Solitary	-
Nycticryphes semicollaris	South American Painted-snipe	Freshwater	Wetland	Closed/ Vegetated	Short/ Medium	Dense	Mo-nogamous/ Semicolonial	-
Oreopholus ruficollis	Tawny-throated Dotterel	Freshwater	Beach	Open/ Sand/ Gravel	None/Short	Sparse	Solitary	-
Phegornis mitchellii	Diademed Sandpiper-Plover	Freshwater	Grassland-Puna	Open/ Vegetated/ Rocky	Short/ Medium	Sparse/ Moderate	Solitary/ Semicolonial	3500-5000
Pluvianellus socialis	Magellanic Plover	Freshwater/ Brackish	Lake and Stream Edges	Open/ Exposed Soil	None	Sparse	Solitary	-
Recurvirostra andina	Andean Avocet	Alkaline/ Saltwater	Wetland	Open/ Exposed Soil	None/ Short	None/ Sparse	Semicolonial	>2500

Appendix 6. Nesting characteristics in non-Arctic or sub-Arctic habitats (cont.)

BREED IN SOUTH AMERICA								
Scientific name	English name	Primary Ecosystem	Principle Breeding Habitat	Nesting Substrate	Nesting - Vegetation Height	Nesting - Vegetation Density	Nesting Behavior	Altitude (m)
Thinocorus orbignyianus	Grey-breasted Seedsnipe	Freshwater	Grassland	Open/ Vegetated	Short	Sparse/ Moderate	Solitary	400-5000
Thinocorus rumicivorus	Least Seedsnipe	-	Steppe	Open/ Exposed Soil	None	Sparse	Solitary	-
Vanellus chilensis	Southern Lapwing	Freshwater	Pasture/ Grassland/ Agricultural Fields	Open/ Vegetated	Short/ Medium	Sparse/ Moderate	Solitary/ Semicolonial	-
Vanellus resplendens	Andean Lapwing	Freshwater	Grassland	Open/ Exposed Soil/ Vegetated	Short/ Medium	Sparse/ Moderate	Solitary	2700-5000

Appendix 7. Shorebird Management Guide

This template can be used to draft a basic management guide that defines what species of shorebird use the site and when, the habitats they require, the plan to provide the resources those species need, and the methods to measure success. Not all sections will be relevant for every site. Cite literature where possible.

I. INTRODUCTION

Site Description

1. Site Name:
2. City, State or Province, Country:
3. Area (hectares):
4. Site Designations: (e.g. Ramsar, WHSRN, IBA etc)
5. General description of site: (e.g. general geography, habitat types, historic change)
6. Map: (Map of site with labeled subsections or areas, highlight areas of high shorebird use and areas where threats are focused, if possible.)
7. Ownership: (What organizations, agency, person(s) currently owns the site? What organizations own sites adjacent to or surrounding the site that may influence the success of this effort?)
8. Human Context Associated with Area: (What is the human context associated with the area? E.g. Is it an urban refuge, an agricultural region surrounded by low density population, a tourist attraction with high population influxes in the summer?)
9. Stakeholders: (What people or groups have vested interest in the site and what is their connection?)
10. Potential Partners: (This is a list of current and/ or potential partners that work with the site to achieve desired outcome)

II. CONSERVATION TARGETS

1. Description of Shorebird Use in the Area: (*General description of how shorebirds use the area, include any specific and unique details about* use)
2. Shorebird Species: (*Provide information about all the shorebirds that use the site*)
3. Priority Shorebird Species and Timing of Occurrence: (*This can include a description of the species that are National, state/provincial, regional, or site-specific priorities but needs to include a few specific species that will benefit from targeted conservation actions. Use the chart below to indicate the months of the year when an individual species or group of species are present in your area. Indicate if the species breeds in your area in the last column with a Y)*

Appendix 7. Shorebird Management Guide (cont.)

MONTH	1	2	3	4	5	6	7	8	9	10	11	12	B?
Species	J	F	M	A	M	J	J	A	S	O	N	D	

4. Habitats: (check off habitat types present at your site and provide additional details as needed)

Y?	PRIMARY HABITAT TYPE	SECONDARY HABITAT TYPE	DETAILS
	Coastal Tidal Wetlands	Estuarine Riverine	
	Inland Non-tidal Wetlands	Palustrine Lacustrine Riverine Saline	
	Managed Impoundments	Fresh Brackish Saline	
	Uplands	Grasslands Woodlands Grazed Lands	
	Agriculture and Aquaculture		

5. Other Priority Bird Species or Taxa: (e.g. cetaceans, amphibians, invertebrates)

6. Other Priorities at the Site: (e.g. economically viable ranching, ecotourism, etc.)

III. THREATS

These are the areas of greatest threat to shorebird populations as identified in Atlantic Flyway Shorebird Initiative and Pacific Americas Shorebird Conservation Strategy.

Select the threats that apply to your site, provide further details regarding the specifics of each threat at the site, and write-in other threats that are not listed.

- ❑ Residential and Commercial Development – Residential and Commercial Development refers to threats of habitat loss and change due to housing and urban development and expansion, commercial and industrial areas, and the spatial footprint of tourism and recreation areas. These types of development result in direct loss or alteration of all shorebird habitat types, particularly in coastal systems, freshwater wetlands, and saline lakes.

- ❑ Aquaculture and Agriculture - There are instances in which agriculture and aquaculture provide habitat for shorebirds, but the presence of agriculture and aquaculture represent a change from natural process to human driven processes.

- ❑ Invasive and or Problematic Species (Predation and Problematic Plants) – Threats from native and non-native animals and plants that have or are predicted to have negative effects on shorebirds.

- ❑ Human Intrusions and Disturbance - Human Intrusions and Disturbance refer to threats caused by humans from non-consumptive use and activities in natural areas that alter and disturb habitats. For shorebirds, these types of threats are often the results of recreational activities including but not limited to off-road vehicles, beach driving, birdwatching, kite-surfing, off-leash dogs, and other leisure activities on coastlines.

- ❑ Biological Resource Use (Hunting) – the legal and illegal take of shorebirds for recreation and consumptive uses.

- ❑ Natural Systems Modification - threats from actions that degrade or alter natural processes and environments. For shorebirds, this can include changes to coastal systems through coastal engineering, river diversions, and dredging, in tidal systems through diking and reduced tidal flow, in upland and grassland habitats through suppression of fire and other natural disturbances that maintained short grass habitats, and in freshwater wetlands and riverine habitats through development of impoundments and diversions.

- ❑ Climate change - threats from climate change will vary by location but can include sea level rise, shifting habitats, increased climate variability, trophic mismatch.

- ❑ Other

IV. OBJECTIVES

Objectives are the desired results or outcomes of a particular set of activities. *The management guide can have multiple objectives. List the objectives you seek to achieve with this management guide (can be one or many)*

EXAMPLE: To improve roosting habitat conditions for X priority shorebird species

EXAMPLE: To improve habitat conditions for X shorebirds on the beach during tourist season

V. CONSERVATION ACTIONS

Conservation actions are designed to achieve specific desired results. Some of the strategies (green) and actions (bulleted points) outlined in the Atlantic Flyway Shorebird Initiative and Pacific Americas Shorebird Conservation Strategy include the following but not all are listed here.

Select the actions you will use to address threats and help achieve the objectives at your site. If your actions are not listed, please add your own. Then, describe the associated activities that should be taken to achieve the desired objectives. Actions can be habitat specific and/ or threat-focused. If management actions require rotations or will occur in response to observed habitat states, describe that here. Different management actions can be applied to different areas within the site. In addition to conservation actions, be sure to include details about: habitat specific management, infrastructure improvements, community engagement, information gathering, workshops and meetings with stakeholders, timing of implementation / management schedule, monitoring, reflection and adaptive management.

❑ Manage Habitats (CMP Action 1. Land / Water Management)

- Reduce predation, disturbance, hunting pressure, loss of habitat to coastal engineering and development, invasive or problematic species
- Identify, protect, maintain, restore or enhance breeding habitats
- Identify, protect, maintain, restore or enhance migration or nonbreeding habitats
- Secure water for shorebird habitats
- Develop and implement best management practices for wetlands and agricultural lands

❑ Cultivate and Empower Conservation Constituencies (CMP Action 3. Awareness Raising)

- Engage volunteers in citizen science projects
- Engage citizens through education and/ or volunteer programs

❑ Develop Environmental and Wildlife Protection Policies (CMP Action 6. Conservation Designation & Planning and 7. Legal & Policy Frameworks)

- Develop and enforce off-road vehicle management plans with key agencies and landowners to limit disturbance of nesting shorebirds
- Promote policies to control dogs in important coastal shorebird sites

❑ Strengthen Compliance and Enforcement (CMP Action 4. Law Enforcement & Prosecution)

- Create an aware constituency that respects environmental and wildlife policies and laws and adherence to protected area management plans.
- Reduce illegal shooting of shorebirds through education and enforcement.
- Establish community-based committees and patrols to monitor and report violations of environmental and wildlife policies
- Manage beach access and use during the nesting season to protect key breeding areas

- ❑ Improve Knowledge of Present and Future Habitats (CMP Action 8. Research and Monitoring, 9. Education and Training)
  - Educate and influence decision-makers about using climate-smart conservation principles and nature-based approaches to improve coastal resilience
  - Create a science and adaptive management program, including establishing baseline data and considering climate change scenarios, to make management decisions.

VI. PERFORMANCE MEASURES AND MONITORING

How will you track your progress? What kind of monitoring program will be put in place? How will you know if your actions are effective?

1. Expected Results (What would be the result of the implementation of the above strategies and actions?)
2. Performance Metrics (Performance metrics may include:
   - ❑ # of shorebirds (baseline)
   - ❑ % increase in population
   - ❑ # young per pair
   - ❑ # Hectares enhanced, restored, protected, or under improved management
   - ❑ # Kilometers of shoreline enhanced, restored, protected, or under improved management
3. Monitoring Plan (See Monitoring chapter of the Management Manual for guidance and recommended literature.)

VII. TIMELINE

MANAGEMENT ACTIONS AND ACTIVITIES	MONTH											
	1	2	3	4	5	6	7	8	9	10	11	12
	J	F	M	A	M	J	J	A	S	O	N	D
ACTION 1												
Activity related to Action 1												
Activity related to Action 1												
Performance measures related to Action 1												
ACTION 2												
Activity related to Action 2												
Performance measures related to Action 2												

VIII. BUDGET

Describe the necessary budget requirements estimated to implement this management strategy. Will additional equipment be needed to implement these actions? Will additional staff be required, or will these actions be possible with the current staff? What additional skills or services might be necessary?

IX. LITERATURE CITED

Appendix 8. Migration strategies and species occurrence in the Americas

Dominant migration strategies (Long = Long distance >12,000km, Medium = Medium/intermediate distance 6,000 – 12,000 km, Short = short distance <6,000 km) as defined by Skagen and Knopf (1993). Migration distances from Blake 1997; Skagen and Knopf 1993; Canevari et al., 2001; O'Brien et al., 2006). Species occurrence as Breeding or Resident (B), Nonbreeding or Migratory (NB), Vagrant (V) in North and Central American and South America as defined by the American Ornithological Society and South American Classification Committee. Regions of breeding and nonbreeding seasons in Arctic, Subarctic, Temperate (if both North and South Temperate zones), North Temperate, South Temperate, Tropical, and Antarctic regions of the Americas from Birds of the World.

MIGRATION STRATEGY	SCIENTIFIC NAME	ENGLISH NAME	OCCURRENCE IN NORTH AND/OR CENTRAL AMERICA	OCCURRENCE IN SOUTH AMERICA	BREEDING REGION	NONBREEDING REGION
Long	*Arenaria interpres*	Ruddy Turnstone	B	NB	Arctic; Subarctic	Temperate; Tropics
	Bartramia longicauda	Upland Sandpiper	B	NB	Subarctic; North Temperate	South Temperate
	Calidris alba	Sanderling	B	NB	Arctic; Subarctic	Temperate; Tropics
	Calidris bairdii	Baird's Sandpiper	B	NB	Arctic; Subarctic	Tropics; South Temperate
	Calidris canutus	Red Knot	B	NB	Arctic; Subarctic	Temperate; Tropics
	Calidris fuscicollis	White-rumped Sandpiper	B	NB	Arctic	South Temperate
	Calidris himantopus	Stilt Sandpiper	B	NB	Arctic; Subarctic	Temperate; Tropics
	Calidris melanotos	Pectoral Sandpiper	B	NB	Arctic; Subarctic	Temperate; Tropics
	Calidris pusilla	Semipalmated Sandpiper	B	NB	Arctic; Subarctic	Tropics; South Temperate
	Calidris subruficollis	Buff-breasted Sandpiper	B	NB	Arctic	South Temperate
	Limosa haemastica	Hudsonian Godwit	B	NB	Arctic; Subarctic	South Temperate
	Limosa lapponica	Bar-tailed Godwit	B	NB	Arctic; Subarctic	South Pacific/ Eastern Hemisphere
	Numenius phaeopus	Whimbrel	B	NB	Arctic; Subarctic	Temperate; Tropics
	Numenius tahitiensis	Bristle-thighed Curlew	B	NB	Subarctic	South Pacific/ Eastern Hemisphere
	Phalaropus fulicarius	Red Phalarope	B	NB	Arctic; Subarctic	Temperate; Tropics
	Phalaropus lobatus	Red-necked Phalarope	B	NB	Arctic; Subarctic	Tropics
	Phalaropus tricolor	Wilson's Phalarope	B	NB	North Temperate	Tropics, South Temperate
	Pluvialis dominica	American Golden-Plover	B	NB	Arctic; Subarctic	South Temperate
	Pluvialis fulva	Pacific Golden-Plover	B	V	Arctic; Subarctic	North Temperate
Medium	*Actitis macularius*	Spotted Sandpiper	B	NB	Subarctic; North Temperate	Temperate; Tropics
	Arenaria melanocephala	Black Turnstone	B	V	Arctic; Subarctic	North Temperate

Appendix 8. Migration strategies and species occurrence in the Americas (cont.)

MIGRATION STRATEGY	SCIENTIFIC NAME	ENGLISH NAME	OCCURRENCE IN NORTH AND/OR CENTRAL AMERICA	OCCURRENCE IN SOUTH AMERICA	BREEDING REGION	NONBREEDING REGION
	Calidris alpina	Dunlin	B	NB	Arctic; Subarctic	North Temperate
	Calidris maritima	Purple Sandpiper	B	-	Arctic	North Temperate
	Calidris mauri	Western Sandpiper	B	NB	Arctic; Subarctic	North Temperate; Tropics
	Calidris minutilla	Least Sandpiper	B	NB	Arctic; Subarctic	North Temperate; Tropics
	Calidris ptilocnemis	Rock Sandpiper	B	-	Subarctic	Subarctic; North Temperate
	Calidris virgata	Surfbird	B	NB	Subarctic	Temperate; Tropics
	Charadrius falklandicus	Two-banded Plover	-	B	South Temperate	South Temperate
	Charadrius modestus	Rufous-chested Dotterel	-	B	South Temperate	South Temperate
	Charadrius semipalmatus	Semipalmated Plover	B	NB	Arctic; Subarctic	Temperate; Tropics
	Chionis albus	Snowy Sheathbill	-	NB	Antarctic	Antarctic; South Temperate
	Himantopus mexicanus	Black-necked Stilt	B	B	Tropics; Temperate	Temperate; Tropics
	Limnodromus griseus	Short-billed Dowitcher	B	NB	Subarctic	North Temperate; Tropics
	Limnodromus scolopaceus	Long-billed Dowitcher	B	V	Arctic; Subarctic	North Temperate; Tropics
	Pluvialis squatarola	Black-bellied Plover	B	NB	Arctic; Subarctic	Temperate; Tropics
	Tringa flavipes	Lesser Yellowlegs	B	NB	Arctic; Subarctic	Temperate; Tropics
	Tringa incana	Wandering Tattler	B	NB	Arctic; Subarctic	North Temperate; Tropics
	Tringa melanoleuca	Greater Yellowlegs	B	NB	Subarctic; North Temperate	Temperate; Tropics
	Tringa solitaria	Solitary Sandpiper	B	NB	Subarctic; North Temperate	Temperate; Tropics
Non	*Attagis gayi*	Rufous-bellied Seedsnipe	-	B	Tropics; South Temperate	Tropics; South Temperate
	Attagis malouinus	White-bellied Seedsnipe	-	B	South Temperate	South Temperate
	Burhinus bistriatus	Double-striped Thick-knee	B	B	Tropics	Tropics
	Burhinus superciliaris	Peruvian Thick-knee	-	B	Tropics	Tropics
	Charadrius collaris	Collared Plover	B	B	Tropics; South Temperate	Tropics; South Temperate
	Gallinago imperialis	Imperial Snipe	-	B	Tropics	Tropics

Appendix 8. Migration strategies and species occurrence in the Americas (cont.)

MIGRATION STRATEGY	SCIENTIFIC NAME	ENGLISH NAME	OCCURRENCE IN NORTH AND/OR CENTRAL AMERICA	OCCURRENCE IN SOUTH AMERICA	BREEDING REGION	NONBREEDING REGION
	Gallinago jamesoni	Andean Snipe	-	B	Tropics	Tropics
	Gallinago nobilis	Noble Snipe	-	B	Tropics	Tropics
	Gallinago stricklandii	Fuegian Snipe	-	B	South Temperate	South Temperate
	Gallinago undulata	Giant Snipe	-	B	Tropics; South Temperate	Tropics; South Temperate
	Hoploxypterus cayanus	Pied Lapwing	-	B	Tropics; South Temperate	Tropics; South Temperate
	Jacana jacana	Wattled Jacana	B	B	Tropics; Temperate	Tropics; Temperate
	Jacana spinosa	Northern jacana	B	-	Tropics	Tropics
	Nycticryphes semicollaris	South American Painted-snipe	-	B	South Temperate	South Temperate
	Recurvirostra andina	Andean Avocet	-	B	Tropics; South Temperate	Tropics; South Temperate
Partial	*Gallinago paraguaiae*	South American Snipe	-	B	Tropics; South Temperate	Tropics; South Temperate
Short	*Charadrius melodus*	Piping Plover	B	V	North Temperate	North Temperate
	Charadrius montanus	Mountain Plover	B	-	North Temperate	North Temperate
	Charadrius nivosus	Snowy Plover	B	NB/B	Tropics; Temperate	Tropics; Temperate
	Charadrius vociferus	Killdeer	B	NB/B	Subarctic; North Temperate; Tropics	North Temperate; Tropics
	Charadrius wilsonia	Wilson's Plover	B	NB/B	North Temperate; Tropics	North Temperate; Tropics
	Gallinago delicata	Wilson's Snipe	B	NB	Arctic; Subarctic; North Temperate	North Temperate; Tropics
	Haematopus ater	Blackish Oystercatcher	B	B	Tropics; South Temperate	Tropics; South Temperate
	Haematopus bachmani	Black Oystercatcher	B	-	Subarctic; North Temperate	Subarctic; North Temperate
	Haematopus palliatus	American Oystercatcher	B	B	Tropics; Temperate	Tropics; Temperate
	Haematopus leucopodus	Magellanic Oystercatcher	-	B	South Temperate	South Temperate
	Limosa fedoa	Marbled Godwit	B	NB	Subarctic; North Temperate	North Temperate; Tropics
	Numenius americanus	Long-billed Curlew	B	NB	North Temperate	North Temperate; Tropics
	Pluvianellus socialis	Magellanic Plover	-	B	South Temperate	South Temperate
	Recurvirostra americana	American Avocet	B	V	North Temperate; Tropics	North Temperate; Tropics
	Scolopax minor	American Woodcock	B	-	North Temperate	North Temperate

Appendix 8. Migration strategies and species occurrence in the Americas (cont.)

MIGRATION STRATEGY	SCIENTIFIC NAME	ENGLISH NAME	OCCURRENCE IN NORTH AND/OR CENTRAL AMERICA	OCCURRENCE IN SOUTH AMERICA	BREEDING REGION	NONBREEDING REGION
	Thinocorus rumicivorus	Least Seedsnipe	-	B	Tropics; South Temperate	Tropics; South Temperate
	Tringa semipalmata	Willet	B	NB	North Temperate	North Temperate; Tropics
	Vanellus chilensis	Southern Lapwing	NB	B	Tropics; South Temperate	Tropics; South Temperate
Altitudinal	*Charadrius alticola*	Puna Plover	-	B	Tropics	Tropics
	Gallinago andina	Puna Snipe	-	B	Tropics	Tropics
	Oreopholus ruficollis	Tawny-throated Dotterel	-	B	Tropics; South Temperate	Tropics; South Temperate
	Phegornis mitchellii	Diademed Sandpiper-Plover	-	B	Tropics; South Temperate	Tropics; South Temperate
	Thinocorus orbignyianus	Grey-breasted Seedsnipe	-	B	Tropics; South Temperate	Tropics; South Temperate
	Vanellus resplendens	Andean Lapwing	-	B	Tropics; South Temperate	Tropics; South Temperate

Appendix 9. Documented invertebrate prey items

Data collected through shorebird behavioral observations, analysis of feces or regurgitated pellets, or gut sampling of predated or harvested specimens collected in associated habitats (CTW-Coastal Tidal Wetlands, INW – Inland Nontidal Wetlands, MI – Managed Impoundments, U – Uplands, AA – Agriculture and Aquaculture) and subhabitats (e.g. Estuarine, Marine). This is not a comprehensive list of all invertebrates that may be available to shorebirds, but rather the confirmed consumed invertebrate taxa, genera, and species, based on available literature.

o - observation is from the more general habitat category x - observation was collected within a subhabitat

CTW		INW				MI		U		AA								
ESTUARINE	MARINE	PALUSTRINE	LACUSTRINE	RIVERINE	SALINE	FRESHWATER	BRACKISH	GRAZED LANDS	GRASSLANDS	RICE	AGRICULTURE ONLY	PHYLUM	CLASS	ORDER	FAMILY	GENUS SPECIES	COMMON NAME	SOURCES
		x	x			x						Annelida	Hirudinea				Leeches	Smith et al 2012
			x			o								Arhynchobdel-lida	Hirudinidae		Proboscisless Leeches	Davis and Smith 1998, Anderson and Smith 1998
			x			o								Rhynchobdel-lida	Glossiphoniidae		Freshwater Jawless Leeches	Anderson and Smith 1998
			x				x	x			x		Oligochaeta				Earthworms	Cummins and Wuycheck 1971, Anderson and Smith 1998, Davis and Smith 1998, Ausden et al 2003, Dybala et al 2017
											x			Haplotaxida	Lumbricidae	*Lumbricus*	Earthworms	Evans Ogden et al 2005
x			o			o				o			Polychaeta				Polychaetes	Cummins and Wuycheck 1971, Evans Ogden et al 2005, Dybala et al 2017
x	x													Capitellida	Capitellidae	*Capitella capitata*		Stenzel et al 1976
x	x													Eunicida	Lumbrineridae	*Scoletoma zonata*		Stenzel et al 1976
	x													Glyceriformia	Glyceridae	*Glycera americana*		D'amico et al 2004, Hernández 2007
	x													Phyllodocida	Nereididae	*Laeonereis actua*		Hernández 2007

Appendix 9. Documented invertebrate prey items (cont.)

CTW		INW				MI		U		AA								
ESTUARINE	MARINE	PALUSTRINE	LACUSTRINE	RIVERINE	SALINE	FRESHWATER	BRACKISH	GRAZED LANDS	GRASSLANDS	RICE	AGRICULTURE ONLY	PHYLUM	CLASS	ORDER	FAMILY	GENUS SPECIES	COMMON NAME	SOURCES
x														Phyllodocida	Nereididae	*Perinereis gualpensis*		Velásquez and Navarro 1993
o														Phyllodocida	Nereididae	*Hediste*	Nereid Polychaete Worms	Skagen and Oman 1996, Ausden et al 2003
	x													Scolecida	Travisiidae	*Travisia olens*		D'amico et al 2004, Hernández 2007, Musmeci 2007
			o			x		x	x			Arthropoda	Arachnida	Araneae			Spiders	Ausden et al 2003, Isaach et al 2005, Smith et al 2012, Dybala et al 2017
					x								Branchiopoda	Anostraca	Artemiidae	*Artemia*	Brine shrimp (adult + sub-adult)	Jehl 1988, Caudell and Conover 2006
			x										Copepoda				Copepod	Davis and Smith 1998, Dybala et al 2017
o			o			o				o			Crustacea					Cummins and Wuycheck 1971
			x			o								Anostraca			Fairy Shrimp	Anderson and Smith 1998, Davis and Smith 1998
			x			o								Cladocera			Water Fleas	Sugden 1973, Anderson and Smith 1998, Davis and Smith 1998, Smith et al 2012, Dybala et al 2017
			x			o								Diplostraca	Leptesheriidae		Clam Shrimp	Anderson and Smith 1998, Davis and Smith 1998
			x											Isopoda			Isopods	Anderson and Smith 1998, Ausden et al 2003
			x			o								Notostraca	Triopsidae		Tadpole Shrimp	Anderson and Smith 1998, Davis and Smith 1998

Appendix 9. Documented invertebrate prey items (cont.)

CTW		INW				MI		U		AA								
ESTUARINE	MARINE	PALUSTRINE	LACUSTRINE	RIVERINE	SALINE	FRESHWATER	BRACKISH	GRAZED LANDS	GRASSLANDS	RICE	AGRICULTURE ONLY	PHYLUM	CLASS	ORDER	FAMILY	GENUS SPECIES	COMMON NAME	SOURCES
	x	x	x		x									Diptera	Dolichopodidae		Long-legged flies (larvae)	Alexander et al 1996, Skagen and Oman 1996, Smith and Nol 2000, Ausden et al 2003
			x											Diptera	Tipulidae		Large Crane Flies (larvae)	Driver 1981, Skagen and Oman 1996, Ausden et al 2003, Evans Ogden et al 2005
	o	x	x		x	o								Diptera	Chironomidae		Chironomid (larvae)	Sugden 1973, Alexander et al 1996
								x	x					Diptera	Bibionidae		March Flies	Ausden et al 2003
								x	x					Diptera	Stratiomyidae		Soldier Flies	Cummins and Wuycheck 1971, Ausden et al 2003
		x	x		x	o								Diptera	Ephydridae	*Ephydra*	Brine flies	Alexander et al 1996, Anderson and Smith 1998, Caudell and Conover 2006
		x	x		x									Diptera	Ceratopogonidae		Biting Midges (larvae)	Alexander et al 1996
											x	Arthropoda	Insecta	Diptera - Cyclorrhapha			Muscoid Flies and Allies	Evans Ogden et al 2005
		x	x			x								Ephemeroptera			Mayflies	Cummins and Wuycheck 1971, Davis and Smith 1998, Smith et al 2012, Dybala et al 2017
o			o			o								Hemiptera			True Bugs, Hoppers, Aphids, and Allies	Skagen and Oman 1996, Smith et al 2012
										x				Hemiptera	Veliidae		Ripple Bugs	Cifuentes and Renjifo 2016
		x	x	x	x		x							Hemiptera	Corixidae		Water Boatmen	Alexander et al 1996, Anderson and Smith 1998, Caudell and Conover 2006, Dybala et al 2017,

Appendix 9. Documented invertebrate prey items (cont.)

CTW		INW				MI		U		AA								
ESTUARINE	MARINE	PALUSTRINE	LACUSTRINE	RIVERINE	SALINE	FRESHWATER	BRACKISH	GRAZED LANDS	GRASSLANDS	RICE	AGRICULTURE ONLY	PHYLUM	CLASS	ORDER	FAMILY	GENUS SPECIES	COMMON NAME	SOURCES
x				o		x		x	x			Arthropoda	Insecta	Coleoptera			Beetles (adult and larvae)	Sugden 1973, Stenzel et al 1976, Isaach et al 2005, Smith et al 2012
			x											Coleoptera	Chrysomelidae		Leaf Beetles	Cummins and Wuycheck 1971, Skagen and Oman 1996
	x													Coleoptera	Scarabaeidae	*Dyscinetus*	Rice Beetles	Alemany 2000
	x													Coleoptera	Tenibrionidae	*Phalerisida maculata*	Darkling Beetles	Castro et al 2009
			x											Coleoptera	Staphylinidae		Rove Beetles	Davis and Smith 1998
				o										Coleoptera	Carabidae		Carabid Beetles	Skagen and Oman 1996, Evans Ogden et al 2005
				o										Coleoptera	Elateridae		Click Beetles (adult and larvae)	Ausden et al 2003
		x	x		x									Coleoptera	Hydrophilidae		Water Scavenger Beetles	Alexander et al 1996, Davis and Smith 1998, Dybala et al 2017
		x	x		x		o							Coleoptera	Dytiscidae		Predaceous Diving Beetles	Anderson and Smith 1998, Davis and Smith 1998, Dybala et al 2017
								x	x					Coleoptera	Curculionidae	*Naupactus*	White-fringed Weevils	Alfaro et al 2015
		x	x		x									Coleoptera	Haliplidae		Crawling Water Beetles (larvae)	Alexander et al 1996
x	x	x	x			x						Arthropoda	Insecta	Diptera			Flies (adult, larvae, and pupae)	Stenzel et al 1976, Isaach et al 2005,Smith et al 2012
	x													Diptera	Canacidae		Beach Flies (larvae)	Smith and Nol 2000

Appendix 9. Documented invertebrate prey items (cont.)

CTW		INW				MI		U		AA								
ESTUARINE	MARINE	PALUSTRINE	LACUSTRINE	RIVERINE	SALINE	FRESHWATER	BRACKISH	GRAZED LANDS	GRASSLANDS	RICE	AGRICULTURE ONLY	PHYLUM	CLASS	ORDER	FAMILY	GENUS SPECIES	COMMON NAME	SOURCES
								x	x					Orthoptera	Acrididae	*Ronderosia*	Spur-throated Grasshoppers	Alfaro et al 2015
			o			x								Trichoptera			Caddisflies	Cummins and Wuycheck 1971, Smith et al 2012, Gerwig et al 2016
x	x											Arthropoda	Malacostraca	Amphipoda	Talitridae		Sandhoppers and Landhoppers	Stenzel et al 1976
x	x														Hyalellidae	*Allorchestes angusta*		Stenzel et al 1976
x	x														Ampithoidae	*Ampithoe*		Stenzel et al 1976
x	x														Aoridae	*Grandidier-ella japonica*		Stenzel et al 1976
o															Gammaridae		Gammarid and Corophorid amphipods	Skagen and Oman 1996
x															Talitridae	*Traskorches-tia traskiana*	Pacific Beach Hopper	Stenzel et al 1976
	x														Corophiidae	*Corophium volutator*		Skagen and Oman 1996, Gerwing et al 2016
	x														Aoridae	*Grandi-dierella bonnieroides*		McNeil et al 1995
x	x													Decapoda	Portunidae	*Carcinus marinus*	European Green Crab	Skagen and Oman 1996, Ausden et al 2003
x	x														Callianassidae	*Callianassa*	Ghost Shrimps	Leeman et al 2001
x	x														Callianassidae	*Neotrypaea californiensis*	Bay Ghost Shrimp	Stenzel et al 1976

Appendix 9. Documented invertebrate prey items (cont.)

CTW		INW				MI		U		AA								
ESTUARINE	MARINE	PALUSTRINE	LACUSTRINE	RIVERINE	SALINE	FRESHWATER	BRACKISH	GRAZED LANDS	GRASSLANDS	RICE	AGRICULTURE ONLY	PHYLUM	CLASS	ORDER	FAMILY	GENUS SPECIES	COMMON NAME	SOURCES
			x			o								Hemiptera	Notonectidae		Backswimmers	Anderson and Smith 1998, Davis and Smith 1998
o		o				o								Hymenoptera				Skagen and Oman 1996
								x	x					Hymenoptera	Formicidae	*Camponotus*	Carpenter and Sugar Ants	Alfaro et al 2015
								x	x					Hymenoptera	Formicidae	*Acromyrmex*	Leaf-cutter Ants	Alfaro et al 2015
			x			o								Lepidoptera			Lepidoptera (larvae/ caterpillars)	Anderson and Smith 1998, Ausden et al 2003, Isaach et al 2005
			x											Odonata	Coenagrionidae		Narrow-winged Damselflies (nymphs)	Cummins and Wuycheck 1971, Davis 1996, Davis and Smith 1998
				o										Odonata			Dragonflies and Damselflies	Dybala et al 2017
			x			o								Odonata	Libellulidae		Skimmers (nymphs)	Cummins and Wuycheck 1971, Anderson and Smith 1998, Davis and Smith 1998
								x						Orthoptera	Acridoidea		Grasshoppers	Isaach et al 2005
		x	x		x									Orthoptera	Acrididae		Short-horned Grasshoppers	Alexander et al 1996
								x	x					Orthoptera	Acrididae	*Borellia bruneri*	Stidulating Slant-faced Grasshoppers	Alfaro et al 2015
								x	x					Orthoptera	Acrididae	*Dichroplus elongatus*	Spur-throated Grasshoppers	Alfaro et al 2015
								x	x					Orthoptera	Acrididae	*Dichroplus pratensis*	Spur-throated Grasshoppers	Alfaro et al 2015

Appendix 9. Documented invertebrate prey items (cont.)

CTW		INW				MI		U		AA								
ESTUARINE	MARINE	PALUSTRINE	LACUSTRINE	RIVERINE	SALINE	FRESHWATER	BRACKISH	GRAZED LANDS	GRASSLANDS	RICE	AGRICULTURE ONLY	PHYLUM	CLASS	ORDER	FAMILY	GENUS SPECIES	COMMON NAME	SOURCES
x	x													Tanaidacea	Leptocheliidae	*Leptochelia dubia*		Stenzel et al 1976
	x											Arthropoda	Merostomata	Xiphosurida	Limulidae	*Limulus*	Horseshoe Crab (eggs)	Skagen and Oman
o		o								o			Ostracoda				Seed Shrimp, Ostracods	Skagen and Oman 1996, Smith et al 2012, Dybala et al 2017
	x												Ostracoda	Myodocopida	Cylindroleberi-didae	*Cycloleberis poulseni*		Hernández 2007
		x	x			x						Mollusca	Bivalvia				Molluscs	Smith et al 2012
x	x													Cardiida	Tellinidae	*Macoma*		Stenzel et al 1976, Evans Ogden et al 2005
x	x													Cardiida	Tellinidae	*Tellina/ Ardeamya petitiana*		Hernández 2007, Fedrizzi et al 2016
x	x														Cardiidae	*Clinocardium nuttallii*	Nuttall's Cockle	Stenzel et al 1976
	x													Imparidentia	Lutrariinae	*Darina solenoides*		D'amico et al 2004, Espoz 2007, Hernández 2007
x	x													Myida	Myidae	*Cryptomya californica*	California Softshell	Stenzel et al 1976
	x													Mytilida	Mytilidae	*Brachidontes rodriguezii*		Gonzalez et al 1996
	x														Mytilidae	*Mytilus edulis*		Baker et al 1996
o														Mytilidae		*True Mussels*	Cummins and Wuy-check 1971, Skagen and Oman 1996	

Appendix 9. Documented invertebrate prey items (cont.)

CTW		INW				MI		U		AA								
ESTUARINE	MARINE	PALUSTRINE	LACUSTRINE	RIVERINE	SALINE	FRESHWATER	BRACKISH	GRAZED LANDS	GRASSLANDS	RICE	AGRICULTURE ONLY	PHYLUM	CLASS	ORDER	FAMILY	GENUS SPECIES	COMMON NAME	SOURCES
x	x														Cancridae	*Romaleon antennarium*	Pacific Rock Crab	Stenzel et al 1976
x	x														Cancridae	*Metacarcinus magister*	Dungeness Crab	Stenzel et al 1976
x	x														Grapsidae	*Pachygrap-sus crassipes*	Striped Shore Crab	Stenzel et al 1976
x															Ocypodidae	*Minuca rapax*	Mudflat Fiddler Crab	Fedrizzi et al 2016
x															Ocypodidae	*Uca maracoani*	Brazilian Fiddler Crab	Fedrizzi et al 2016
x															Ocypodidae	*Minuca mordax*	Biting Fiddler Crab	Fedrizzi et al 2016
	x														Ocypodidae	*Leptuca thayeri*	Atlantic Mangrove Fiddler Crab	Smith and Nol 2000
x	x														Paguridae	*Pagurus*		Stenzel et al 1976
	x														Penaeidae	*Penaeus*	Penaeid Shrimp	McNeil et al 1995
x	x														Upogebiidae	*Upogebia pugettensis*	Blue Mud Shrimp	Stenzel et al 1976
x	x														Varunidae	*Hemigrapsus oregonensis*	Yellow Shore Crab	Stenzel et al 1976, Leeman et al 2001
x	x														Varunidae	*Hemigrapsus nudus*	Purple Shore Crab	Stenzel et al 1976
	x														Varunidae	*Cyrtograspus affinis*		Hernández 2007, Hernández and Bala 2016
	x													Isopoda	Sphaeromatidae	*Exos-phaeroma*		Hernández 2007, Hernández and Bala 2016

Appendix 9. Documented invertebrate prey items (cont.)

CTW		INW				MI		U		AA								
ESTUARINE	MARINE	PALUSTRINE	LACUSTRINE	RIVERINE	SALINE	FRESHWATER	BRACKISH	GRAZED LANDS	GRASSLANDS	RICE	AGRICULTURE ONLY	PHYLUM	CLASS	ORDER	FAMILY	GENUS SPECIES	COMMON NAME	SOURCES
			x			o								Hygrophila	Planorbidae		Ramshorn Snails	Cummins and Wuycheck 1971, Anderson and Smith 1998, Davis and Smith 1998, Dybala et al 2017
			x			o								Hygrophila	Lymnaeidae		Pond Snails	Sugden 1973, Anderson and Smith 1998
x	x													Littorinimor-pha	Littorinidae	*Littorina scutulata*	Checkered Periwinkle	Stenzel et al 1976
x	x														Littorinidae	*Lacuna*	Lacuna Snails	Stenzel et al 1976
	x														Cochliopidae	*Heleobia australis*		Alemany 2000
o															Hydrobiidae		Mud Snails	Skagen and Oman 1996
o														Mesogas-tropoda	Nassariidae		Nassa Mud Snails	Skagen and Oman 1996
			x			o								Stylom-matophora			Common Land Snails and Slugs	Anderson and Smith 1998
		x	x			x											Nematodes	Smith et al 2012

Appendix 9. Documented invertebrate prey items (cont.)

CTW		INW				MI		U		AA								
ESTUARINE	MARINE	PALUSTRINE	LACUSTRINE	RIVERINE	SALINE	FRESHWATER	BRACKISH	GRAZED LANDS	GRASSLANDS	RICE	AGRICULTURE ONLY	PHYLUM	CLASS	ORDER	FAMILY	GENUS SPECIES	COMMON NAME	SOURCES
x	x													Venerida	Veneridae	*Gemma gemma*	Amethyst Gem Clam	Stenzel et al 1976
x	x														Veneridae	*Nutricola tantilla*		Stenzel et al 1976
x	x														Veneridae	*Leukoma staminea*	Pacific Littleneck Clam	Stenzel et al 1976
x															Cardiidae	*Cardium*	Cockles	Fedrizzi et al 2016
	x														Mesodesmatidae	*Mesodesma donacium*	Surf Clams (siphons)	Castro et al 2009
o															Veneridae		Tellinid and Venerid Clams	Skagen and Oman 1996
	x														Donacidae	*Donax hanleyanus*		Harrington et al 1986, Fedrizzi et al 2016
		x	x			x						Mollusca	Gastropoda				Snails and Slugs	Smith et al 2012
x	x													Caenogas-tropoda	Potamididae	*Cerithide-opsis californica*	California Horn Snail	Stenzel et al 1976
x															Batillariidae	*Batillaria attramentaria*		St. Clair 2013
x															Cerithiidae	*Bittium*	Needle-Whelks	Evans Ogden et al 2005
			x			o								Hygrophila	Physidae		Bladder Snails	Anderson and Smith 1998, Davis and Smith 1998, Dybala et al 2017

Appendix 10. Energetic values for shorebird prey items

Energy content (per kg or g, wet, dry, and ash-free dry weight), assimilation of nutrients, net energy content (dry weight x assimilation rate), and crude percent protein of invertebrate prey items consumed by shorebirds, derived from multiple literature sources.

PHYLUM	CLASS	ORDER	FAMILY	GENUS	COMMON NAME	MJ/KG DRY	KJ/G DRY	KJ/G WET	KJ/G ASH-FREE DRY	ASSIMI-LATION	NEC	% PROTEIN	KCAL/G	SOURCES
Annelida	Hirudinea	Arhynchobdellida	Hirudinidae		Proboscisless Leeches							76.20	5.40	Davis and Smith 1998, Anderson and Smith 1998
		Rhynchobdellida	Glossiphoniidae		Freshwater Jawless Leeches							64.20	5.30	Anderson and Smith 1998
	Oligochaeta				Earthworms	21.31	23.34					62.00	5.40	Cummins and Wuycheck 1971, Anderson and Smith 1998, Davis and Smith 1998, Ausden et al 2003, Dybala et al 2017
	Polychaeta	Phyllodocida	Nereididae	*Hediste*	Neried Polychaete Worms		20.34	1059.00						Skagen and Oman 1996, Ausden et al 2003
				Laeonereis			13.70							Hernández 2007
		Scolecida	Travisiidae	*Travisia*			10.51							Hernández 2007
				Travisia			10.92							Hernández 2007
					Polychaetes	15.38	14.67							Cummins and Wuycheck 1971, Evans Ogden et al 2005, Dybala et al 2017
Arthropoda	Arachnida	Araneae			Spiders	21.81								Ausden et al 2003, Isacch et al 2005, Dybala et al 2017
	Bran-chiopoda	Anostraca	Artemiidae	*Artemia*	Brine shrimp (adults + sub-adults)		21.88			0.87	19.12			Jehl 1988, Caudell and Conover 2006
				Artemia	Brine shrimp (cysts)		23.51			0.52	12.18			Caudell and Conover 2006
	Copepoda				Copepods	24.12								Davis and Smith 1998, Dybala et al 2017
	Crustacea	Anostraca			Fairy Shrimp							49.70	5.10	Anderson and Smith 1998, Davis and Smith 1998

Appendix 10. Energetic values for shorebird prey items (cont.)

PHYLUM	CLASS	ORDER	FAMILY	GENUS	COMMON NAME	MJ/KG DRY	KJ/G DRY	KJ/G WET	KJ/G ASH-FREE DRY	ASSIMI-LATION	NEC	% PROTEIN	KCAL/G	SOURCES
		Cladocera			Water Fleas	22.07	11.35					47.60	4.80	Anderson and Smith 1998, Davis and Smith 1998, Dybala et al 2017
		Diplostraca	Leptesheriidae		Clam Shrimp							38.80	3.20	Anderson and Smith 1998, Davis and Smith 1998
		Isopoda			Isopods							42.90	4.60	Anderson and Smith 1998, Ausden et al 2003
		Notostraca	Triopsidae		Tadpole Shrimp							57.70	4.50	Anderson and Smith 1998, Davis and Smith 1998
							18.88	817.00	5369.00					Cummins and Wuycheck 1971
	Insecta	Coleoptera			(adults and larvae)		24.85							Sugden 1973, Stenzel et al 1976, Isacch et al 2005
			Chrysomelidae		Leaf Beetles							60.10	5.20	Cummins and Wuycheck 1971, Skagen and Oman 1996
			Staphylinidae		Rove Beetles									Davis and Smith 1998
			Hydrophilidae		Water Scavenger Beetles	22.99	22.49							Anderson and Smith 1998, Davis and Smith 1998, Dybala et al 2017
			Dytiscidae		Predaceous Diving Beetles	24.31								Anderson and Smith 1998, Davis and Smith 1998, Dybala et al 2018
					Predaceous Diving Beetles (adult)							64.64	6.00	Anderson and Smith 1998, Davis and Smith 1998, Dybala et al 2019
					Predaceous Diving Beetles (larvae)							73.07	5.30	Driver et al 1974, Alexander et al 1996, Davis and Smith 1998
Arthropoda	Arthropoda	Diptera	Tipulidae		Large Crane Flies (larvae)							43.80	5.40	Driver 1981, Skagen and Oman 1996, Ausden et al 2003, Evans Ogden et al 2005

Appendix 10. Energetic values for shorebird prey items (cont.)

PHYLUM	CLASS	ORDER	FAMILY	GENUS	COMMON NAME	MJ/KG DRY	KJ/G DRY	KJ/G WET	KJ/G ASH-FREE DRY	ASSIMI-LATION	NEC	% PROTEIN	KCAL/G	SOURCES
			Chironomidae		Chironomid (larvae)		18.02							Sugden 1973, Alexander et al 1996
					Chironomid (larvae)	19.51	23.80			0.73	17.37			Cummins and Wuycheck 1971, Skagen and Oman 1996, Dybala et al 2017
			Stratiomyidae		Soldier Flies		12.01							Cummins and Wuycheck 1971, Ausden et al 2003
			Ephydridae	*Ephydra*	Brine Flies, Shore Flies (adult)		22.64			0.87	19.79			Jehl 1988, Caudell and Conover 2006, Dybala et al 2017
					Brine Flies (larvae)	17.32	18.75			0.73	13.61	17.80	3.80	Anderson and Smith 1998, Alexander et al 1996, Caudell and Conover 2006
		Ephemeroptera			Mayflies	22.95	22.90							Cummins and Wuycheck 1971, Davis and Smith 1998, Dybala et al 2017
		Hemiptera	Corixidae		Water Boatmen		22.25							Sugden 1973
			Corixidae		Water Boatmen	22.59	23.60			0.90	21.17	59.50	5.30	Alexander et al 1996, Anderson and Smith 1998, Caudell and Conover 2006, Dybala et al 2017
			Notonectidae		Backswimmers							60.20	4.10	Anderson and Smith 1998, Davis and Smith 1998
		Lepidoptera			Lepidoptera (larvae/ caterpillars)							49.70	5.10	Anderson and Smith 1998, Ausden et al 2003, Isacch et al 2005
		Odonata	Coenagrionidae		Narrow-winged Damselflies (nymphs)		22.40					67.40	4.80	Cummins and Wuycheck 1971, Davis 1996, Davis and Smith 1998
					Dragonflies and Damselflies	22.43								Dybala et al 2017
			Libellulidae		Skimmers (nymphs)		21.34					64.60	5.10	Cummins and Wuycheck 1971, Anderson and Smith 1998, Davis and Smith 1998

Appendix 10. Energetic values for shorebird prey items (cont.)

PHYLUM	CLASS	ORDER	FAMILY	GENUS	COMMON NAME	MJ/KG DRY	KJ/G DRY	KJ/G WET	KJ/G ASH-FREE DRY	ASSIMI-LATION	NEC	% PROTEIN	KCAL/G	SOURCES
		Trichoptera			Caddisflies		20.93							Cummins and Wuycheck 1971, Gerwig et al 2016
	Malacos-traca	Amphipoda	Gammaridae		Gammarid and Corophorid Amphipods									Skagen and Oman 1996
		Isopoda	Sphaeromatidae	*Exos-phaeroma*		5.5								Hernández 2007
	Ostracoda				Seed Shrimp, Ostracods	24.83								Skagen and Oman 1996, Dybala et al 2017
Mollusca	Bivalvia	Mytiloida	Mytilidae		True Mussels		19.26							Cummins and Wuycheck 1971, Skagen and Oman 1996
		Imparidentia	Lutrariinae	*Darina*			22.00							Hernández 2007
		Imparidentia	Lutrariinae	*Darina*			20.18					50.16	5.30	Hernández 2007
		Cardiida	Tellinidae	*Tellina/ Ardeamya*		11.60						41.90	4.70	Hernández 2007
	Gastropoda	Hygrophila	Physidae		Bladder Snails	16.32						47.90	3.90	Anderson and Smith 1998, Davis and Smith 1998, Dybala et al 2017
			Planorbidae		Ramshorn Snails	9.13	1.94					45.90	3.90	Anderson and Smith 1998, Davis and Smith 1998, Cummins and Wuycheck 1971, Dybala et al 2017
			Lymnaeidae		Pond snails		3.85					37.90	2.70	Sugden 1973, Anderson and Smith 1998
		Stylommatophora			Common Land Snails and Slugs							43.90	3.50	Anderson and Smith 1998
					Snails and Slugs	11.50								Dybala et al 2017
							13.06		5492.00					Cummins and Wuycheck 1971

Appendix 11. The Atlantic Flyway Shorebird Business Strategy and the Pacific Americas Shorebird Conservation Strategy summarize the highest ranked threats to shorebirds in each flyway, respectively.

The threats in both strategies were matched with the corresponding Open Standards For the Practice of Conservation Classification of Conservation Actions and Threats Version 2.0 (Conservation Measures Partnership 2016).

CMP DIRECT THREATS CLASSIFICATION V 2.0	ATLANTIC FLYWAY SHOREBIRD INITIATIVE	PACIFIC AMERICAS SHOREBIRD CONSERVATION STRATEGY
1. Residential & Commercial Development		Development
1.1 Housing & Urban Areas	Habitat Loss and Change: Residential and Commercial Development	
1.2 Commercial & Industrial Areas	Habitat Loss and Change: Residential and Commercial Development	
1.3 Tourism & Recreation Areas		
2. Agriculture & Aquaculture		
2.4 Marine & Freshwater Aquaculture	Aquaculture	Aquaculture
5. Biological Resource Use		
5.1 Hunting & Collecting Terrestrial Animals	Hunting	
6. Human Intrusions & Disturbance	Human Disturbance	Human Disturbance
6.1 Recreational Activities	Active and passive recreation activities, off-road/highway vehicles, dogs, fireworks, beach raking, monitoring for other species	
7. Natural System Modifications	Habitat Loss and Change: Coastal Engineering	Shoreline and Wetland Modification
7.2 Dams & Water Management / Use	Habitat Loss and Change: Incompatible Natural Resource Management	Water Use and Management
8. Invasive & Problematic Species, Pathogens & Genes	Habitat Loss and Change: Invasive species	
8.1 Invasive Non-Native / Alien Plants & Animals	Predation	Invasive Species
8.2 Problematic Native Plants & Animals	Predation	Problematic Native Species
11. Climate Change	Climate Change	Climate Change
11.1 Ecosystem Encroachment		
11.2 Changes in Geochemical Regimes		
11.3 Changes in Temperature Regimes		
11.4 Changes in Precipitation & Hydrological Regimes		
11.5 Severe / Extreme Weather Events		

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manomet

125 Manomet Point Road
Plymouth, MA 02360
manomet.org