




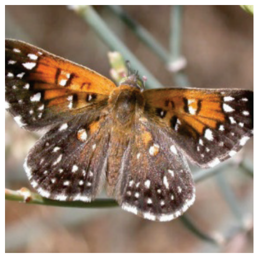


"The conservation landscape has changed, the playing field has changed and the stakes have changed. Human demands on the environment combined with environmental stressors are creating an urgent need for conservation choices. The scale of issues and challenges we face is unprecedented and impacts us all; no single entity has the resources necessary to address these challenges on its own. Conserving the Future acknowledges that **strategic, collaborative, science-based landscape conservation—along with effective public outreach, education and environmental awareness—is the only path forward** to conserve America's wildlife and wild places."

CONSERVING THE FUTURE: WILDLIFE REFUGES AND THE NEXT GENERATION (USFWS 2011)

Natural Resource Management Plan for the San Francisco Bay National Wildlife Refuge Complex

September 2019

ON THE COVER

From left to right, top to bottom

California tiger salamander (*Ambystoma californiense*), USFWS
Tidal marsh, Judy Irving © Pelican Media
Western snowy plover (*Charadrius alexandrinus nivosus*), © Aric Crabb, Bay Area News Group
Farallon Islands, Brian O'Neil
Marin Islands National Wildlife Refuge, USFWS
Lange's metalmark butterfly (*Apodemia mormo langei*), USFWS
Children restoring native plants, Student and Teachers Restoring a Watershed, (Point Blue Conservation Science)
Marbled godwits and willets, Judy Irving © Pelican Media
Vernal pool grasslands, USFWS

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San Francisco Bay National Wildlife Refuge Complex Natural Resource Management Plan

Signatures

Prepared By:	Staff of the San Francisco Bay National Wildlife Refuge Complex: Joy Albertson, Chris Caris, Susan Euing, Aidona Kakouros, Diane Kodama, Ivette Loredo, Meg Marriott, Gerry McChesney, Cheryl Strong, Rachel Tertes Giselle Block, Coastal Zone Biologist, Region 8 Inventory and Monitoring Initiative Allyssa Overbay, Biological Sciences Technician, Region 8 Inventory and Monitoring Initiative
Submitted By:	Anne Morkill, Project Leader, San Francisco Bay National Wildlife Refuge Complex — Date: 24 Sept 2019
Reviewed By:	Kaylene Keller, Inventory and Monitoring Coordinator — Date: 10/10/19 Mark Pelz, Chief, Natural Resources Division — Date: 24 Sept 2019 Stacy Armitage, Refuge Supervisor — Date: 9/30/19
Approved By:	Polly Wheeler, Assistant Regional Director, Refuges — Date: 10.1.19

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Abbreviations

ADEP	Antioch Dunes evening primrose
BCDC	San Francisco Bay Conservation and Development Commission
BRRIT	Bay Restoration Regulatory Integration Team
CCP	comprehensive conservation plan
CCW	Contra Costa wallflower
CDFW	California Department of Fish and Wildlife
CLMA	cooperative land management agreement
CNPS	California Native Plant Society
CTS	California tiger salamander
Estuary	San Francisco Estuary
HSU	Humboldt State University
IMP	inventory and monitoring plan
ISP	San Francisco Estuary Invasive Spartina Project
KEA	key ecological attribute *or* key engagment attribute
LMB	Lange's metalmark butterfly
MHHW	mean higher high water
MHW	mean high water
NEPA	National Environmental Policy Act
NRMP	natural resource management plan
NWR	national wildlife refuge
OSPR	California Department of Fish and Wildlife's Office of Spill Prevention and Response
refuge	national wildlife refuge
Refuge Complex	San Francisco Bay National Wildlife Refuge Complex
Refuge System	National Wildlife Refuge System
RIRA	Ridgway's rail
ROC	resource of concern
SBB	Smith's blue butterfly
SCEP	Sonoma Creek Marsh Enhancement Project
SCLTS	Santa Cruz long-toed salamander
SEFI	Southeast Farallon Island, Farallon Islands National Wildlife Refuge
Service	U.S. Fish and Wildlife Service
SFBBO	San Francisco Bay Bird Observatory
SFI	South Farallon Islands , Farallon Islands National Wildlife Refuge
SMHM	salt marsh harvest mouse
SNPL	western snowy plover
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
VPTS	vernal pool tadpole shrimp

Abstract

Over the past 2 decades, the U.S. Fish and Wildlife Service (Service) developed a comprehensive conservation plan (CCP) for each of the seven refuges in the San Francisco Bay National Wildlife Refuge Complex (Refuge Complex): Antioch Dunes, Don Edwards San Francisco Bay, Ellicott Slough, Farallon Islands, Marin Islands, Salinas River, and San Pablo Bay. The CCPs describe desired future conditions at each refuge and provide long-range guidance and management direction to achieve refuge purposes, help fulfill the National Wildlife Refuge System mission, and maintain or restore the ecological integrity of the refuge. Several factors have affected our ability to achieve all conservation goals and objectives laid out in CCPs, however. These factors include significant declines in federal funding and staffing levels over the past several years (at least since fiscal year 2010), a changing landscape in the context of human demands on the environment, and environmental stressors such as invasive species and climate change. Subsequently, as we persist to "do more with less" in ways that are "how we've always done it," we face uncertainties due to increasing workloads and a lack of clear priorities. To address these challenges and promote a more adaptive, evidence-based approach to conservation within the Refuge Complex, the Service is taking a new approach, specifically in how we make decisions and deploy limited resources optimally to help us achieve our conservation mission. This approach involves 1) identification of natural resource conservation priorities (also known as *priority resources of conservation concern* or *conservation targets*), 2) refinement of conservation goals and objectives so that it's crystal clear what conservation success looks like, 3) identification of the highest priority management strategies—most likely to lead to achieving stated goals and objectives, 4) identification of the highest priority surveys needed to evaluate progress in achieving goals and objectives, and 5) instituting a regular practice of evaluation, learning, and adaptation through annual work planning and evaluation. The methods and results of this new conservation approach are presented in this Natural Resource management Plan (NRMP), a companion inventory and monitoring plan (IMP), and a 5-year work plan. The NRMP also describes how human well-being will benefit from natural resource conservation in the Refuge Complex and lays out specific strategies to build public support and stewardship for natural resource conservation and advance the Service's mission to connect people with nature. The IMP provides details about surveys needed to evaluate conservation progress, and the 5-year work plan provides operational details needed for implementation and evaluation. Together, the NRMP, IMP, and 5-year work plan provide a foundation for focusing limited resources where they are most needed, help institute a more evidence-based approach to conservation, promote more realistic staff workloads, and ultimately increase our likelihood of conservation success in a rapidly changing world.

Chapter 1—Introduction

1.1 The San Francisco Bay National Wildlife Refuge Complex

The National Wildlife Refuge System (Refuge System) was established in 1903 with the designation of the first bird reserve by President Theodore Roosevelt at Pelican Island, Florida. The mission of the Refuge System was reaffirmed in the National Wildlife Refuge System Improvement Act of 1997 "to administer a national network of lands and waters for the conservation, management and, where appropriate, restoration of the fish, wildlife and plant resources and their habitats within the United States for the benefit of present and future generations of Americans." As of September 30, 2018, the Refuge System constitutes the world's largest conservation area network, comprising 562 national wildlife refuges and 38 wetland management districts totaling over 150 million acres. The Refuge System is administered by the U.S. Fish and Wildlife Service (Service), a bureau of the U.S. Department of the Interior.

The San Francisco Bay National Wildlife Refuge Complex (Refuge Complex) consists of seven national wildlife refuges (NWRs) (listed in order of establishment): Farallon Islands NWR (1909), Don Edwards San Francisco Bay NWR (1972), Salinas River NWR (1973), San Pablo Bay NWR (1974), Ellicott Slough NWR (1975), Antioch Dunes NWR (1980), and Marin Islands NWR (1992). Due to the refuges' geographic proximity and common challenges, the Service organized these refuges as a Refuge Complex for administrative purposes.

These refuges were established in response to declining wildlife populations from commercial harvesting that began in the late 19th century and rapid habitat loss from human development that ramped up in the mid-20th century. Now these refuges protect a variety of wetland and associated upland habitats that support nesting, foraging, wintering, and resting points for millions of migratory birds along the Pacific Flyway. The refuges also provide vital habitat for several species of birds, mammals, insects, amphibians, and plants that are federally listed or state-listed as threatened or endangered, as well as other species of concern. Unlike most other NWRs, which are predominantly in rural or remote locations, these seven refuges share the challenge of pursuing wildlife conservation objectives in the midst of highly urbanized areas. Today, the San Francisco–Monterey Bay area is home to nearly 9 million people across 11 counties and more than 100 incorporated cities spread over some 10,000 square miles, including the major metropolitan areas of San Francisco, Oakland, and San Jose.

1.2 Refuge Conservation Planning: Past and Present

The Service completed comprehensive conservation plans (CCPs) for each of the seven refuges in the Refuge Complex to guide management over a 15-year period, pursuant to the 1997 Improvement Act.[1] Each CCP describes the refuge history and ecology of its natural resources and lays out the desired future conditions and long-range guidance to accomplish the purposes for which each refuge was established. The comprehensive conservation planning process helps the Service achieve the refuge purposes and the Refuge System mission by identifying goals, objectives, and strategies to implement at each refuge, including proposed staffing and funding levels necessary to fulfill the goals. The CCPs and accompanying environmental assessments address Service legal mandates,

[1] The CCPs can be accessed at *https://ecos.fws.gov/ServCat/Search/Advanced/17*.

policies, goals, and National Environmental Policy Act (NEPA) compliance. The Service acknowledges that the strategies identified in CCPs may exceed current budget allocations and do not guarantee a commitment of resources.

We (Refuge Complex staff) have been implementing various strategies consistent with the goals and objectives originally identified for each refuge; however, several factors have affected our ability to fully focus on the most effective strategies and assess outcomes. These factors include significant declines in federal funding and staffing levels over the past several years (at least since fiscal year 2010), a changing landscape in the context of human demands on the environment, and environmental stressors such as invasive species and climate change. Subsequently, as we persist to "do more with less" in ways that are "how we've always done it," we face uncertainties due to increasing workloads and lack of clear priorities. We must reflect on the work we have done and consider new approaches in how we make decisions and deploy limited resources optimally to refocus on the most important strategies and natural resource surveys with greatest likelihood of helping us achieve our conservation mission.

1.3 Plan Purpose, Need, and Objectives

Inspired by the Service's 21st century strategic vision for the Refuge System, *Conserving the Future: Wildlife Refuges and the Next Generation* (USFWS 2011), we approached our refocusing task by considering the unique ecosystems represented by individual refuges within the broader landscape conservation context of the San Francisco–Monterey Bay Area. Using the *Open Standards for the Practice of Conservation* (Open Standards; Conservation Measures Partnership 2013) as a structured priority-setting process, we developed a natural resource management plan (NRMP) and its companion inventory and monitoring plan (IMP). A step-down management plan from the CCP, this NRMP serves as the refuge's habitat management plan, pursuant to Service policy (620 FW 1). While CCPs identify overarching refuge management goals, objectives, and strategies for a particular refuge, habitat management plans "step down" the direction provided in a CCP to provide refuge managers with more specific guidance and prescriptions for the implementation of management strategies on refuge lands. The NRMP identifies priority resources of concern in the Refuge Complex (hereafter referred to as conservation targets), and associated priority strategies to conserve them given limited resources. We recognize that the health of the conservation targets provides various ecosystem services that benefit humans; accordingly, a unique aspect of this NRMP is its inclusion of human well-being targets that directly link to conservation targets. For example, wetlands provide regulating services such as pollutant filtration and flood protection. Ecosystems also provide cultural services, non-material benefits that people derive through recreation, aesthetic or spiritual enrichment, and education. By assessing a range of human well-being targets, we identified several strategies for public engagement that will be essential for addressing many threats to our conservation targets. Conservation targets are detailed in chapter 4. Priority human well-being targets are detailed in chapter 5.

One of the most important elements of the NRMP is the provision of specific, measurable, results-oriented, and time-bound goals and objectives. These goals and objectives are critical for evaluating conservation progress, learning, and adaptation. Many of these goals and objectives require surveys to assess progress in achieving goals and objectives. The companion IMP provides more detail about these surveys; it also shows the links between scientific information and management needs as well as information gaps.

On-the-ground implementation of the NRMP and IMP is guided by a 5-year work plan. The work plan lays out specific activities related to management strategies and surveys, who is responsible for carrying them out, and when they will be carried out. Together, the NRMP, IMP, and associated 5-year work plan will promote a more adaptive and evidenced-based approach to conservation in the Refuge Complex.

The desired outcomes that guided the work planning effort for the NRMP and IMP are listed in the following.

- A multi-year work plan is developed for the San Francisco Bay National Wildlife Refuge Complex that—
  - optimally allocates staffing and funding to help meet priority refuge purposes
  - focuses on strategies and actions with the greatest conservation benefit
  - provides a level of consistency across the refuges for developing survey protocols and integrating data for a broader perspective across the landscape
  - links individual performance and accomplishments (roles, responsibilities, daily tasks) to priority conservation targets
  - creates a framework for balancing workload on priority actions with building capacity to take on new opportunities and emerging issues, while also being able to justify saying "no" to non-priority projects
  - provides a platform for annual work planning, budgeting, and performance assessment
  - integrates all programs—biology, visitor services, maintenance, law enforcement, administration—to enhance coordination across the Refuge Complex to reach shared goals.
- Refuge Complex staff and key partners have a collective understanding about the priority conservation and human well-being targets, threats/challenges, and management strategies across the Refuge Complex, and they accordingly support the processes and decisions about how to allocate limited staffing and funding resources.
- Refuge Complex staff can articulate how our work aligns with the Service's regional and national priorities, as well as within the larger landscape goals for the San Francisco–Monterey Bay Area so that we can better leverage partnership and funding opportunities.

1.4 Physiographic and Ecological Summary of the Region

California is the most biodiverse state in the United States and one of the most biodiverse regions in the world outside of the tropics (Mooney and Zavaleta 2016). California's high level of endemism and species richness is due to its Mediterranean climate and diversity of landscapes from offshore islands, coastal lowlands, large estuaries and alluvial valleys, forested mountain ranges, and desert (Griffith et al. 2016). While more than 30% of California's species are threatened with extinction, only a remarkable <0.3% of its native species have been driven to global extinction, perhaps in large part due to the extensive network of protected areas that cover 46% of the state's land area (Mooney and Zavaleta 2016). It is within this context that the refuges in the San Francisco–Monterey Bay Area contribute substantially to protecting and restoring some of California's iconic habitats and associated flora and fauna.

California encompasses 13 Level III Ecoregions, a spatial framework that recognizes areas of general similarity in ecosystems and in the type, quality, and quantity of environmental characteristics including geology, physiography, vegetation, climate, soils, land use, wildlife, and hydrology (Griffith et al. 2016). Six of the refuges in the Refuge Complex fall within the Central California Foothills and Coastal Mountains Level III Ecoregion and encompass representative samples of several habitat types found in this ecoregion, including tidal wetlands, grasslands, oak woodlands, and dunes. The seventh refuge, Farallon Islands NWR, is a group of small granitic islands located 26 miles offshore in the Pacific Ocean and falls within the Coast Range Level III Ecoregion. The following information summarizes the general ecological setting within which our refuges are situated. Chapter 4 provides more specific descriptions of the physiographic and ecological setting for each specific conservation target. Further details about the natural resources in each of the seven refuges, including historical context and lists of plant and animal species known to occur on the refuges, can be found in the refuge's CCP.

1.4.1 San Francisco Bay Region

San Francisco Bay is the largest estuary on the west coast of the United States and one of the most important staging and wintering areas for migratory waterfowl in the Pacific Flyway. It has been designated a Western Hemisphere Shorebird Reserve Network site of hemispheric importance. Up to 1 million shorebirds can be counted foraging on the Bay's extensive mudflats at the peak of spring migration. San Francisco Bay is also the winter home for more than 50% of the diving ducks in the Pacific Flyway, including one of the largest wintering populations of canvasbacks in North America.

The San Francisco Estuary (Estuary) contains the largest expanses of tidal marshes in California. The early 19th century tidal marsh, before substantial human impact, is estimated to have been approximately 190,000 acres (Goals Project 1999). Major alteration of the Estuary tidal marshes occurred during and after the California Gold Rush. The principal causes of tidal marsh loss were diking for agricultural uses in the North Bay and solar salt production in the South Bay. Large patches of marsh in the North Bay were diked off starting in the mid-1800s to support haying, grain production, and livestock grazing. The solar salt industry began building managed salt ponds in the mid-1850s and rapidly expanded in the 1920s–30s, eventually converting more 27,000 acres of former tidal marsh. In addition, roughly 50,000 acres of tidal marsh were filled to allow urban development, including expansion of airports, shipping ports, industry, commercial and suburban residential development, and landfills.

Today, only about 40,000 acres of tidal marsh remain, much of which occurs along the bayside fringes of levees and along the large tidal channels or mudflats. Formerly diked baylands in the North Bay are being restored back to tidal marsh, including several projects on the San Pablo Bay NWR. Managed salt ponds are still a prominent feature in the San Francisco Bay, particularly in the South Bay. The South Bay Salt Pond Restoration Project, the largest wetland restoration project on the west coast of the United States, has a goal of restoring up to 9,600 acres of former salt ponds back to tidal marsh, along with maintaining habitat (via managed ponds) for shorebirds and waterfowl, on the Don Edwards San Francisco Bay NWR. The Estuary is also home to several endemic species found nowhere else, including the Ridgway's rail (*Rallus obsoletus obsoletus*; formerly California clapper rail) (RIRA) and salt marsh harvest mouse (*Reithrodontomys raviventris*) (SMHM).

An important ecotone habitat between salt marshes and adjacent uplands was extensive lowland alkaline grassland with complexes of vernal pools, vernal swales, and marshes that support salt-tolerant plants. The vernal pool grasslands in the Warm Springs Subunit of the Don Edwards San Francisco Bay NWR are the only surviving representatives of this former ecotone in the Bay Area.

Another rare habitat feature within San Francisco Bay are the rocky islands, including the Marin Islands NWR. West Marin Island is home to one of the largest heron (*Ardea alba, A. Herodias, Nycticorax nycticorax*) and egret (*Egretta thula*) breeding colonies in northern California. There are no available historic data on the specific natural conditions of the Marin Islands, but they were thought to primarily consist of coast live oak woodlands, coastal sage scrub, and coastal grasslands (Baye 2005). The islands have been isolated from the mainland for approximately 3,000 years; therefore, the remnant native flora on the Marin Islands represents a limited sample of flora once commonly found along northeastern San Francisco Bay.

Lange's metalmark butterfly (*Apodemia mormo langei*) (LMB) exists entirely on the Antioch Dunes NWR, small isolated remnant sand dunes that once formed more extensively along the Sacramento–San Joaquin River but were reduced in extent and quality as a result of industrial activities such as sand mining.

1.4.2 Monterey Bay Region

The Monterey Bay region supports a broad range of habitat types including coastal dunes, wetlands, coastal chaparral, grasslands, and redwood forests. The region is a biological transition zone from southern to northern California and supports a high level of biological diversity, including many threatened and endangered species. The local climate is modified greatly by marine influence owing to its proximity to the Pacific Ocean.

Historical accounts from the mid-1800s describe the main watersheds as supporting shallow lakes, sloughs, marsh vegetation, and willow thickets, including a large wetland complex that included the lower Salinas River, Elkhorn Slough, and Pajaro River. Beginning in the 1870s, major landscape changes occurred from drainage operations and reclamation efforts that converted native habitats to agricultural production. By the 1950s, more than 90% of the region's original wetlands had been converted to agricultural production and residential developments. Ellicott Slough NWR is located within the Pajaro Valley watershed and includes isolated ephemeral ponds that form in the hilly wooded terrain and which are heavily dependent on rainfall captured within the watershed.

Lands that now make up the Salinas River NWR were spared from conversion because of their close proximity to the ocean, susceptibility to flooding, and former military ownership. The coastal sand dunes on the Salinas River NWR represent the northern tip of a dune system that extends more than 12 miles along the Monterey Bay shoreline. The Salinas River NWR is now one of only a few places in the area where a significant expanse of wetland and riparian habitat remains.

1.4.3 Farallon Islands

Located about 26 miles offshore, the Farallon Islands' size, topographic complexity, geologic history of isolation, and distance from other islands and the mainland have led to high endemism in flora and fauna (Mooney and Zavaleta 2016). Because of their isolation, island plant communities tend to have fewer total plant species than the mainland and are often dominated by local endemics that evolved in these unique island environments. These islands support the largest seabird breeding colony outside of Alaska as well as significant proportions of five species of pinnipeds: northern fur seal (*Callorhinus ursinus*), Steller sea lion, California sea lion (*Zalophus californianus*), harbor seal (*Phoca vitulina*), and northern elephant seal (*Mirounga angustirostris*).

The islands sit perched on the edge of the continental shelf within the California Current System, one of the most productive ecosystems in the ocean. Biodiversity of the islands is driven in large part by seasonal coastal upwelling that transports nutrients into the uppermost water depths and fuels phytoplankton blooms. These blooms support a diverse food web from zooplankton and forage fish to top predators such as seabirds, pinnipeds, and whales. Together with the waters surrounding the islands, the Farallon Islands are a critically important biodiversity hot spot protected as part of the Greater Farallones National Marine Sanctuary and included within the Golden Gate Biosphere reserve designated by the UNESCO Man and the Biosphere Programme.

Chapter 2—Methods

2.1 Project Team

This NRMP was developed by staff from the Refuge Complex and the Pacific Southwest Region Inventory and Monitoring Program (hereafter referred to collectively as the project team; table 1). The project team consulted many other individuals, both within and outside the USFWS, to inform this NRMP and subsequent IMP. Organizations providing significant topical expertise or assistance with developing portions of this NRMP included the following.

- California Landscape Conservation Cooperative
- Foundations of Success
- San Francisco Bay Wildlife Society

Table 1. Project team for the San Francisco Bay National Wildlife Refuge Complex Natural Resource Management Plan.

Name	*Position*	*Primary Role in Project*
Erin Aceituno*	GIS Specialist, Region 8 Inventory and Monitoring Program	Data support—GIS, maps
Joy Albertson	Supervisory Wildlife Biologist	Core planning team
Melisa Amato	Wildlife Refuge Specialist, San Pablo Bay NWR	Human well-being team
Cindy Ballard	Administrative Officer	Administrative team
Chris Barr	Deputy Refuge Complex Manager	Core planning team
Giselle Block*	Inventory and Monitoring Specialist, Region 8 Inventory and Monitoring Program	Core planning team
Don Brubaker	Manager, San Pablo Bay, Antioch Dunes, and Marin Islands NWRs	Tidal marsh ecosystem, riverine dune ecosystem, estuarine island ecosystem teams
Chris Caris	Wildlife Biologist	Coastal dune ecosystem and Pajaro Valley watershed teams
Winnie Chan	Natural Resource Planner	Core planning team
Ennis Chauhan	Pathways Intern	Human well-being team
Colter Cook	Education Specialist, San Francisco Bay Wildlife Society	Human well-being team
Doug Cordell	Public Affairs Officer	Human well-being team
Rachel Esralew*	Hydrologist, Region 8 Inventory and Monitoring Program	Data support: hydrology, climate change
Susan Euing	Wildlife Biologist, Antioch Dunes NWR and Alameda Point	Riverine dune and waterbird ecosystem teams
Juan Flores	Maintenance Worker	Infrastructure maintenance team
Tia Glagolev	Environmental Education Specialist	Human well-being team
Jim Griffin	Maintenance Worker	Infrastructure maintenance team

Name	*Position*	*Primary Role in Project*
Aidona Kakouros	Refuge Complex Botanist	Vernal pool grassland and estuarine island ecosystem teams
Kaylene Keller*	GIS and Data Manager and Ecologist, Region 8 Inventory and Monitoring Program	Data support—resources of concern, legacy data collection
Diane Kodama	Refuge Manager, Salinas River and Ellicott Slough NWRs	Coastal dune ecosystem and Pajaro Valley watershed teams
Ivette Loredo	Wildlife Refuge Specialist, Don Edwards San Francisco Bay NWR	Tidal marsh ecosystem and vernal pool grassland ecosystem teams
Meg Marriott	Wildlife Biologist, San Pablo Bay and Marin Islands NWR	Tidal marsh ecosystem, estuarine island ecosystem, and waterbird teams
Gerry McChesney	Refuge Manager, Farallon Islands NWR	Marine island ecosystem team
Carmen Minch	Outdoor Recreation Planner	Human well-being team
Genie Moore	Environmental Education Specialist	Human well-being team
Anne Morkill	Refuge Complex Manager	Core planning team
Paul Mueller	Volunteer Coordinator	Human well-being team
Jesse Navarro	Federal Wildlife Officer	Law enforcement team
Allyssa Overbay*	Biological Science Technician, Region 8 Inventory and Monitoring Program	Editor
Glendale Phan	Federal Wildlife Officer	Law enforcement team
Hope Presley	Interpretive Specialist, San Francisco Bay Wildlife Society	Human well-being team
Calvin Sahara	Maintenance Worker	Infrastructure maintenance team
Jonathan Shore	Wildlife Refuge Specialist, Farallon Islands NWR	Marine island ecosystem team
Micheal Springman	Maintenance Team Leader	Infrastructure maintenance team
Cheryl Strong	Wildlife Biologist, Don Edwards San Francisco Bay NWR	Tidal marsh ecosystem and waterbird teams
Louis Terrazas	Wildlife Refuge Specialist, Antioch Dunes and San Pablo Bay NWRs	Riverine dune ecosystem team
Rachel Tertes	Wildlife Biologist, Don Edwards San Francisco Bay NWR	Tidal marsh ecosystem and waterbird teams
Ellen Tong	Budget Technician	Administrative team
Jared Underwood	Refuge Manager, Don Edwards San Francisco Bay NWR	Tidal marsh ecosystem, waterbird and human well-being teams
Ed VanTil	Maintenance Worker	Infrastructure maintenance team

Key: GIS = Geographic Information Systems; NRMP = natural resource management plan.

Notes: All individuals listed in the table are staff of the San Francisco Bay National Wildlife Refuge Complex unless otherwise noted; Region 8 Inventory and Monitoring Program staff are noted with an asterisk (*).

The core team is the group of individuals responsible for planning and carrying out the project.

Individuals are listed with their primary teams but may have participated on multiple teams.

2.2 Planning Approach

Development of this NRMP was guided by the *Region 8 Methodology for Identifying Priority Resources of Concern* (USFWS 2015) and the Open Standards for the Practice of Conservation (Conservation Measures Partnership 2013). How these resources were used is described in the following. Additional planning methods specifically relating to human well-being targets are discussed further in chapter 5.

2.2.1 Identifying Priority Natural Resources of Concern

Refuges support a wide variety of interacting species, communities, and ecosystems. Although conserving all aspects of natural biodiversity is desired, the Service lacks the resources to focus on every element of biodiversity in the Refuge Complex. For this reason, the project team prioritized natural resources of conservation concern that should be a focus of management in the Refuge Complex, referred to as *priority ROCs* (Service policy 620 FW 1), *targets*, or *conservation targets* (the latter is used most frequently in this NRMP).[2] Priority ROCs or conservation targets can be species, communities, or ecosystems, and their selection is central to the development of conservation strategies presented in this NRMP and the ability of the Refuge Complex to evaluate conservation progress over time.

The project team followed these 6 generalized steps to identify Refuge Complex conservation targets:

1. Compile refuge species lists and standardize species scientific names to the International Taxonomic information standard (IT IS; see *https://www.itis.gov/*).
2. Compile refuge purposes and establishing legislation.
3. Compile larger landscape conservation plans applicable to the refuge(s).
4. Compile lists of sensitive (such as federally threatened and endangered species) and USFWS trust species (such as migratory birds and anadromous fish)
5. Develop and apply species ranking criteria using lists above (2–4) and Refuge Complex elicitation.
6. Review ranking results and identify priority conservation targets. These are high-ranking species (such as federally listed species), communities of high-ranking species (such as waterbirds), or ecosystems (such as a vernal pool grassland ecosystem).

Resulting priority conservation targets (communities or ecosystems) presented in this NRMP have one or more of the following characteristics, including:

- identified in refuge purposes or establishing legislation
- support federally listed threatened or endangered species
- found in limited areas that overlap a refuge (or refuges) in the Refuge Complex
- identified as Service trust resources (i.e., migratory birds, anadromous and interjurisdictional fish, marine mammals, federally listed species [601 FW 1.8])

[2] These and other terms are defined in appendix A, "*Glossary*."

- identified as a priority natural resource in larger landscape conservation plans
- indicative/representative of ecological processes or drivers that shape refuge communities/ecosystems or surrounding landscapes
- support maintenance or restoration of biological integrity, diversity, and environmental health (601 FW 3)
- provide a direct or indirect benefit to people

The criteria and associated scoring and weights used to calculate species scores and ultimately select Refuge Complex conservation targets are referenced in appendix B.

Additional details about the target general selection process are presented in *Methodology for Identifying Priority Resources of Concern* (USFWS 2015a).

2.2.2 Planning Process and Timeline

The project team used the Open Standards conservation planning process to support development and to guide implementation of the NRMP. This process promotes an adaptive and evidence-based conservation practices by encouraging the following:

- specifying measurable desired results in terms of conservation outcomes, not just actions
- documenting our assumptions behind management strategies
- being explicit about how we believe our actions will lead to desired results
- monitoring outcomes to track conservation progress and test our assumptions regarding how our actions lead to desired results
- adapting strategies based on what we learn by using data and analyses (evidence) to promote doing more of what works (and less of what does not work)
- sharing our results and being transparent about what worked and what did not work to advance conservation at a larger landscape scale

Figure 1 shows the five steps composing the Open Standards adaptive management cycle. The NRMP and companion IMP represent steps one and two of the Open Standards process and provide refuge staff with a framework for annual evaluation, learning, and adaptation (steps 4–5, figure 1) via the 5-year work plan.

Figure 1. Conservation Measures Partnership's Open Standards process.

Source: Open Standards for the Practice of Conservation (Conservation Measures Partnership 2013)

Specific planning activities leading to this NRMP, the IMP, and the 5-year work plan from fall 2016 to June 2018 are presented here:

1. Project planning: activities and timeline.
2. Gather Refuge Complex legacy data (such as species lists, management plans, and reports).
3. Define the project team, stakeholders, and expert advisors.
4. Define the Refuge Complex NRMP spatial scope.
5. Identified Refuge Complex conservation targets (see Section 2.2.1, *Identifying Priority Resources of Concern*) and human well-being targets.
6. Select key ecological/engagement attributes (KEAs) for assessing target health through time.
7. Conduct a target viability analysis: assess the current status, trend, and desired future status of conservation targets in terms of selected KEAs.
8. Develop SMART (specific, measureable, achievable, relevant, and time-bound) conservation and human well-being goals—what success looks like in terms of targets and associated KEAs.
9. Conduct a threat analysis. Identify the most critical threats to the targets.
10. Develop a conceptual model depicting the relationship between targets, critical threats, and opportunities.
11. Using information generated from steps 1–10, identify priority management strategies:
    a. Identify, describe, and prioritize management strategies aimed at reducing threats to conservation targets or directly restoring targets.
    b. Prioritize management strategies.
    c. Document assumptions about how priority management strategies will improve the conservation or human well-being situation (results chains).
    d. Develop SMART objectives that specify the expected near-term results of management strategies.
12. Identify surveys needed to inform progress on goals and objectives.

13. Developed expected near-term (5-year) budget and timeline for implementing strategies and conducting surveys.
14. Develop a 5-year work plan: activities related to priority strategies and surveys.
15. Estimate time and funding needed to implement 5-year workplan; refine work plan, as needed, to ensure it is achievable given expected resources (e.g., staff, funding).

The project team carried out these steps through in-person workshops involving all Refuge Complex staff (table 2), monthly core team meetings, and management team meetings involving refuge and program managers. In addition, Refuge Complex staff formed teams to focus on individual natural resource and human well-being targets. These teams worked together during and after workshops to complete each step of the NRMP process.

Table 2. Schedule of workshops used to inform the San Francisco Bay National Wildlife Refuge Complex Natural Resource Management Plan.

When	*Workshop Length (days)*	*Topic*	*Participants*
December 2016	1	Identify priority resources of concern, part 1	Refuge managers, wildlife refuge specialists, biologists, visitor services staff
January 2017	1	Identify priority resources of concern, part 2	Refuge managers, wildlife refuge specialists, biologists, visitor services staff
February 2017	2	Conservation target viability, status, and goals	All staff
March 2017	1	Threats to conservation targets	All staff
March 2017	2	Conservation targets: conceptual models	All staff
April 2017	1	Identify human well-being targets, part 1	All staff
May 2017	2	Conservation target strategies and activities	All staff
June 2017	1	Conservation target results chains and objectives	All staff
July 2017	1	Prioritize conservation target surveys	Refuge managers, wildlife refuge specialists, biologists, visitor services staff
August 2017	1	Budget, timeline, work assignments	Managers and program leads
September 2017	1	Staff report on draft workplan	All staff
November 2017	1	Identify human well-being targets, part 2	All staff
January 2018	1	Human well-being target viability	Refuge managers, wildlife refuge specialists, visitor services staff
February 2018	1	Threats to human well-being targets, part 1	Refuge managers, wildlife refuge specialists, visitor services staff
March 2018	1	Threats to human well-being targets, part 2; human well-being conceptual models, part 1	Refuge managers, wildlife refuge specialists, visitor services staff
April 2018	1	Human well-being conceptual models, part 2; human well-being strategies and activities, part 1	Refuge managers, wildlife refuge specialists, visitor services staff
May 2018	2	Human well-being strategies and activities, part 2; identifying human well-being target surveys	Refuge managers, wildlife refuge specialists, visitor services staff
June 2018	1	Human well-being target results chains and objectives, timeline, work assignments	Visitor services staff

2.2.3 Terminology

Throughout this NRMP we use the following terminology when referring to the conservation planning process or results. These and other terms are defined in appendix A, "*Glossary*."

- *Conservation target:* species, communities, or ecosystems that best represent the biodiversity and purpose of the refuge and are the focus of natural resource management; synonymous with refuge priority resources of concern, or ROCs.
- *Human well-being target*: benefits humans receive from conservation targets in the form of ecosystem services (e.g., water purification, recreation).
- *Key ecological attribute (KEA):* aspects of a conservation target's biology or ecology that define a healthy conservation target. Missing or altered KEAs would lead to the outright loss or extreme degradation of that conservation target over time. Examples include population size, reproductive success, community composition or structure, habitat connectivity, hydrological regime, sediment dynamics, and fire regime.
- *Threat:* a human-induced action that stresses—or has the potential to stress—one or more conservation targets. Examples include logging, contaminants, invasive species introductions, land and habitat conversion, fire suppression, altered hydrology, and human disturbance.
- *Stress:* the expression of a threat on a conservation target or how it negatively impacts the target. Examples include reduced size or extent of a population or ecosystem, reduced reproductive success, habitat loss, reduced habitat connectivity, altered community composition or structure, and altered sediment dynamics.
- *Conservation goal (*often referred to simply as a *goal):* a formal statement detailing a desired conservation outcome in terms of conservation targets and associated KEAs.
- *Objective:* a formal statement detailing what a refuge team hopes to achieve for its intermediate results on the way to achieving a goal—in other words, objectives help project teams measure progress toward conservation. Objectives often focus on threat abatement (like invasive species control) or restoration.
- *Strategy:* a group of actions that work together to reduce one or more threats or to restore natural systems.

Appendix B provides a reference to criteria and scoring details used to inform selection of refuge conservation targets, critical threats, and priority strategies. Lastly, we used Miradi adaptive management software to facilitate the development of this plan.

Chapter 3—Summary of Results

3.1 Conservation Scope

The spatial scope of this NRMP encompasses lands within the approved boundaries of the seven national wildlife refuges composing the Refuge Complex (listed in order of year established): Farallon Islands NWR (1909), Don Edwards San Francisco Bay NWR (1972), Salinas River NWR (1973), San Pablo Bay NWR (1974), Ellicott Slough NWR (1975), Antioch Dunes NWR (1980), and Marin Islands NWR (1992) (figure 2). Due to their geographic proximity and common challenges, the Service organized these seven refuges as a Refuge Complex for administrative purposes. Although the Service's management jurisdiction is limited, the Refuge Complex may engage in conservation activities in the larger landscape. The Refuge Complex recognizes that the health of natural resources on refuge-managed lands is connected to the health of the larger landscape in which the refuges are situated. Therefore, conservation work carried out by the Refuge Complex involves many conservation partners and extends beyond the boundary of the Refuge Complex.

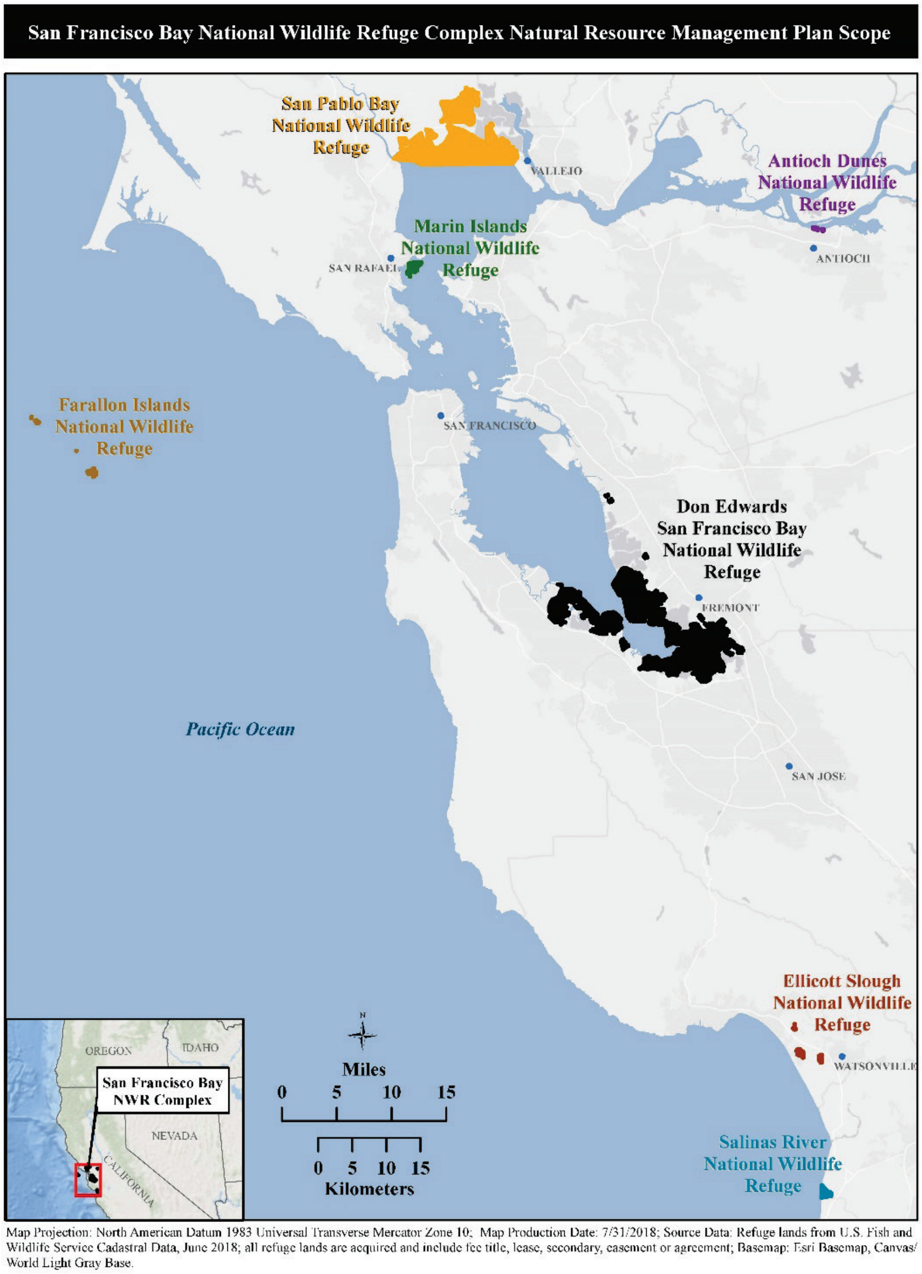


Figure 2. Geographic setting of the seven refuges of the San Francisco Bay National Wildlife Refuge Complex.

3.2 Conservation Targets

Natural resource conservation targets of the Refuge Complex encompass seven ecosystems and one species assemblage. Representative abiotic and biotic features of these targets are collectively referred to in this document as *nested targets*. Table 4 identifies targets and representative nested targets of the Refuge Complex. Conservation targets were selected by Refuge Complex staff during the ROC prioritization process (see section 2.2.1). These targets provide a foundation for identifying the most critical environmental threats to Refuge Complex natural resources, the most important management strategies to implement, and the most important surveys to conduct. The conservation situation describing each target is described in chapter 4. Human well-being targets associated with these natural resource targets are described in chapter 5.

Table 4. Priority conservation targets and nested targets of the San Francisco Bay National Wildlife Refuge Complex (listed in alphabetical order).

Priority Conservation Target	*Nested Targets*	*Associated Refuge(s)*
Coastal sand dune ecosystem	Central dune scrub, beach and central foredune, Smith's blue butterfly, western snowy plover	Salinas River NWR
Estuarine island ecosystem	Oak/buckeye forest, grasslands, coastal scrub, coast bluff-cliffs, intertidal marsh beach, locally rare native plants, arboreal salamander, native pollinators	Marin Islands NWR
Marine island ecosystem	Breeding seabirds, pinnipeds, Farallon camel cricket, arboreal salamander, maritime goldfields, pinnipeds	Farallon NWR
Pajaro Valley watershed	California tiger salamander, Santa Cruz long-toed salamander, ponds, oak woodlands, grasslands	Ellicott Slough NWR
Riverine sand dune ecosystem	Lange's metalmark butterfly, Contra Costa wallflower, Antioch Dunes evening primrose	Antioch Dunes NWR
Tidal marsh ecosystem	Ridgway's rail, salt marsh harvest mouse, common yellowthroat, song sparrow, marsh-upland transition zone, low marsh, high marsh, native tidal marsh plants, native fish, harbor seal	Don Edwards San Francisco Bay NWR, San Pablo Bay NWR
Vernal pool grassland ecosystem	Contra Costa goldfields, vernal pool plants, vernal pool tadpole shrimp, California tiger salamander	Don Edwards San Francisco Bay NWR
Waterbirds	Breeding waterbirds (Don Edwards San Francisco Bay NWR): Forster's tern, Caspian tern, American avocet, black-necked stilt Breeding waterbirds (Marin Islands NWR): great blue heron, great egret, snowy egret, black-crowned night heron, wintering and migratory shorebirds, waterfowl, and grebes	Don Edwards San Francisco Bay NWR, San Pablo Bay NWR, Marin Islands NWR

3.4 Target Viability and Goals

Refuge Complex staff used survey reports, survey data, expert opinion, and the published literature to assess the status and trends of priority conservation targets and identify future desired conditions (SMART goals) in terms of KEAs and associated indicators. Based on the best available information, the current status of each KEA (in terms of one or more indicators) were classified as *Poor*, *Fair*, *Good*, or *Very Good*, as described below.

- *Poor:* restoration increasingly difficult; target at risk of extirpation
- *Fair:* outside acceptable natural range of variation; below threshold and requires human intervention

- *Good*: within acceptable natural range of variation; some intervention required for maintenance
- *Very Good*: Ultimate desired status (e.g., may find this in recovery plans or other management plans); requires little intervention for maintenance

Of the 25 KEAs, 3 (12%) are Poor, 11 (44%) are Fair, 6 (24%) are Good, 3 (12%) are Very Good, and 2 (8%) are unknown (table 5). The trend in KEAs is negative (decreasing) for 6 KEAs (24%), stable or increasing for 13 KEAs (52%), and unknown for 6 KEAs (24%).

Many of the KEAs and associated indicators were surveyed in the past by Refuge Complex staff or their partners, but a few are new or just recently initiated, hence the unknowns. Additional details about status and trends of Refuge Complex conservation targets, KEAs, indicators, and SMART goals is provided in chapter 4. Status and trends of human well-being targets is provided in chapter 5.

Table 5. Status of conservation targets (N=8) across the seven refuges of the San Francisco Bay National Wildlife Refuge Complex.

Conservation Target	*Refuge ID*	*Key Ecological Attribute*	*Current Rating*	*Trend*
Coastal sand dune ecosystem	Salinas River NWR	Western snowy plover reproductive success	Good	Decreasing
		Smith's blue butterfly population size	Fair	Unknown
		Sand dune vegetation cover and composition	Very Good	Stable
Estuarine island ecosystem	Marin Islands NWR	Native plant composition and abundance	Fair	Decreasing
Marine island ecosystem	Farallon Islands NWR	Ashy-storm petrel population size	Fair	Decreasing
		Native plant cover and composition	Fair	Stable
		Pinniped population size	Good	Increasing
		Seabird population size	Good	Increasing
Pajaro Valley Watershed	Ellicott Slough NWR	Grassland and woodland extent	Fair	Unknown
		Santa Cruz long-toed salamander and California tiger salamander population size	Fair	Unknown
		Pond hydroperiod	Good	Increasing
		Salamander reproductive success	Good	Increasing
Riverine sand dune ecosystem	Antioch Dunes NWR	Lange's metalmark butterfly population size	Poor	Decreasing
		Sand dune vegetation cover and composition	Poor	Unknown
Tidal marsh ecosystem	San Pablo Bay NWR, Don Edwards San Francisco Bay NWR	Average rate of change of Ridgway's rail density at Don Edwards San Francisco Bay NWR (long-term)	Unknown	Unknown
		Ridgway's rail density (short-term)	Unknown	Unknown
		Extent of high-quality tidal marsh	Fair	Increasing
Vernal pool grassland ecosystem	Don Edwards San Francisco Bay NWR	Grassland vegetation structure and composition	Fair	Increasing
		Vernal pool vegetation composition	Fair	Stable

Conservation Target	*Refuge ID*	*Key Ecological Attribute*	*Current Rating*	*Trend*
		California tiger salamander breeding activity and vernal pool hydrology	Very Good	Increasing
		Presence of vernal pool tadpole shrimp	Very Good	Stable
Waterbirds	Don Edwards San Francisco Bay NWR	Number of waterbird breeding pairs	Fair	Decreasing
	San Pablo Bay NWR, Don Edwards San Francisco Bay NWR	Wintering shorebird species richness and abundance	Fair	Stable
		Wintering waterfowl and grebe species richness and abundance	Good	Stable
	Marin Islands NWR	Number of heron and egret breeding pairs	Poor	Decreasing

3.5 Critical Threats

A variety of human-caused threats put stress on conservation targets of the Refuge Complex (table 6). Evaluation of the scope severity and irreversibility of environmental threats was based on expert opinion and freely available information (such as refuge reports and published literature). When looking across the refuges and conservation targets of the Refuge Complex, the most critical threats (summary rating of Very High) are climate change, invasive plants, mammalian predators, land conversion, and oil spills (table 6). A more detailed summary of critical threats by conservation target and refuge is provided in chapter 4. A summary of threats to human well-being targets is provided in chapter 5. Information gained from the threat analysis was used to prioritize management strategies at individual refuges or across the Refuge Complex (such as a Refuge Complex–level strategy to address invasive plants).

3.5.1 Climate Change

Because of the uncertainty surrounding climate change and the high risk of potential harm to Refuge Complex resources, the Inventory and Monitoring Program, Foundations of Success, and the California Landscape Conservation Cooperative summarized how climate might change in the vicinity of Refuge Complex lands and how these changes might stress priority conservation targets. A more detailed summary of projected climatic changes and potential effects are summarized in the following unpublished reports:

- *San Francisco Bay National Wildlife Refuge Complex Climate Assessment* (California Landscape Conservation Cooperative, USFWS Region 8 Inventory and Monitoring Program, and Foundations of Success 2018)
- *Antioch Dunes National Wildlife Refuge Climate Inventory and Summary* (Esralew 2015)
- *Salinas River National Wildlife Refuge Climate Summary and Climate Change Exposure Analysis* (Esralew and Michehl 2017)
- *San Pablo Bay National Wildlife Refuge Climate Adaptation Plan* (Veloz et al. 2016)
- *Water Resources Inventory and Assessment, Ellicott Slough National Wildlife Refuge* (Esralew and Michehl 2015)

Data and information provided in these documents were current at the time of development, but we recognize our understanding of climate change and its impacts will continue to improve. In the future, current information should be consulted when refining strategies laid out in this NRMP. Climatic changes and resulting stress to conservation targets is presented in chapter 4.

3.5.2 Conceptual Models

We developed conceptual models for each of the conservation and human well-being targets to better understand the relationship between targets, threats, contributing factors, and priority strategies to reduce threats or directly restore targets. This information was primarily used to inform where conservation action is most needed. See chapter 4 "Conservation Target Summaries" or chapter 5 "Priority Surveys for the Human Well-Being Targets" for target-specific models. The models contained within this NRMP are focused on the most critical threats. Full models that encompass all threats (Low to Very high) can be found in the Miradi file associated with this NRMP (appendix B).

3.6 Management Strategies

A variety of management strategies were identified by target teams as a priority to implement across the Refuge Complex to conserve the eight conservation targets (table 6). Approximately half of the strategy types focus on direct abatement of critical threats (classified as Very high or High) while other strategies are aimed at mitigating critical threats through ecological restoration (abiotic or biotic), species reintroduction, partnership development, or research. The most common strategy type across Refuge Complex targets were invasive plant management, ecological restoration, and predator management. Here, ecological restoration incudes activities focused on restoring (or enhancing) a biotic or abiotic component of an ecosystem. Examples include native plant restoration, sand placement to restore sand dunes, grazing to improve plant composition, or restoring tidal hydrology to a salt marsh. Although not a direct ecological threat, lack of "good" data management (via practices or tools) was also cited as a significant challenge in the Refuge Complex.

To help address common needs or challenges, we identified several Complex-wide strategies related to invasive plants, data management, predator management, and mosquito management. Priority Complex-level strategies for the next five years (FY2018–FY2022) are focused on invasive plants and data management and are described in the following.

3.6.1 Refuge Complex Strategy: Invasive Plant Management

Invasive plants were identified as a critical threat across the Refuge Complex. Not surprisingly, seven of the eight target teams identified invasive plant management as a priority to implement over the next 5 years. Currently, all seven refuges are managing invasive plants. The manner in which invasive plant management is practiced in the Refuge Complex varies from refuge to refuge, and the efficacy of practices is well-documented in some cases but not in others. In general, the NRMP process helped the Refuge Complex recognize that a more strategic, adaptive, and coordinated approach is needed for the entire Refuge Complex. To meet this need, the Refuge Complex will establish a team of Refuge Complex staff to develop and implement a Complex-wide strategy for invasive plant management. The strategy will help ensure: 1) resources are allocated on the most problematic plants in the Refuge Complex, 2) an integrated pest management approach is employed, and 3) results of management are monitored to ensure resources are focused on the most effective IPM strategies and we can share what we learn. Activities involved with this strategy may include:

- Prioritize invasive plant threats (via invasive plant workshops)
- Baseline inventories

- Develop or refine existing IPM or weed plans that are informed by the NWRS Guide to Invasive Plant Management Planning (USFWS 2018)
- Development or refinement of vegetation monitoring protocols
- Monitoring efficacy of IPM techniques
- Coordinating IPM and monitoring across the Refuge Complex

As specific activities are developed, they will be added to the Refuge Complex five-year work plan.

3.6.2 Refuge Complex Strategy: Data Management

Issues with data management (spatial and non-spatial) consistently emerged throughout the NRMP process. These issues encompass internet connectivity, data organization, data storage, data structures, and data collection. Like invasive plant management, the Refuge Complex will form a team to work on addressing data management issues with the long-term goal of ensuring data we collect and store can be efficiently or effectively utilized to complete all or parts of our work activities. We recognized that some at the national, regional, and field station level have expertise on various data management topics and have experience with, and knowledge of, data management procedures, existing resources, and trainings that could help us meet our goal for improving data management across the Refuge Complex. Steps to carrying out this strategy include the following:

1) Identify and document data management issues
2) Prioritize issues
3) Identify potential solutions
4) Provide station protocols and/or guidelines for proper collection, use and archive of data and records management
5) Improve data infrastructure to support data storage and accessibility

The current Refuge Complex data management processes, capabilities are fragmented amongst the data owners. Assigning custody of data to appropriate personnel and providing appropriate controls and procedures for data collection, use and records management will improve storage and facilitate use of data. In the near-term (FY 2019–2020), the data team will document, prioritize, and begin to develop and implement activities to improve Refuge Complex data management.

Table 6. Biological conservation targets and priority strategies employed to conserve them within the San Francisco Bay National Wildlife Refuge Complex: FY2018–2022.

	Coastal Dune Ecosystem (Salinas River NWR)	*Estuarine Island Ecosystem (Marin Islands NWR)*	*Marine Island Ecosystem (Farallon Islands NWR)*	*Pajaro Valley Watershed (Ellicott Slough NWR)*	*Riverine Dune Ecosystem (Antioch Dunes NWR)*	*Tidal Marsh Ecosystem (San Pablo Bay and Don Edwards SF Bay NWRs)*	*Vernal Pool Ecosystem (Don Edwards SF Bay NWR)*	*Waterbirds (San Pablo Bay, Don Edwards SF Bay, Marin Islands NWRs)*
Invasive plant management	X	X	X	X	X	X	X	
Predator management	X		X			X		X
Human disturbance management	X							X
Oil spill response			X					
Wildfire management					X			
Ecological restoration		X	X		X	X	X	
Species reintroduction					X			
Research				X				
Land protection	X			X				
Partnership development	X							

3.7 Inventory, Monitoring, and Research

Priority inventory, monitoring, or research activities are summarized for each conservation or human well-being target (see target-specific sections in chapter 4 “Conservation Target Summaries” and chapter 5 “Priority Surveys for the Human Well-Being Targets”). Current or proposed inventory or monitoring surveys are tightly linked to NRMP goals and objectives, meaning the survey measure is explicitly mentioned in a SMART goal or objective contained in this NRMP. Research is treated as a management strategy, rather than a survey, to help inform future management decisions and refine management strategies. All inventory and monitoring surveys presented in this NRMP are documented in the NWRS centralized survey database PRIMR and referenced herein. The IMP contains additional details about each survey presented in this NRMP.

3.8 Work Plan

To help guide implementation of this NRMP, and associated IMP, the Refuge Complex developed a companion five-year work plan (see link to workplan in appendix B). The work plan guides on-the-ground implementation of priority strategies and surveys laid out in the NRMP (and companion IMP) and includes the following information:

- Activities associated with priority strategies and surveys
- Lead positions for strategies and surveys (people responsible for organizing a leading a strategy or survey)
- Positions assigned to carry out strategy and survey activities
- Time allocation: estimated time needed by each position to carry out assigned activities in a given year
- Cost: estimated cost associated with a given strategy or survey activity in a given year

Most importantly, the work plan provides a framework for evaluation and adjustment—both within and across years. For example, the work plan can be used to:

- Assess implementation of strategies and surveys
- Identify, discuss, and respond to implementation challenges
- Adjust strategies and surveys as learning happens or conditions change
- Adjust people, funding, and time as conditions change
- Create more manageable workloads for staff in a given year
- Help staff stay focused on priority strategies and surveys

Conservation Measures Partnership, *http://www.conservationmeasures.org/*

Currently, the work plan format is a spreadsheet. The Refuge Complex will continue to work with the Inventory and Monitoring program to create a work planning database that better meets work planning and evaluation needs. Additional details on how work planning information is incorporated into annual evaluation, learning, and adaptation is presented in section 6.3 “Annual Evaluation and Work Planning.”

Table 7. Human-induced threats to priority conservation targets (N=8) of the San Francisco Bay National Wildlife Refuge Complex.

Threat Category	*Threat*	*CDE*	*EIE*	*MIE*	*PVW*	*RDE*	*TME: SFB*	*TME: SNP*	*VPG*	*WTB: Wintering SNP, SFB*	*WTB: Breeding MRI*	*WTB: Breeding San Pablo Bay NWR*	*Refuge Complex Summary Rating*
Climate change	Air temperature regime (LT)	H	H	H	VH	VH	H	H	H	H	VH	VH	VH
Climate change	Extreme weather events (NT)	H	M	H	L		VH	VH			H	H	VH
Climate change	Ocean chemistry (LT)			VH			VH	VH					VH
Climate change	Sea level rise (LT)	VH		VH			VH	VH		L	VH	VH	VH
Climate change	Water temperature regime (LT)			VH	H		H	H		VH	H	H	VH
Climate change	Extreme weather events (LT)	H	H	VH	VH		VH	VH			VH	VH	VH
Climate change	Precipitation regime (LT)	H	H	H	VH	VH	H	H	H				VH
Invasive and other problematic species	Invasive plants	VH	VH	H	VH	VH	H	H	H	M	L	M	VH
Invasive and other problematic species	Mammalian predators	H		H			H	L		L	VH	VH	VH
Land development	Land conversion (legacy or current)		L	M	H	H	H	H	M	VH		VH	VH
Pollution	Oil spills	M	M	H			H	L		M	M	M	H
Climate change	Air temperature regime (NT)	H	L	M	M		M	M	L	M	M	M	H
Climate change	Ocean chemistry (NT)			M			H	VH					H
Climate change	Precipitation regime (NT)	H	L	M	L	H	M	H	L				H
Climate change	Climate change: sea level rise (NT)	H		M			M	H		L	H	H	H
Climate change	Water temperature regime (NT)			H	M		M	M		M	M	M	H
Invasive and other problematic species	Avian predators	H		H			M	L		L	L	H	H
Transportation Corridors	Roads, railways, or levees				H		H	H	L		L		H
Biological resource use	Hunting or poaching: legacy or current			H		M				L			M
Climate change	Ocean upwelling (LT)			H									M
Climate change	Ocean upwelling (NT)			H									M
Human disturbance	Human disturbance: recreation	M					L	L		L	M	L	M

Threat Category	*Threat*	*CDE*	*EIE*	*MIE*	*PVW*	*RDE*	*TME: SFB*	*TME: SNP*	*VPG*	*WTB: Wintering SNP, SFB*	*WTB: Breeding MRI*	*WTB: Breeding San Pablo Bay NWR*	*Refuge Complex Summary Rating*
Human disturbance	Refuge management activities		M	L		M				L	L	L	M
Invasive and other problematic species	Invasive aquatic wildlife				M		M	M	L	L			M
Invasive species	Disease		M	M	L	M			M	L	L	L	M
Natural system modifications	Lack of native grazers								H				M
Pollution	Agricultural pesticides, fertilizers, urban runoff, and other pollutants	L	M	M	L		M	L	L	M	L	H	M
Pollution	Mosquito control pesticides				L	H	L	L	L				M
Human disturbance	Illegal activities by humans	M			L		L	L	L	L	H	L	M
Biological resource use	Commercial fisheries			M									L
Human disturbance	Aircraft disturbance			L									L
Human disturbance	Boat disturbance			L						L			L
Human disturbance	Mosquito management: disturbance						L	L	L				L
Invasive and other problematic species	Native nuisance species (predation)				L				M				L
Pollution	Gypsum deposition					M							L
Pollution	Marine debris		L	L			L	L		L			L
Pollution	Point source pollution			M									L

Key: Target abbreviations: CDE = coastal dune ecosystem at Salinas River NWR; EIE = estuarine island ecosystem at Marin Islands NWR; MIE = marine island ecosystem at Farallon Islands NWR; RDE = riverine dune ecosystem at Antioch Dunes NWR; TME = tidal marsh ecosystem at San Pablo Bay NWR and Don Edwards San Francisco Bay NWR; PVG = Pajaro Valley watershed at Ellicott Slough NWR; VPG = vernal pool grassland at Don Edwards San Francisco Bay NWR; WTB = waterbirds at Don Edwards San Francisco Bay NWR, San Pablo Bay NWR, and Marin Islands NWR.

Threat abbreviations: L (dark green) = Low; M (light green) = Medium; H (yellow) = High; VH (red) = Very High.

Threat: LT = Long-term, NT = Near-term

Chapter 4—Conservation Target Summaries

4.1 Coastal Sand Dune Ecosystem

Information sources used to describe the coastal dune ecosystem are presented below. Any other sources are cited in-text.

- *Recovery Plan for the Pacific Coast Population of the Western Snowy Plover (Charadrius nivosus nivosus)* (USFWS 2007)
- *Salinas River National Wildlife Refuge Comprehensive Conservation Plan* (USFWS 2002)
- *San Francisco Bay NWR Complex Climate Assessment* (California Landscape Conservation Cooperative et al. 2018a)
- *Smith's Blue Butterfly (Euphilotes enoptes smithi) 5-Year Review: Summary and Evaluation (*(USFWS 2006)
- *Smith's Blue Butterfly Recovery Plan* (USFWS 1984)
- *Species Profile for Western Snowy Plover (Charadrius nivosus nivosus)* (USFWS 2018)

4.1.1 Overview

The coastal sand dune ecosystem occurs at Salinas River NWR. Here, the coastal dunes represent one of the most intact dune ecosystems found in Monterey Bay, California (figure 3), they provide connectivity between protected dunes in Monterey Bay, and they support a unique juxtaposition of beach, dunes, and adjacent wetland environments, which is rare along the California coast and found nowhere else in Monterey Bay. The coastal sand dune ecosystem also provides habitat for a diverse community of waterbirds and dune-adapted plant and wildlife species. For example, one of the largest Monterey Bay breeding populations of western snowy plover (*Charadrius nivosus nivosus,* SNPL), which is federally listed as threatened and found on the refuge.

Nested Targets of the Coastal Sand Dune Ecosystem:

- Western snowy plover (SNPL)
- Smith's blue butterfly (SBB)
- Central dune scrub (dune scrub, backdune)
- Central foredune and beach

The 367-acre refuge was established in 1973 because of its particular value in conserving migratory birds. Between 1973 and 1990, the lands were managed by the California Department and Fish and Game (now the California Department of Fish and Wildlife [CDFW]) under a cooperative agreement with the Service.

The refuge is located approximately 11 miles north of Monterey, where the Salinas River empties into Monterey Bay. The refuge is bounded by Salinas River State Beach to the north, the Big Sur Land Trust Martin Dunes to the south, Salinas River to the northeast, and the Pacific Ocean to the west (figure 4). Agricultural lands lie predominantly east of the refuge. The beach and associated dunes at Salinas River NWR encompass approximately 50 acres of foredunes and dune scrub (or backdunes) (USFWS 2006).

In addition to beach and coastal sand dunes, the refuge encompasses grassland, wetland (saline pond, salt marsh), and riparian forest and scrub environments (figure 4). The refuge's 2002 CCP identifies conservation goals, objectives, and strategies that encompass all the biodiversity found at Salinas River NWR. Because resources within the Refuge Complex are increasingly limited, conservation efforts were prioritized. Coastal sand dunes were identified as a high conservation priority for the refuge and Refuge Complex. As more resources or opportunities become available, conservation efforts can expand into other environments of the refuge.

4.1.2 Ecology

Central dune scrub (backdune) at Salinas River NWR. Credit: Larry Wade, USFWS

Coastal sand dunes (and associated beach) are transition environments between terrestrial and marine ecosystems and occur where there is an adequate supply of sand and where prevailing winds are strong enough for sand movement to occur (Everard et al. 2010). Coastal dunes are subjected to salt spray, high winds, a shifting substrate, porous soils, and high solar radiation (Pickart 2008). They are dynamic environments which are constantly changing in response to environmental factors such as winds, waves, and tides. Intact coastal sand dune ecosystems support a diverse assemblage of plants and animals that are uniquely adapted to ocean influences (such as salt spray and wind), shifting sands, and nutrient-poor soils. Endangered and threatened species inhabiting coastal dunes of the refuge are Smith's blue butterfly (*Euphilotes enoptes smithi*; SBB) (federally listed as endangered), Monterey spineflower (*Chorizanthe pungens*) (federally listed as threatened), and the Pacific coast population of SNPL (*Charadrius nivosus nivosus*) (federally listed as threatened, California species of special concern). The vision statement of the refuge CCP explicitly states that endangered or threatened species will receive management priority, with special emphasis on the conservation and recovery of SNPL (USFWS 2002).

Central Foredune, Beach, and Central Dune Scrub

Beach is defined here as a strip of sandy substrate that extends from the mean high tide line to the foredune (Pickart and Barbour 2007). The beach and, to a lesser extent, the foredune experience high exposure to salt spray and wind and contain a shifting, sandy substrate with low water-holding capacity and low organic matter content. The foredune is a ridge that runs parallel to the prevailing winds and perpendicular to the beach at Salinas River NWR. The foredune plant community typifies sand dunes in the early stages of colonization and stabilization by plants above the high tide line. Foredunes and associated beach compose approximately 36 acres of the refuge and provide year-round habitat for SNPL as well as many other waterbird species.

Dune scrub, also referred to as the *backdune*, is found landward of the foredune and is more stabilized (with vegetation) relative to the foredune. Dune scrub is characterized by a dense cover of low, perennial, woody subshrubs and herbaceous vegetation. Dune scrub can form "blowouts" where high winds uproot or cover established dune vegetation and set back the successional stage of the dune. Dune scrub composes approximately 15 acres of the refuge and provides habitat for SBB as well as Monterey spineflower and other plant species considered rare in California (by the California Native Plant Society, CNPS) such as Monterey Indian paintbrush (*Castilleja latifolia),* branching beach aster (*Coreothogyne leucophylla*), and coast wallflower (*Erysimum asmmophilum).*

Western Snowy Plover

Western snowy plover (*Charadrius nivosus nivosus)*.
Credit: © Aric Crabb, Bay Area News Group

The Pacific coast population of the western snowy plover (SNPL) includes individuals that nest adjacent to tidal waters of the Pacific Ocean (USFWS 2018a). The Pacific coast breeding population extends from Damon Point, Washington, south to Bahia Magdalena, Baja California, Mexico (USFWS 2007). At Salinas River NWR, SNPL establishes nests primarily in foredune and beach environments and forages in a wide variety of coastal environments found on and adjacent to the refuge. In 1993, the Pacific Coast population of SNPL was federally listed as threatened due to a variety of threats including human disturbance, urban development, predation by birds and mammals, and invasive plants (USFWS 1993, 2007).

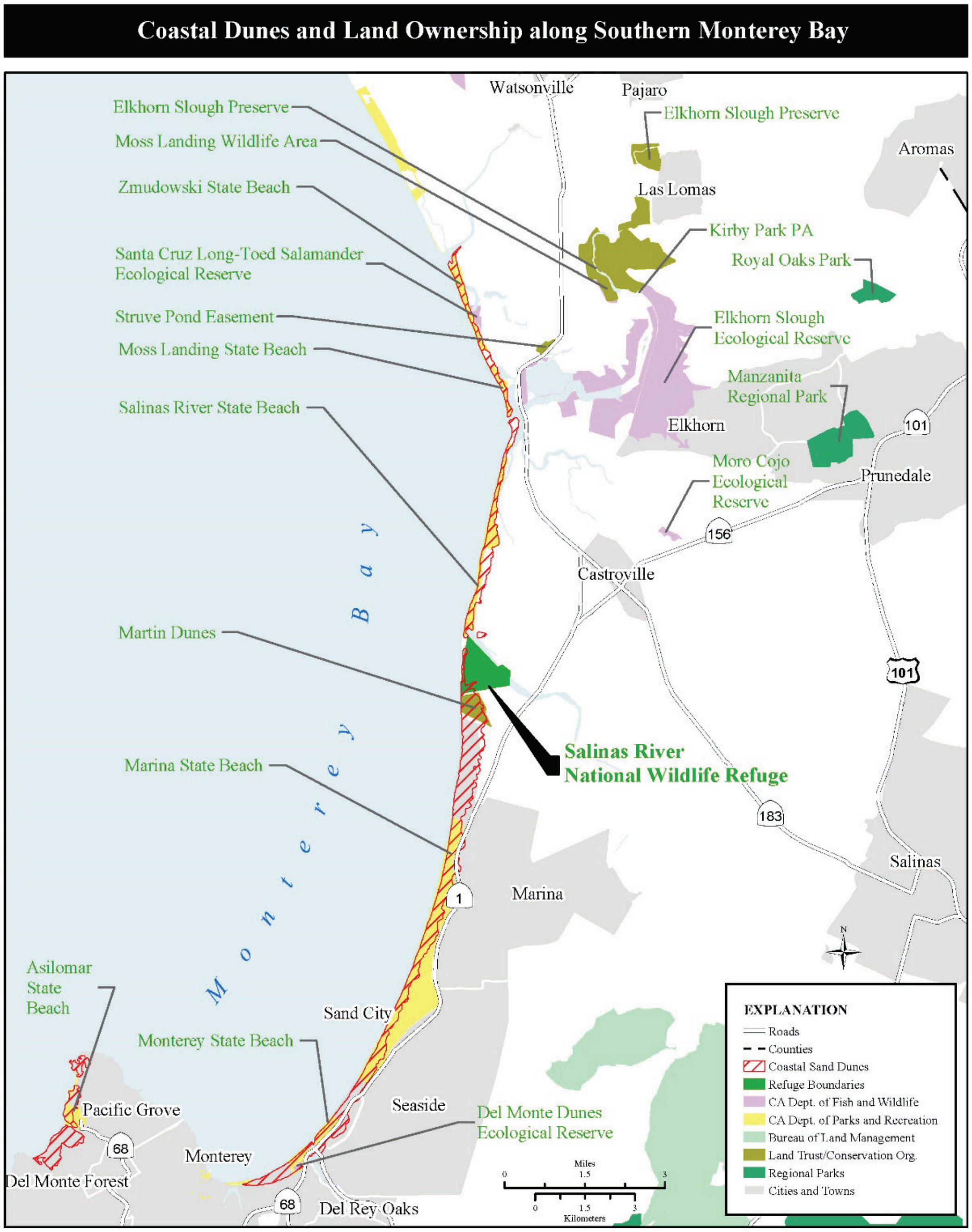
SNPL breeding habitat occurs near water—primarily above the high tide line—on coastal beaches, sand spits, dune-backed beaches, sparsely vegetated dunes, beaches at creek and river mouths, and salt pans at lagoons and estuaries (USFWS 2007). In general, the species nests in flat, open environments with sandy or saline substrates (Widrig 1980; Wilson 1980; Stenzel et al. 1981). Studies from southern California suggest SNPL nests in areas with 6–18% vegetative cover that is usually less than 6 centimeters in height (Powell et al. 1995, 1996). The species feeds on aquatic and terrestrial invertebrates found in wet sand and surf-cast kelp within the intertidal zone; in dry sand areas above the high tide; on salt pans; on spoil sites; and along the edges of salt marshes, salt ponds, and lagoons (USFWS 2007).

Smith's Blue Butterfly

Smith's blue butterfly (*Euphilotes enoptes smithi*).
Credit: © Dale Hameister

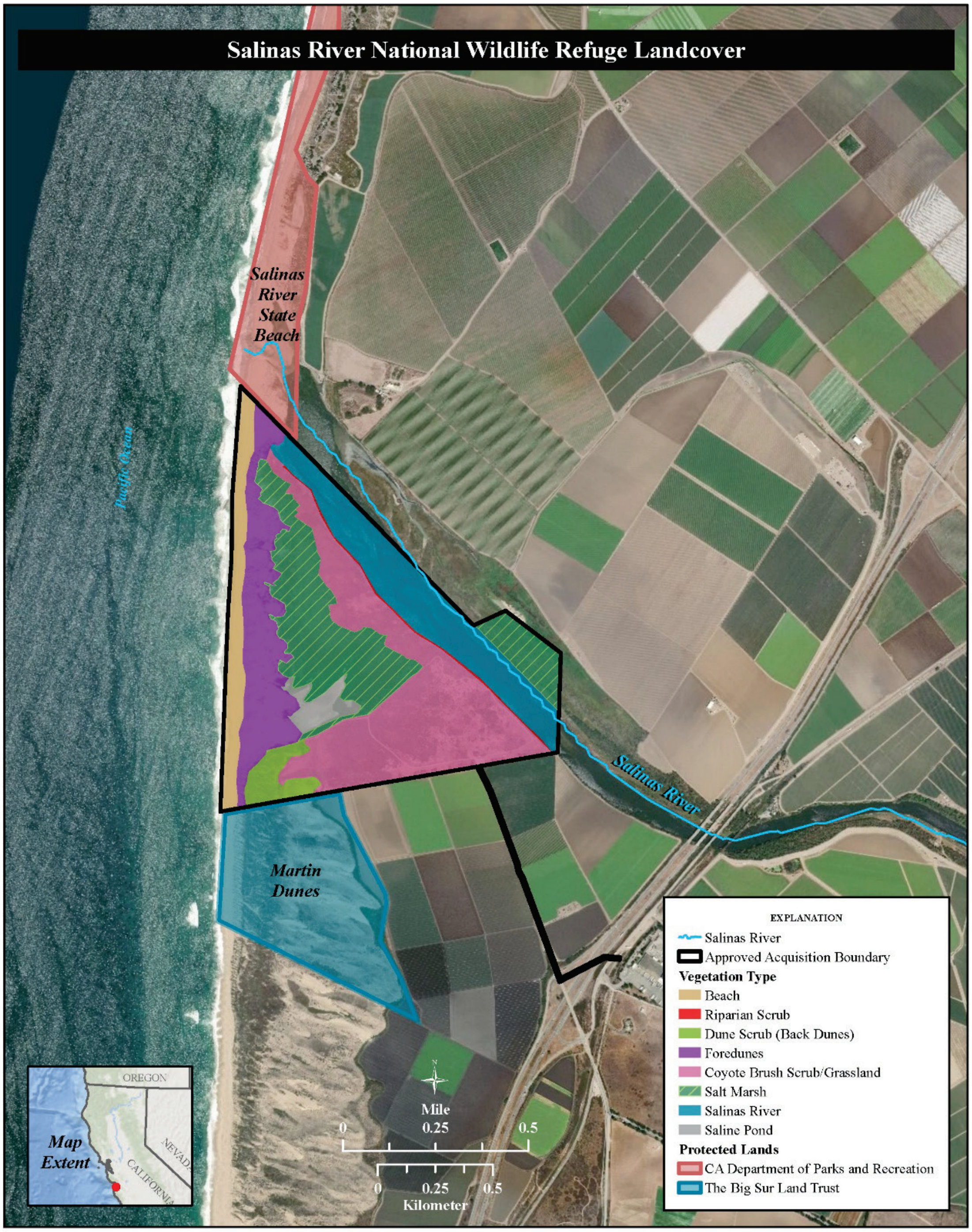
In 1976, SBB was federally listed as endangered as a result of habitat loss from human developments and sand dune degradation from off-road vehicle use and invasive plants such as the common ice plant (*Mesembryanthemum crystallinum*) and European beachgrass (*Ammophila arenaria)*. The SBB recovery plan objectives focus on (1) maintaining viable populations at the 10 occupied sites at the time of listing and (2) establishing viable populations at additional sites (USFWS 1984). A 5-year species review conducted in 2005 suggested down-listing SBB to threatened because the occupied range of the species is larger than what was known at the time of listing (USFWS 2006). The known species range stretches from Monterey Bay south to northern San Luis Obispo County. The refuge represents the northernmost known locality. No critical habitat has been designated for the subspecies.

SBB is associated with coastal and inland sand dunes, as well as chaparral and grassland vegetation communities along the central California coast. At Salinas River NWR, SBB is primarily associated with central dune scrub. The species spends its entire life cycle in association with two plant species, seaside buckwheat (*Eriogonum latifolium)* and seacliff buckwheat (*E. parvifolium)* (Black and Vaughan 2005). For example, adults feed on the nectar, use the plants as perching sites, and deposit eggs on the flowers, and larvae feed on the flowers and seeds.



Map Projection: North American Datum 1983 Universal Transverse Mercator Zone 10; Map Production Date: 12/6/2018; Source Data: Refuge boundaries from U.S. Fish & Wildlife Service Cadastral Data, August 2017.Sources: Natural Resources Conservation Service, CA Department of Parks and Recreation, CA Department of Fish and Game, Bureau of Land Management, and GreenInfo Network. Original map created in 2001 during Comprehensive Conservation Planning.

Figure 3. Salinas River National Wildlife Refuge and surrounding protected lands in Monterey Bay, California.



Map Projection: North American Datum 1983 Universal Transverse Mercator Zone 10; Map Production Date: 12/6/2018; Source Data: Refuge boundaries from U.S. Fish & Wildlife Service Cadastral Data using Acquired tracts, August 2017;National Hydrology Dataset downloaded from US Geological Survey in June 2017; Landcover data created by refuge; Protected lands identified from refuge data, then parcel data was used for polygons; Imagery is Esri Basemap World Imagery.

Figure 4. Landcover types and adjacent lands of Salinas River National Wildlife Refuge.

4.1.3 Target Status, Trends, and Goals

Three KEAs and associated indicators were selected to represent the integrity and health of the coastal sand dune ecosystem at Salinas River NWR: 1) sand dune vegetation cover and composition, 2) SNPL reproductive success, and 3) SBB population size. Based on current knowledge of the status and trends of KEAs and associated indicators, the health of the coastal dune ecosystem at Salinas River NWR is considered Good. The relationship between indicator measures and the status of the sand dunes (Poor to Very Good) is detailed in the Refuge Complex conservation target viability database (appendix B). KEAs, associated indicators, indicator status and trends, and desired future conditions (SMART goals) are summarized in table 8.

KEA 1: Sand Dune Vegetation Cover and Composition

Sand dune vegetation cover and composition is indicated by 1) percent cover of dune-associated native plant species in the foredune and central dune scrub vegetation communities and 2) percent cover of open sand in foredune and central dune scrub environments. Understanding the status and trends of dune vegetation is important because the vegetation cover and composition strongly influence biodiversity of the sand dunes; many dune-adapted species depend on availability of open sand and dune-adapted plant species. For example, SBB survival is dependent on two dune plant species, seaside and seacliff buckwheat, and SNPL is associated with sparsely vegetated environments found in intact sand dunes. Further, trends in sand dune vegetation are linked to underlying sand dune dynamics and formation. Altering sand dune vegetation will influence sand dunes and, in turn, the species that depend on them. Formal inventory or monitoring of sand dune vegetation cover and composition has not been conducted at Salinas River NWR. For this reason, statements about the status of vegetation cover and composition provided here are based on best professional judgment (refuge staff and Kriss Neuman from Point Blue Conservation Science). The percent cover of dune-associated native plant species is considered Very Good and percent cover of open sand is considered Good (table 8).

KEA 2: Western Snowy Plover Reproductive Success

Reproductive success of SNPL is highly dependent on the health of the coastal sand dune ecosystem, particularly the foredunes. SNPL is sensitive to and responds quickly to changes in land cover characteristics (such as percent sand cover) and threats such as predators and human disturbance. Because of these sensitivities, SNPL can provide early warning signs of stress to the coastal sand dune ecosystem. In addition, recovery of this species is based on the following population demographic metrics: (1) a breeding population >3,000 breeding adults sustained for 10 consecutive years across 6 recovery units (400 in Sonoma to Monterey recovery unit #4) and (2) reproductive success of >1 fledged young (per male) for 5 years within each recovery unit (USFWS 2007).

Point Blue Conservation Science, with the assistance of refuge staff and the California Department of Parks and Recreation, has monitored SNPL populations in Monterey Bay since 1984 (Point Blue Conservation Science 2018) to assess recovery and inform refuge management decisions. Long-term population data show the number of SNPL breeding adults has increased in Monterey Bay since 1999. In 2017, 403 breeding adults were recorded in Monterey Bay. This value exceeded the USFWS recovery target (for recovery unit #4) of 400 breeding adults for 5 of the last 10 years. During the same year, 33 SNPL nesting attempts[3] were recorded at Salinas River NWR, representing 9% of nesting attempts in beach/dune sites across Monterey Bay. Reproductive success of SNPL at Salinas River NWR is indicated by:

- Clutch hatching success (%) = (# nests with ≥1 egg hatched/total # nests) *100
- Fledging success (%) = (# banded chicks fledged/# banded chicks) *100

[3] Nesting attempts is the sum of nests found at the egg stage or brood stage.

From 2015 to 2017, the average SNPL clutch hatching success at Salinas River NWR was 46%. This value is below the Monterey Bay average of 61% from 1999 to 2014 (Point Blue Conservation Science 2016, 2018) and is considered Fair (=40–50%). From 2015 to 2017, the average SNPL fledging success at Salinas River NWR was 48% (banded chicks), which is above the 5-year average of 40% for Monterey Bay from 1999 to 2014 (Point Blue Conservation Science 2016, 2018) and is considered Good (=41–50%). Declines in hatching and fledging success at Salinas River NWR are primarily attributed to avian and mammalian predation (Caris 2016; Point Blue Conservation Science 2016, 2018). In 2017, 87% of SNPL nest losses at the refuge were attributed to common ravens (*Corvus corax*). Overall, the long-term trend (10-year) in SNPL reproductive success at the refuge—and Monterey Bay as a whole—is declining. Indicator viability scales (measures of Poor to Very Good), status, and trends of SNPL reproductive success were assessed using expert opinion (refuge staff and Kriss Neuman from Point Blue Conservation Science) and available survey reports (Point Blue Conservation Science 2016, 2018).

KEA 3: Smith's Blue Butterfly Population Size

Because of the strong link between SBB populations with intact coastal sand dunes (specifically central dune scrub or back dunes) containing seaside and seacliff buckwheat plant populations, the status and trends of SBB populations are representative of coastal sand dune ecosystem health. Surveys conducted at Marina State Beach, approximately 3 miles south of the refuge, yielded a population estimate of 4,511 adults (Arnold 1986). At Fort Ord sites further south in Monterey Bay, SBB population estimates ranged from 3,081 to 5,201 over 3 years (1977–1979) (Arnold 1978, 1981, 1983). The estimated population size of SBB at Salinas River NWR was 1,483 in 2015, 974 in 2016, and 605 in 2017 (Caris 2016, 2017, 2018). Although the trend is decreasing, longer-term data are needed to better understand population status and natural fluctuations over time. The status of SBB populations is estimated as Fair. Indicator viability scales (measures of Poor to Very Good), status, and trends were developed by refuge staff (with survey protocol and data analysis assistance from Dick Arnold, PhD.) and will be improved over time as additional data become available.

Table 8. Current status and desired future state (goals) of the coastal sand dune ecosystem at Salinas River National Wildlife Refuge in terms of key ecological attributes and indicators.

Key Ecological Attribute	*Indicator*	*Status: Recent Measure (Trend)*	*Status Source*	*Goal*
Sand dune vegetation cover and composition	% cover of dune-associated native plant species in the foredune and dune scrub	Good: foredune = 97%; backdune = 90% (stable)	Best educated guess	CDE_G01. Over the next 15 years (2018–2032), the proportion of dune vegetation cover comprised of dune-associated native plant species is >95% in the foredunes and >85% in the backdunes (dune scrub) at Salinas River NWR.
Sand dune vegetation cover and composition	% cover open sand in the foredune and dune scrub	Very good: foredune = 95%; backdune = <20% (stable)	Best educated guess	CDE_G02. Over the next 15 years (2018–2032), % sand cover is ≥90 in the foredunes and <20% bare ground in the dune scrub (back dunes) at Salinas River NWR.
Western snowy plover reproductive success	Mean clutch hatching success (%) = (# nests with ≥1 egg hatched / total # nests) *100. Mean is 3-year running average	Fair: 46% (decreasing)	Point Blue Conservation Science (2016, 2018)	CDE_G03. Over the next 15 years (2018–2032), western snowy plover clutch hatching success ([# nests with ≥1 egg hatched/total # nests]*100) is >40% at Salinas River NWR. Goal evaluated based on a 3-year moving average.
Western snowy plover reproductive success	Mean fledging success (%) = (# banded chicks fledged/ # banded chicks) *100. Mean is 3-year running average	Good: 48% (decreasing)	Point Blue Conservation Science (2016, 2018)	CDE_G04. Over the next 15 years (2018–2032), western snowy plover fledging success ([# banded chicks fledged/# banded chicks]*100) is >40% at Salinas River NWR. Goal evaluated based on a 3-year moving average.
Smith's blue butterfly population size	Index of Smith's blue population size (estimated # adults). Mean over 3 years (running average)	Fair: 605 (trend unknown)	2015–2017 Refuge surveys (Caris 2016, 2017, 2018)	CDE_G05. Over the next 15 years (2018–2032), the estimated population size of Smith's Blue butterfly at Salinas River NWR is ≥900 at Salinas River NWR. Goal evaluated based on a 3-year moving average.

Note: Status designations: red = Poor, yellow = Fair, light green = Good, dark green = Very Good. Refer to the San Francisco Bay National Wildlife Refuge Complex viability database for additional details (appendix B.

The term *backdunes* is synonymous *with dune scrub*. Trends assessed over a 10-year period.

4.1.4 Critical Threats

The most critical threats (classified as High or Very High threats) to the coastal dune ecosystem are invasive plants, climate change, and increasing avian and mammalian predator populations. Human disturbance and illegal activities by humans (such as trespassing) pose a medium to high threats. Lower ranked threats (low to medium) are Salinas River breach activities, oil spills, and contaminants (such as agricultural pesticides). A conceptual model depicting threats to the coastal dune ecosystem, their relationship to biophysical factors of the ecosystem, and strategies aimed at reducing the most critical threats or directly restoring the dune ecosystem is depicted in figure 5. The most critical threats (High to Very High) to the coastal dune ecosystem are summarized in the following.

Invasive Plants (Very High Threat)

Invasive plants of greatest concern to the coastal dune ecosystem at Salinas River NWR have one or more of the following characteristics:

1. Alter the dune profile through stabilization and change dune topography to a much steeper gradient (Pickart and Sawyer 1998). Stabilization can facilitate competitive ability of invasive plants, resulting in their further spread and loss of open sand.
2. Exclude native plants, such as seaside and seacliff buckwheat, upon which SBB relies (Arnold and Goins 1987). Monotypic stands of invasive plants can reduce or eliminate native plants associated with coastal sand dunes, including loss of rare dune-associated plant species such as the Monterey spineflower (Pickart and Barbour 2007; Seabloom and Wiedemann 1994).
3. Reduce available SNPL nesting habitat quality. SNPL prefer sparse vegetation for nesting; increases in invasive plant cover are one of several factors that lead to decline in Pacific coast SNPL active nesting areas and breeding/wintering populations (USFWS 2007).
4. Provide habitat for mammalian predators that would otherwise be precluded by intact dunes with low vegetative cover (USFWS 2007).

Common ice plant (*Mesembryanthemum crystallinum*) and introduced beachgrass (*Ammophila* spp.) exhibit these characteristics are a current concern and therefore a focus of management at Salinas River NWR.

Factors that contribute positively (+) or negatively (-) to the invasive plant threat include:

- Neighboring seed sources (-). The refuge is surrounded by neighboring lands that contain uncontrolled populations of invasive plants and act as a source for new infestations. The Salinas River is also a source of invasive plants, as the refuge is located at the mouth of the river, where along the banks, seeds and uprooted vegetation from upstream are regularly deposited.
- Human and animal vectors (-). Visitors to the refuge, staff, migrating wildlife, and birds are potential vectors of invasive plants, resulting in new introductions or further spread.
- Propagule bank (-). In some cases, propagules (such as seeds) of invasive plants can remain in the environment for long periods of time (years) and can act as a source for re-establishment following control efforts.
- Weed management area, local land trusts, and other partners (+). The Monterey County Weed Management Area and other conservation organizations (such as the Big Sur Land Trust) can provide opportunities to share information or provide opportunities to collaborate on larger landscape invasive plant management efforts, such as early detection and rapid response to new invasions or managing established invasive plant populations. These collaborative efforts have the potential to reduce invasive plant threats on the refuge.

Avian and Mammalian Predators (High Threat)

Expanding mammalian and avian predator populations can cause stress and increase mortality of waterbirds. Stress to breeding SNPL populations are of particular concern at the refuge. Increased predator density is considered a major factor limiting SNPL reproductive success at many Pacific coast sites (USFWS 2007; Stenzel et al. 1994). Predation occurs at all SNPL life stages, and disturbance by predators can also cause separation of chicks from adults, resulting in reduced reproductive success and population size (USFWS 2007). In Monterey Bay, common ravens are the dominant avian predators, although raptor species can also cause intermittent and significant mortality (Point Blue Conservation Science 2016, 2018). Mammalian predators include dogs (Canidae), cats (*Felis catus*), foxes (such as red fox [*Vulpes vulpes*]), skunks (*Mephitis* spp.), and opossums (*Didelphis virginiana*) (Point Blue Conservation Science 2018; USFWS 2007). Prior to 1994, wide-scale SNPL nest losses to mammalian predators throughout the Monterey Bay area were documented. Following initiation of mammalian predator management at Salinas River NWR and throughout Monterey Bay (1993–1999), the number of fledglings per male Monterey Bay-wide increased from 0.86 to 1.1, then declined sharply as avian predation on chicks became increasingly significant (Neuman et al. 2004). Following initiation of avian predator management, fledging success again increased in target areas. Although progress has been made on reducing the overall impact of predators, predation events still occur and can result in significant declines in SNPL reproductive success. For example, in 2015, Salinas River NWR had the second highest number of nests documented in Monterey Bay (N=61), but due in large part to avian predation, fledging success was only 9%, one of the lowest values in Monterey Bay (Point Blue Conservation Science 2016). It is thought that predation on chicks by a resident peregrine falcon (*Falco peregrinus*) was the cause of low fledging success at Salinas River NWR (Caris 2016).

Factors that contribute positively (+) or negatively (-) to the threat of avian or mammalian predation include:

- Local dump (-). Landfills near Salinas River NWR attract predators and may contribute to increased predator populations (such as ravens or crows).
- Lack of visitor infrastructure (-). The Refuge Complex does not have the capacity to maintain trash cans or dumpsters for refuge visitors. At this time, Refuge Complex staff are onsite at Salinas River NWR approximately once per week. The lack of trash receptacles can lead to visitors leaving litter on the beach, river bank, and parking lot, which in turn can attract predators. In addition, human trash can become hazardous to wildlife.
- Local land trusts, nature areas, and partners (+). The refuge works with conservation partners in the Monterey Bay area to collectively manage predator populations.

Climate Change (High to Very High Threat)

Global climatic changes can result in stress to the coastal dune ecosystem. Climate changes of particular concern in the Monterey Bay area include alteration of temperature and precipitation regimes, extreme events (high intensity storms, heat waves), and sea level rise. Key findings from the *San Francisco Bay National Wildlife Refuge Complex Climate Assessment* (CALCC et al. 2018) and the *Water Resources Inventory and Assessment: Salinas River National Wildlife Refuge Climate Inventory and Summary* (Esralew and Michehl 2017) are presented in the following:

- Persistent and substantial increases in temperature were observed for all climate models and emissions scenarios evaluated through 2100, ranging from 9.2 to 13.6 °F.
- The frequency of hotter years and extreme heat events is likely to increase substantially in the future. After 2039, all years had greater mean temperatures than the highest mean temperature observed in the past. By 2100, extreme heat events could occur in 79–100% of years.
- Increases in mean precipitation is likely (up to +81.6% by 2100). There is uncertainty in the change in frequency of wetter years and extreme rain events; some models show increased frequency in wet years and extreme events (17.2%), and some models show no change or decreased frequency of these events.
- Winter droughts (lower winter flows) will likely increase slightly; by 2100, 13.8% of years will have lower winter flows than the lowest flow observed in the past. There is uncertainty, however, as to whether higher winter flows and flood events would increase, decrease, or stay the same.
- Estimates of global sea level rise for California suggest an increase of 14.2 inches by 2050 and a high estimate of 55.1 inches by 2100. The effect of climate change and sea level rise on coastal wetlands will likely increase coastal erosion. The southern coast of Monterey Bay is eroding more rapidly than other coastal areas in the state. Erosion rates between 1 and 6

feet per year have been measured at the coastal dunes between the mouth of the Salinas River and Monterey Harbor, in close proximity to the refuge.

Where coastal dunes are backed by human infrastructure, the capacity of dunes to retreat inland in response to sea level rise could be blocked, thereby reducing the overall extent and connectivity of remaining coastal sand dunes (Feagin et al. 2005). Sea level rise can also disrupt the successional dynamics and coastal processes that lead to the formation of mature coastal dune vegetation communities and biodiversity (Feagin et al. 2005). An increase in severe storms and coastal flooding could be detrimental to reproductive success and survival of insects (such as SBB) and beach-nesting birds (such as SNPL). Warmer air and soil temperatures (especially in winter), changes in precipitation, and an earlier spring transition of weather and ocean patterns have been shown to result in changes in phenological processes in plants and insects. These changes can potentially cause the decoupling of conditions important for survival of species (including SBB), such as insect reproductive events mistimed with peak food availability (driven by plants). Lastly, extreme heat events have been shown to cause mortality (via heat strokes) to bird species that nest in open exposed environments (Overstreet and Rehak 1982).

Human Disturbance from Recreation or Illegal Activities (Medium to High)

Human disturbance includes activities by humans and their pets that lead to changes in the behavior, distribution, and abundance of wildlife and plants (Lafferty et al. 2006; Rodgers 2002; Rust and Illenberger 1996) or that can result in changes to the abiotic features or processes. While single human disturbance events may be non-lethal and temporary, the cumulative effects of multiple disturbances over time may become significant. At Salinas River NWR, disturbance from humans, pets, and off-road vehicles can alter the native plant community (trampling of native dune vegetation) or disturb wildlife, particularly waterbirds. For example, human disturbance can lead to direct mortality (trampling/crushing of bird nests); flush adults from active nests or separate chicks from brooding adults, exposing eggs or young to predation or weather; and interfere with foraging and mating activities—all of which lead to reduced reproductive success (Lafferty 2001; Ruhlen et al. 2003; Lafferty et al. 2006; USFWS 2011). Disturbance of nesting or brooding SNPL by humans and domestic animals (such as dogs) is a major factor affecting SNPL nesting success (USFWS 2011). A study examining the response of SNPL to reductions in human disturbance showed SNPL abundance and fledging rates increased following measures—installing a rope fence, posting signs, and using volunteers/docents—to reduce disturbance (Lafferty et al. 2006). At Salinas River NWR, “symbolic” fencing is maintained around SNPL breeding areas to deter human-mediated disturbances. From 2015 to 2017, causes of SNPL nest losses have been attributed primarily to avian predators, with less than 5% attributed to humans (Point Blue Conservation Science 2016, 2018).

Factors that contribute positively (+) or negatively (-) to the threat of human-mediated disturbance include:

- Lack of outreach to the fishing community (-). Fishing by humans along the beach can disrupt foraging SNPL adults and chicks or cause adults to leave their nests for extended periods of time.
- Lack of visitor infrastructure (-). As noted earlier, due to logistical constraints, the Refuge Complex does not have the capacity to maintain trash cans or dumpsters for refuge visitors. At this time, Refuge Complex staff are onsite at Salinas River NWR approximately once per week. The lack of trash receptacles can lead to visitors leaving litter on the beach, riverbank, and parking lot, which in turn can attract predators. In addition, human trash can become hazardous to natural resources and humans.
- Lack of dog friendly beaches (-). There is a lack of beaches near the refuge that permit dog use. This situation leads to dog use in sensitive wildlife areas such as those found on the refuge.
- Lack of regulatory authority below the mean tide line (-). Refuge policies that limit disturbance (such as no dogs or horses) can only be enforced above the mean high tide line (unless take of an endangered species or migratory bird is observed).

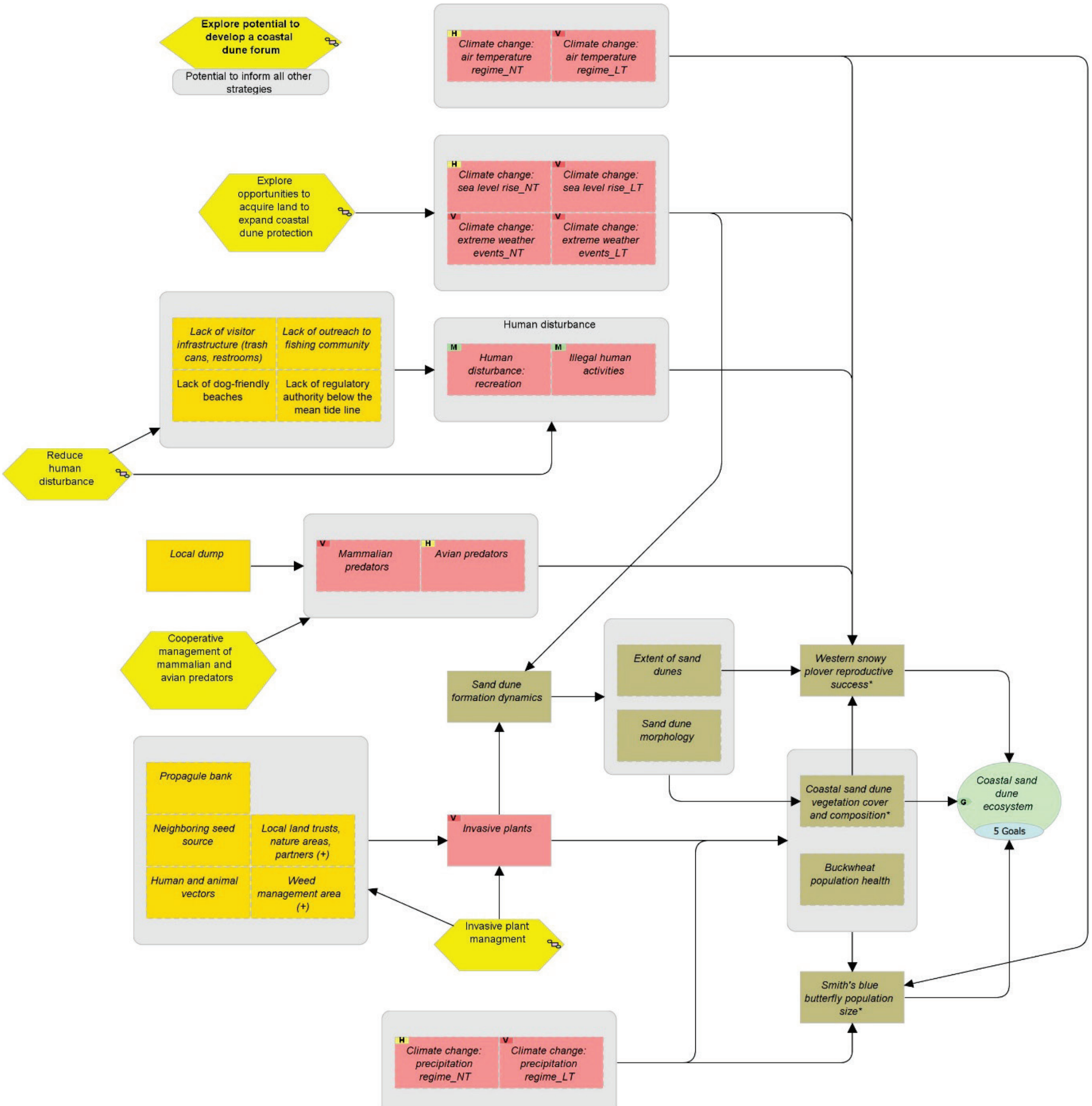


Figure 5. Conceptual model of the coastal sand dune ecosystem at Salinas River National Wildlife Refuge.
Notes: Only Very High or High threats to the ecosystem are depicted here. Legend: green oval = natural resource conservation target; olive box = biophysical or human well-being attribute; pink box = direct threat; orange box = contributing factors; yellow hexagon = conservation strategy. The letters in the upper left portion of threats (pink boxes) represent the summary threat ranking across the seven refuges of the San Francisco National Wildlife Refuge Complex (L=low, M=moderate, H=high, VH=very high).

4.1.5 Conservation Strategies and Objectives

Conservation strategies for the coastal dune ecosystem at Salinas River NWR are focused on reducing or mitigating the most critical threats: invasive plants, predation, climate change, and human disturbance. Threats addressed by each strategy and expected outcomes (objectives) are summarized in table 9. Each strategy is briefly described below in order of priority to implement. Results chains visually depicting the assumptions behind these strategies (how they work) and expected outcomes are stored in the Miradi file associated with this NRMP (see appendix B for a link to this file). Strategies outlined here support recovery actions identified in the *Recovery Plan for the Pacific Coast Population of the Western Snowy Plover* (USFWS 2007).

Invasive Plant Management

Continue to implement integrated pest management strategies aimed at reducing the abundance and distribution of invasive plant threats (such as beachgrass and iceplant [*Carpobrotus edulis*]) in the coastal dunes using chemical and mechanical methods. Improve the refuge invasive plant management strategy through 1) documenting the most harmful invasive plant species (current and potential future); 2) assessing the status of priority invasive plant threats (inventory); 3) refining and documenting invasive plant management strategies (integrated pest management plan) using information from the baseline inventory, invasive plant ecology, and current science; and 4) implementing strategies, monitoring effectiveness of strategies, and adapting strategies as needed. Evaluation and documentation of the refuge invasive plant management strategy will be conducted using a standardized Refuge Complex–level approach to invasive plant management and is discussed in more detail in section 3.6. The Refuge Complex invasive plant management strategy is expected to benefit the coastal dune ecosystem by preserving the dynamic nature of the sand dunes (sand movement and dune formation), maintaining biodiversity of the native dune plant community, and ultimately continue to provide high quality habitat for dune-adapted wildlife (such as SNPL and SBB).

Cooperative Management of Mammalian and Avian Predators

Continue to control avian and mammalian predators threatening the coastal dune ecosystem at Salinas River NWR. This work is guided by the *Salinas River National Wildlife Refuge Predator Management Plan and Environmental Assessment* (USFWS 1993) and the *Salinas River National Wildlife Refuge Avian Predator Management Plan* (USFWS 2002). Predator management is carried out by the U.S. Department of Agriculture (USDA)–Wildlife Services in partnership with conservation partners throughout the Monterey Bay area (such as California State Parks and CDFW). Predator management is primarily carried out using humane and target species–specific non-lethal methods (such as box-type traps, soft-catch padded leg-hold traps, hazing, bow nets, and lures). Lethal methods, including shooting and euthanasia, are used when necessary. Predator management activities include (1) development and maintenance of contracts, agreements, or permits; (2) conducting an annual assessment and planning of predator management activities; (3) assisting with carrying out predator management activities led by USDA–Wildlife Services; and (4) for SNPL productivity surveys (in partnership with Point Blue Conservation Science), documenting and tracking SNPL nest loss from avian and mammalian predators. This strategy is expected to benefit the coastal dune ecosystem by reducing the density of predators and associated waterbird mortality, particularly breeding SNPL.

Reduce Human Disturbance

This strategy is aimed at preventing human-mediated disturbance to the coastal dune ecosystem, particularly waterbirds (such as SNPL) and their habitat. Disturbance sources that are the focus of this strategy are refuge recreationists and illegal activities (such as trespassing in closed areas). The strategy involves (1) continuing to maintain “symbolic” fencing around SNPL breeding areas and (2) developing and implementing a new docent program (recruiting and training volunteers). Symbolic fencing is used to protect SNPL nests, eggs, and chicks during the breeding season. This fencing is not impenetrable to humans. Rather, it is intended to delineate areas where humans should not enter so they do not accidentally crush eggs or flush incubating adults, and it provides an area where chicks can rest and seek shelter when large numbers of people are on the beach. Symbolic fencing is known to reduce the frequency of humans trespassing into sensitive SNPL breeding areas. In the future, a docent program may be developed for Salinas River NWR (and included as a separate strategy) to increase public awareness of how human activities can harm to the coastal dune ecosystem, to deter human disturbance events, and possibly to conduct early detection of SNPL predators. This could reduce SNPL mortality or stress due to direct human causes and result in increased reproductive success.

Explore Opportunities to Acquire Land to Expand Coastal Dune Protection

This strategy is focused on working with conservation partners to identify, prioritize, and act upon dune protection opportunities in the Monterey Bay area. Here, dune protection means acquisition of lands encompassing coastal dunes or acquisition of lands adjacent to coastal dunes that would allow for dune migration with sea level rise. Planned activities include working with partners to identify dune protection opportunities and engaging in public outreach. In the future, this strategy could include efforts to expand the refuge boundary to protect additional coastal dunes or land parcels that would allow migration of current refuge coastal dunes with sea level rise. Expansion of the refuge boundary would require initiating USFWS's planning process for refuge expansion, which culminates with a land protection plan, a conceptual management plan, and a NEPA document. This strategy is intended to mitigate the threat of sea level rise and subsequent loss of coastal dunes on the refuge and in the larger Monterey Bay area.

Explore Potential to Develop a Coastal Dune Forum

This strategy aims to explore the potential to develop a new coastal dune forum with other coastal refuges and partners. Current partners include the California State Parks, Big Sur Land Trust, and the USFWS Coastal Program. Currently, collaboration between Salinas River NWR and other California coastal dune refuges (Humboldt Bay and Guadalupe Dunes NWRs) does not exist. The forum would serve to promote sharing of information about coastal dune conservation and management and increase collaboration among coastal dune land managers in Monterey Bay as well as across the California coast. The dune forum would promote cooperation and draw on collective experience to address common issues/threats, identify viable solutions, and potentially leverage resources. This work is expected to address all threats and help achieve Salinas River NWR goals by improving strategies (learning what works, what does not work) and surveys while leveraging resources. The Open Standards could be used as a platform for focusing the work of the forum.

Table 9. Salinas River National Wildlife Refuge strategies and associated objectives, in order of priority to implement over the next 5 years (2018–2022) to conserve the coastal dune ecosystem.

Strategy Title	*Threat Addressed*	*Expected Outcome (Objectives)*
Invasive plant management	Invasive plants	CDE_O01. By the end of 2022, the San Francisco NWR Complex understands the abundance and distribution of the most critical invasive plant threats to the coastal dune ecosystem at Salinas River NWR. This new understanding will be used to refine (as needed) the management approach and develop new management objectives.
Cooperative management of mammalian and avian predators	Avian predators, mammalian predators	CDE_O02. Over the next 5 years (2018–2022), the frequency of snowy plover egg, chick, and fledgling predation events decreases at Salinas River NWR.
Reduce human disturbance: symbolic fencing	Human disturbance: recreation, illegal activities by humans	CDE_O03. Over the next 5 years (2018–2022), seasonal fencing around snowy plover breeding areas at Salinas River NWR is maintained and prevents human entry, evidenced by no plover nests lost as a direct result of humans. CDE_O04. By 2022, at least 5–10 docents are trained and implementing the beach user education program at Salinas River NWR to educate the public on reducing impacts to the coastal dune ecosystem.
Explore opportunities to acquire land to expand coastal dune protection	Climate change	CDE_O05. Over the next 15 years (2018–2032), the Service is aware of coastal dune protection opportunities in the Monterey Bay area and continues to support these efforts with its conservation partners.
Explore potential to develop a coastal dune forum	All threats	CDE_006. By 2020, a Pacific coastal dune forum is formed and, by 2023, the refuge has gained information from the forum to improve Salinas River NWR conservation strategies or natural resource surveys.

4.1.6 Natural Resource Surveys

Natural resource surveys to assess coastal dune ecosystem health (goals) and effectiveness of refuge management strategies (objectives) are presented below (table 10). Surveys are listed in order of high to low priority (USFWS 2019).

Table 10. Natural resource surveys that will inform progress in achieving coastal dune ecosystem goals and objectives (Salinas River National Wildlife Refuge).

Survey Name	*PRIMR ID*	*Status*	*Survey Frequency*	*Goal or Objective Informed by Survey*	*Survey Coordinator*
Coastal dune vegetation survey: Salinas River NWR	FF08RSLN00-005	Expected	Every 3–5 years	CDE_G01, CDE_G02, CDE_O01	San Francisco Bay National Wildlife Refuge Complex
Western snowy plover productivity survey: Salinas River NWR	FF08RSLN00-002	Current	Annual	CDE_G03, CDE_G04, CDE_O02	Point Blue Conservation Science
Range-wide western snowy plover window survey	FF08RSLN00-004	Current	Annual	Snowy Plover Recovery Objective for Monterey Bay	Point Blue Conservation Science
Smith's Blue butterfly survey	FF08RSLN00-006	Current	Annual	CDE_G05	San Francisco Bay National Wildlife Refuge Complex

Notes: For survey status, current = survey is currently implemented on the refuge; expected = survey will likely be implemented. For expected surveys, the survey frequency is an estimate and may change once a protocol is developed.

4.2 Estuarine Island Ecosystem

Information sources used to describe the estuarine island ecosystem are presented in the following. Any other sources are cited in-text.

- *Marin Islands National Wildlife Refuge and State Ecological Reserve Vegetation Management Plan* (Baye 2005)
- *Marin Islands National Wildlife Refuge Comprehensive Conservation Plan* (USFWS 2007)
- *San Francisco Bay NWR Complex Climate Assessment* (CALCC et al. 2018)

4.2.1 Overview

The estuarine island ecosystem encompasses the terrestrial environments of Marin Islands NWR and State Ecological Reserve, namely East and West Marin Islands (figure 6). These islands support a unique assembly of vegetation communities that have persisted in relative isolation and have been sheltered from many factors that significantly altered species composition on the mainland. The islands are not pristine; however, they represent one of the best examples of coastal native plant communities, particularly with respect to the native species assembly and interactions among them. These islands also supported one of the largest heron and egret rookeries in the San Francisco Bay region; this rookery is addressed in section 4.8, "Waterbirds," along with other waterbird communities in the Refuge Complex.

The refuge, of which the ecosystem is a part, is located in San Rafael Bay in Marin County (figure 6), California, and is situated in the larger Estuary. Marin Islands NWR is approximately 340 acres in size and includes two islands—East Marin Island and West Marin Island, hereafter referred to as *Marin Islands*—and surrounding intertidal and subtidal environments. East Marin Island is approximately 10 acres, and West Marin Island is approximately 3 acres. Marin Islands NWR is managed by the Refuge Complex under a memorandum of understanding with CDFW (USFWS 2007). Prior to refuge establishment in 1992, the Crowley family (Crowley Maritime Corporation) owned and managed the Marin Islands (1929–1991) and used them as a family retreat. The Crowleys constructed two houses and a water tank on East Marin Island; introduced a variety of ornamental non-native plants and animals, including Barbary sheep (*Ammotragus lervia)*, to control vegetation; and quarried rock from East Marin Island to provide building material for one of the on-island houses and nearby San Quentin State Prison, resulting in the formation of a lagoon on the east side of East Marin Island. Two archeological sites and several artifacts recorded on East Marin Island indicate many years of use and occupation by Native Americans prior to Mexico's claims to the Marin Islands in the 1820s.

Nested Targets of the Estuarine Island Ecosystem:

- Oak/buckeye forest, grasslands
- Coastal scrub
- Coast bluff-cliffs
- Intertidal marsh-beach
- Locally rare native plants
- Arboreal salamander
- Native pollinators

4.2.2 Ecology

Despite the influence of many human-induced threats over the last century, such as the introduction of invasive species and development, East Marin Island continues to support a unique and diverse ecosystem. This is likely due to its isolation from the mainland, protection from threats experienced to a greater degree on the mainland (such as predators, human disturbance, and development), and the unique combination of microclimate and soils. For example, over 100 species of native plants have been documented on the approximately 10-acre East Marin Island, which represent 10% of the native species in Marin County, making this location a rich and diverse sanctuary of native California flora. Further, the ecosystem supports plant species such as Michael's rein orchid (*Plantanthera michaelii* [synonym *Piperia michaelii*]) that are endemic to California and considered fairly endangered by CNPS (2018).

Vegetation

The terrestrial (island) component of the estuarine island ecosystem supports a unique assemblage of native coastal California vegetation communities including oak/buckeye woodland, coastal grassland, coastal scrub, coastal bluff/cliffs, and marsh-beach. These vegetation communities are detailed in the *Marin Islands National Wildlife Refuge and State Ecological Reserve Vegetation Management Plan* (Baye 2005). Many non-native plant species have invaded these communities, primarily as a result of human activities (such as active planting of non-native plants by the previous landowners). Plant diversity on the Marin Islands is highly sensitive to the microclimate of San Rafael Bay and is affected by patterns of exposure and shelter to bay winds, marine influences, fog, and precipitation; therefore, it is vulnerable to climatic changes (Baye 2005).

Marin Islands NWR. Credit: USFWS

The duration of the islands' isolation as a result of sea level rise during the late Holocene (Atwater et al. 1979) implies that species with very low rates of long distance dispersal and gene flow may have been separated from the mainland for approximately 3,000 years (Baye 2005). Although no formal research has proved this claim, the Marin Islands may constitute a natural island laboratory for studies of regional population differentiation in coastal and interior plant populations. Several plant species of the Marin Islands are noteworthy for either their biogeographic, ecological, taxonomic, or other conservation significance (Baye 2005): *Adiantum jordanii, Agrostis pallens, Arbutus menziesii, Dudleya farinose, Erigeron foliosus* var*. franciscensis, Eriogonum nudum* var*. auriculatum, Eriophyllum stoechadifolium, Lomatium* spp*., Platanthera* spp*., Pellaea andromedifolia, Polypodium calirhiza,* and *Stephanomeria elata.* In addition, the island supports three native orchid species, all which co-occur in close proximity. Such a situation is considered uncommon or rare in Marin County (Brad Kelly, CNPS—pers. comm. 2009).

Wildlife

East Marin Island and the surrounding tidelands provide breeding, foraging, and roosting habitat for a wide diversity of songbirds, waterbirds (such as shorebirds and waterfowl), and raptors. Wildlife surveys have focused primarily on the heron and egret rookery. This rookery spans both East Marin Island and West Marin Island. Presence of the rookery dates back to at least the 1920s (Connie Peabody, member of the Crowley family who previously owned the islands—pers. comm. 2004). Audubon Canyon Ranch (ACR) has monitored the number of nesting egrets and herons on West Marin Island since 1979 from viewing positions on East Marin Island and by boat. In 1993, ACR began monitoring annual reproductive success of great egrets and great blue herons. Monitoring results suggest the Marin Islands (primarily West Marin Island) have supported one of the largest heron and egret rookeries in the San Francisco Bay area (USFWS 2007). Additional details about the rookery are provided in section 4.8, "Waterbirds."

Other taxa known to occur on East Marin Island include amphibians, reptiles, and mammals. For example, the California slender salamander (*Batrachoseps attenuatus*) was first documented at Marin Islands in 1960 (Anderson 1960) and continues to persist, although population status and trends are unknown. There are no known conservation concerns in California for this species. The Marin Islands have not consistently supported mammal populations, although there have been intermittent observations of raccoons (*Procyon lotor*) and non-native rats (*Rattus spp.*). Raccoons were documented at East Marin Island in 2013 and may persist today. Raccoons may have contributed to the sharp decline in the heron and egret breeding population in 2013. Rats were first documented on the islands in the late 1950s, were subsequently eradicated (Anderson 1960), and once again documented in 2013 (Meg Marriott, USFWS, pers. comm.—2017). Small mammal surveys on East Marin Island in 2002 did not result in any detections (USFWS 2007). River otters (*Lontra canadensis*) have been documented in the immediate vicinity of the Marin Islands (River Otter Ecology Project 2018) and have been recently documented on East Marin Island (Don Brubaker, refuge manager—pers. comm. 2018). Additional information about Marin Islands NWR ecology can be found in the *Marin Islands Comprehensive Conservation Plan and Environmental Assessment* (USFWS 2007), *Marin Islands National Wildlife Refuge and State Ecological Reserve Vegetation Management Plan* (Baye 2005), and annual monitoring reports by Audubon Canyon Ranch (ServCat records).

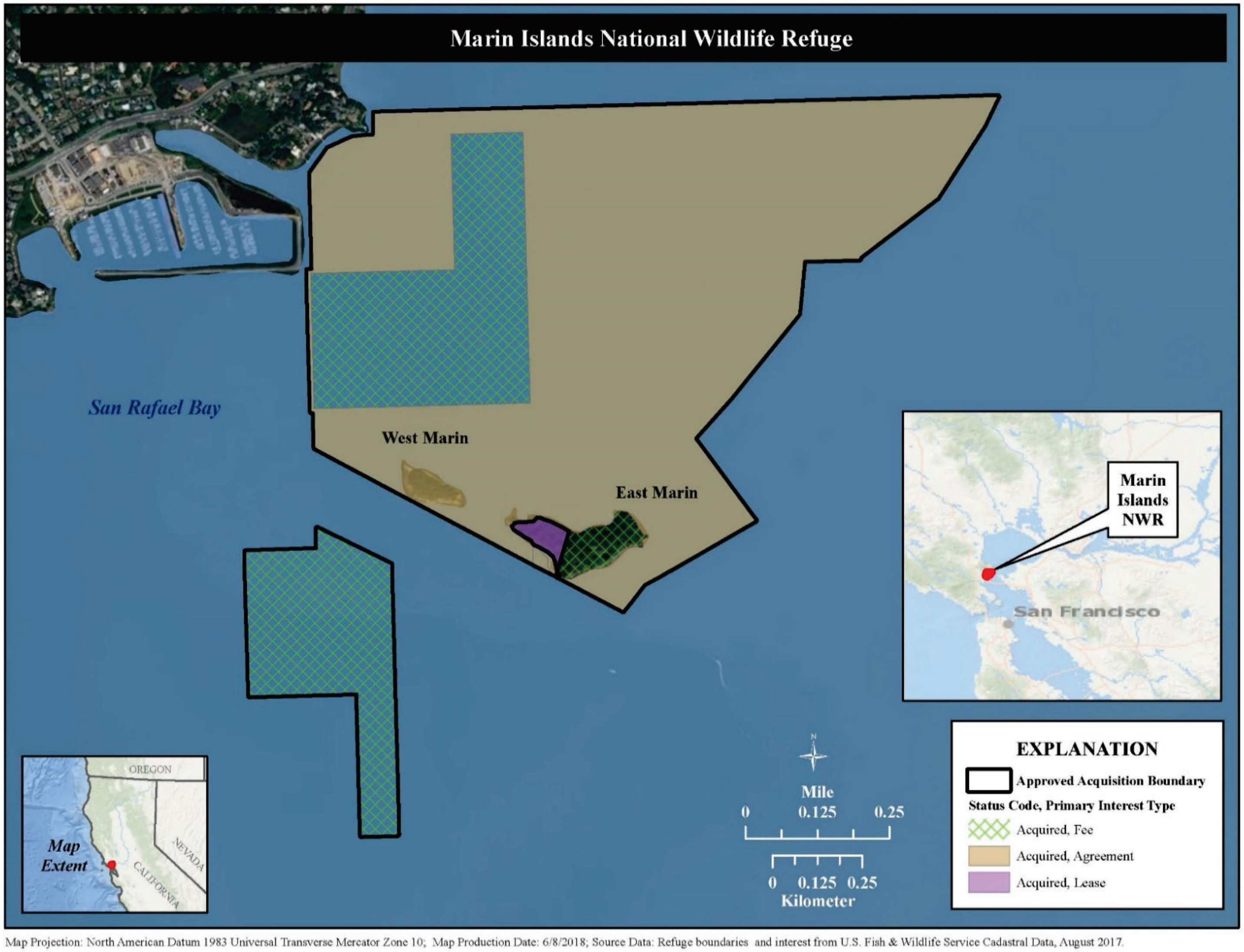


Figure 6. Geographic setting of Marin Islands National Wildlife Refuge and State Ecological Reserve.

Notes: Land status varies within the refuge boundary. Some portions of the refuge are owned by the U. S. Fish and Wildlife Service (Legend = Acquired Fee), are managed under a cooperative agreement with the California Department of Fish and Wildlife (Legend=Acquired Agreement) or are managed under a lease with the California State Lands Commission (Legend=Acquired Lease).

4.2.3 Target Status, Trends, and Goals

The estuarine island ecosystem's KEA is native plant community composition and abundance. Reproductive success of the heron and egret rookery is also an important attribute of this ecosystem but is addressed in section 4.8, "Waterbirds." Native plants form the principal biotic structure of the Marin Islands and provide habitat for a variety of wildlife including birds, insects, reptiles, and amphibians. As such, changes in native vegetation cover and composition are likely to have a cascading effect on wildlife and influence the long-term biodiversity of the islands, including unique plant and animal genotypes that have formed since island isolation (>3,000 years before present).

Three indicators were selected to indicate status and trends of native plant community composition and abundance on East Marin Island: 1) native plant species richness, 2) relative cover (%) of native plants, and 3) population density of three native orchid species (table 11). The abundance and richness of native plants have commonly been used as indicators of ecological restoration success, and several studies have found correlates between vegetation, recovery of wildlife populations (such as birds and insects), and ecological processes (such as nutrient availability) (Ruiz-Jaen and Aide 2005). The population status of the three native orchid species was selected as an indicator due to rarity and unique ecology of the species, and because they are sensitive to precipitation regimes and thus indicative of climate change. Specifically, Michael's rein orchid is a species listed by CNPS as fairly endangered and occurs in "remarkable density and quantity" on East Marin Island (Brad Kelly, CNPS—pers. comm. 2014). In Ackerman's (1977) study of biosystematics for the Piperia genus, *P. michaelii* is described as the most restricted member of the genus in terms of ecology and distribution, occurring almost exclusively near the ocean and with virtually no records showing confirmed sympatry with other orchids of the same genus. The orchids are reliant on their companion fungus and are sensitive to the right soil composition, fungus conditions, and specialized pollinator presence, as well as microclimatic conditions (Ackerman 1977; Arditti et al. 1981; Argue 2012). For these reasons, we consider the orchids as sensitive indicators of both biotic and abiotic health of the system. A declining trend of the rare *P. michaelii* or the discontinued coexistence of the three orchid species could indicate the declining health of the estuarine island ecosystem and represent a significant loss to the floral natural history of Marin County.

Based on the best available information and opinions of Marin Islands NWR staff, the health of the estuarine island ecosystem, in terms of native plant composition and abundance, is considered Fair. Additional details about indicator scales (Poor to Very Good) can be found in the Refuge Complex's conservation target viability database (appendix B). The long-term trend in native plant composition and abundance at East Marin Island is declining as a result of expanding invasive plant populations (Meg Marriott, refuge biologist—pers. comm. 2017). Results from a 2018 vegetation inventory (final report in prep) will provide new insights on vegetation status on East Marin Island. Indicator status/trends and goals for this target should be revisited following completion of the inventory.

A summary of KEAs, associated indicators, indicator status and trends, and desired future conditions (SMART goals) is presented in table 10.

KEA 1: Native Plant Composition and Abundance (East Marin Island)

Indicator: Native Plant Species Richness

Botanical surveys conducted from 1991 to 1993 (N=4 surveys) documented 65 native plant species on the Marin Islands (Ornduff and Vasey 1995). In 2003, botanical surveys conducted by CNPS (USFWS 2012) on East Marin Island added 30 native species, raising the number of native plant species to 95. In 2005, native plant species richness was again estimated at 95 (Baye 2005), representing approximately 10% of the known flora for Marin County (Howell 1970). Surveys in the early 1990s also followed a period of intense drought and grazing by Barbary sheep. Over the long-term, native plant species richness and abundance will likely decline if invasive plant populations continue to expand on the Marin Islands (Baye 2005).

Indicator: Relative Cover of Native Plants (%)
It is estimated that less than 50% of the flora vegetative cover on East Marin Island is composed of native plants. Further, native plant cover is believed to be declining as a result of increasing invasive plant populations (Meg Marriott, refuge biologist—pers. comm. 2017). According to qualitative assessment from Peter Baye (2005), plant species that have small populations and are at risk of extinction (from East Marin Island) include *Aster chilensis, Camissonia ovata, Cynoglossum grande, Carex globosa, Eriophyllum confertiflorum, Festuca californica, Iris macrosiphon, Iva axillaris, Luzula comosa, Monardella villosa, Platanthera michaelii, Phacelia distans, Potentilla glandulosa, Solidago californica, Stephanomeria elata*, *Viola pedunculata,* and *Zigadenus fremontii.* This list should be re-evaluated over time as drought, invasive species, management activities, and chance events occur.

Coastal Rein Orchid (*Platanthera elongata*).
Credit: Doreen and Vernon Smith, Marin Chapter of the CA Native Plant Society

Indicator: Population Density of Three Orchid Species
East Marin Island hosts three species of orchid: *Platanthera michaelii*, *P. elongata*, and *P. transversa* (table 12). In 2010, 292 *P. michaelii*, 15 *P. elongate*, and 10 *P. transversa* plants were documented during informal botanical surveys on East Marin Island. Prior to 2010, only one orchid species, *P. michaelii*, was known to occur on East Marin Island. The other two *Platanthera* species were likely misidentified as *P. michaelii* because they are morphologically similar to *P. michaelii*.

Table 11. Current status and desired future state (goals) of the estuarine island ecosystem at Marin Islands National Wildlife Refuge in terms of key ecological attributes and indicators.

Key Ecological Attribute	*Indicator*	*Status: Recent Measure (Trend)*	*Status Source*	*Goal*
Native plant composition and abundance	Native plant species richness	Fair: 85–95 species (decreasing)	Meg Marriott, refuge biologist, Baye (2005)	EIE_G01. Over the next 15 years (2018–2032), at least 95% of the native plant species documented on East Marin Island (Baye 2005) continue to persist.
Native plant composition and abundance	% relative cover of native plants	Poor: <50% (decreasing)	Meg Marriott, refuge biologist	EIE_G02. Over the next 15 years (2018–2032), % relative cover of native plants (to non-native plants) increases to >50% on East Marin Island.
Native plant composition and abundance	Population density of three orchid species: *Platanthera michaelii*, *P. elongata*, and *P. transversa*	Good: Unknown (unknown)	Meg Marriott, refuge biologist	EIE_G03. Over the next 15 years (2018–2032), the estimated density of native *Platanthera* species on East Marin Island is: *P. michaelii* ≥50, *P. elongata* ≥5, *P. transversa* ≥5. Density calculation is based on three defined survey areas of East Marin Island of the Marin Islands NWR.

Note: Status designations: red = Poor, yellow = Fair, light green = Good, dark green = Very Good. Refer to the San Francisco Bay National Wildlife Refuge Complex viability database for additional details (appendix B).

Table 12. Native orchid species of Marin Islands National Wildlife Refuge: taxonomy, range, special status designations, and habitat.

Scientific Name	*Common Name*	*Range*	*Status Designation*	*Habitat*
Platanthera michaelii Synonym: *Piperia michaelii*	Michael's rein orchid	Endemic to California	CNPS rank is 4.2 (limited distribution in California; fairly endangered). State rank S3 (vulnerable). Global rank G3 (vulnerable)	Generally dry sites, coastal scrub, woodland, mixed-evergreen or closed-cone-pine forest
Platanthera elongata Synonym: *Piperia elongata*	Chaparral orchid, wood rein orchid, denseflower rein orchid, coastal rein orchid	California, Oregon, Washington, Idaho, and Canada (British Columbia)	No special designations	Generally dry sites, scrub, chaparral, mixed-evergreen or conifer forest
Plantanthera transversa Synonym: *Piperia transversa*	Flat spurred piperia, mountain piperia, royal rein orchid	California, Oregon, Washington, and Canada (British Columbia)	No special designations	Generally dry sites in chaparral, foothill woodland, yellow pine forest, red fir forest, northern coastal scrub, closed-cone-pine forest

Sources: CNPS 2018; USDA 2018; Ackerman and Lauri 2012a–c.

4.2.4 Critical Threats

A variety of human-induced threats cause stress to the estuarine island ecosystem. The most critical threats (classified as High or Very High threats) are invasive plants, wildfire, and climate change (extreme weather [drought], long-term changes in precipitation and temperature regimes). Oil spills are a Medium threat. Low-ranked threats are disease (such as sudden oak death), marine debris, legacy land conversion (alteration of landcover by previous owners), refuge management activities (such as inadvertent introduction of invasive species), and contaminants. A conceptual model depicting threats to the estuarine island ecosystem, relationship to biophysical factors of the ecosystem, and strategies aimed at reducing the most critical threats is depicted in figure 7. The most critical threats (High to Very High) to the estuarine island ecosystem are summarized below.

Invasive Plants (Very High Threat)

The estuarine island ecosystem, particularly East Marin Island, has a diverse and abundant assemblage of non-native plants. In some cases, non-native plants are causing harm to native flora by displacing them (Baye 2005). As a result, the extent of native plants has decreased, and locally rare and small native plant populations may become extinct if this threat is unmanaged. Changes in the native plant community will lead to reduced habitat quantity and quality of native wildlife species such as insects, birds, and amphibians, including the California slender salamander.

In 2017, Marin Islands NWR prioritized its invasive species to focus allocation of its limited management resources. Among the most invasive plant species are jubata grass (*Cortaderia jubata*), French broom (*Genista monspessulana*), Algerian ivy (*Hedera algeriensis*), iceplant, and Bermuda-buttercup (*Oxalis pes-capre*). For additional information on invasive plant species of the Marin Islands and associated impacts, see *Marin Islands National Wildlife Refuge and State Ecological Reserve Vegetation Management Plan* (Baye 2005). Lastly, an invasive plant inventory conducted at East Marin Island in 2018 provided the first comprehensive assessment about the status and distribution of invasive plants on East Marin Island (Tierra Data Inc. 2018).

Factors that contribute positively (+) or negatively (-) to the invasive plant threat include:

- Illegal activities by humans (-). Recreational boaters illegally access the Marin Islands and can trample native vegetation, introduce invasive plants or disease (such as sudden oak death), and increase risk of wildfire.
- Planting non-native plants by previous landowners (-). Many non-native plant species have been introduced intentionally through planting by the previous landowner (Crowley family).
- Refuge management activities (+/-). Invasive plant control activities (such as application of pesticides) are intended to reduce the invasive plant threat but have the potential to result in non-target effects on native plants. For example, herbicide application is the only practical method to control the invasive Bermuda-buttercup. Herbicide application inevitably kills non-target native species, as they occur in tiny gaps in otherwise vast monocultures of *Oxalis* pes-capra. Refuge staff and volunteers may also inadvertently introduce non-native plants or disease (such as sudden oak death) when visiting and working at the Marin Islands.

Wildfire (High Threat)

Wildfires are likely to occur on East Marin Island as a result of illegal trespassers who camp and build fires there. Illegal trespassing and campfires have been observed by refuge staff and through remote cameras (Don Brubaker, refuge manager—pers. comm. 2017). The islands are closed to the public (signed), but illegal trespassing continues to occur, and remnant buildings are an attractant. With an assortment of light to heavy fuels, fire intensity and severity could be considerable and radically change East Marin Island. Irreversibility of this threat is very high if intense fire is caused and burns the seed bank of native (including rare) plants.

The fire history of the Marin Islands (prior to 2018) is unknown. In general, fire tends to be less frequent in northern coastal California than in many other areas of the western United States (Forrestel et al. 2011), likely as a result of cool temperatures and high humidity. Studies of fire in coastal ecosystems have observed post-fire shifts from woody to herbaceous vegetation following fire (see Forrestel et al. 2011). At Point Reyes National Seashore (Marin County) in 1995, the Vision Fire occurred in an area with similar coastal influences as Marin Islands. Here, the opposite post-fire vegetation change was observed—a shift towards woody cover and away from coastal scrub and grassland. Factors strongly influencing post-fire vegetative changes here were pre-fire vegetation type, burn severity, and topography. The successional pathway following a wildfire at East Marin Island is unknown, but it is likely that a similar set of factors (to Point Reyes) will apply. For example, plant species that are fire-adapted or thrive in disturbed areas, both native and non-native species, would likely increase in abundance. Likewise, fire intensity will likely determine which species survive post-fire.

Factors that contribute positively (+) or negatively (-) to the wildfire threat include:

- Illegal activities by humans (-). Recreational boaters illegally access the Marin Islands and can increase risk of wildfire.

Climate Change (High to Very High Threat)

Global climate changes are likely to result in changes to climate in the San Francisco Bay and may result in stress to the estuarine island ecosystem. Climatic factors of particular concern include extreme events (droughts) and alteration of temperature and precipitation regimes. Summarized below is information about potential climate change and impacts on natural resources. Sources of information include the *San Pablo Bay National Wildlife Refuge Climate Adaptation Plan* (USFWS 2016) and the *San Francisco Complex Climate Summary* (CALCC 2018). The potential climate changes are:

- Climate change projections based on global circulation models downscaled for the North Bay indicate that temperatures will increase. By the last 30 years of this century, North Bay scenarios project average minimum temperatures to increase by 0.5 °C to 5.8 °C and average maximum temperatures to increase by 0.9°C to 5.5 °C relative to conditions over the past 30 years.

- Most climate models point to longer and drier summers and shorter winters characterized by more frequent and more intense storm events (Micheli et al. 2012). Rainfall projections for the North Bay vary among models, with some showing strong declines and some showing moderate increases in annual rainfall through the end of the century. However, most scenarios show an increase in the frequency and intensity of droughts and floods meaning that the rainfall will be increasingly sporadic and less available to plants and wildlife.
- Increasing temperatures and decreasing rainfall can exacerbate the threat of wildfires.
- Warming temperatures and changing precipitation regimes will likely impact the presence and abundance of plants species on the Marin Islands. Models of projected future distributions of plants and vegetation communities based on current climatic envelope indicate shifting ranges of some species, because the climatic envelopes move northward and upslope as average temperatures get warmer.

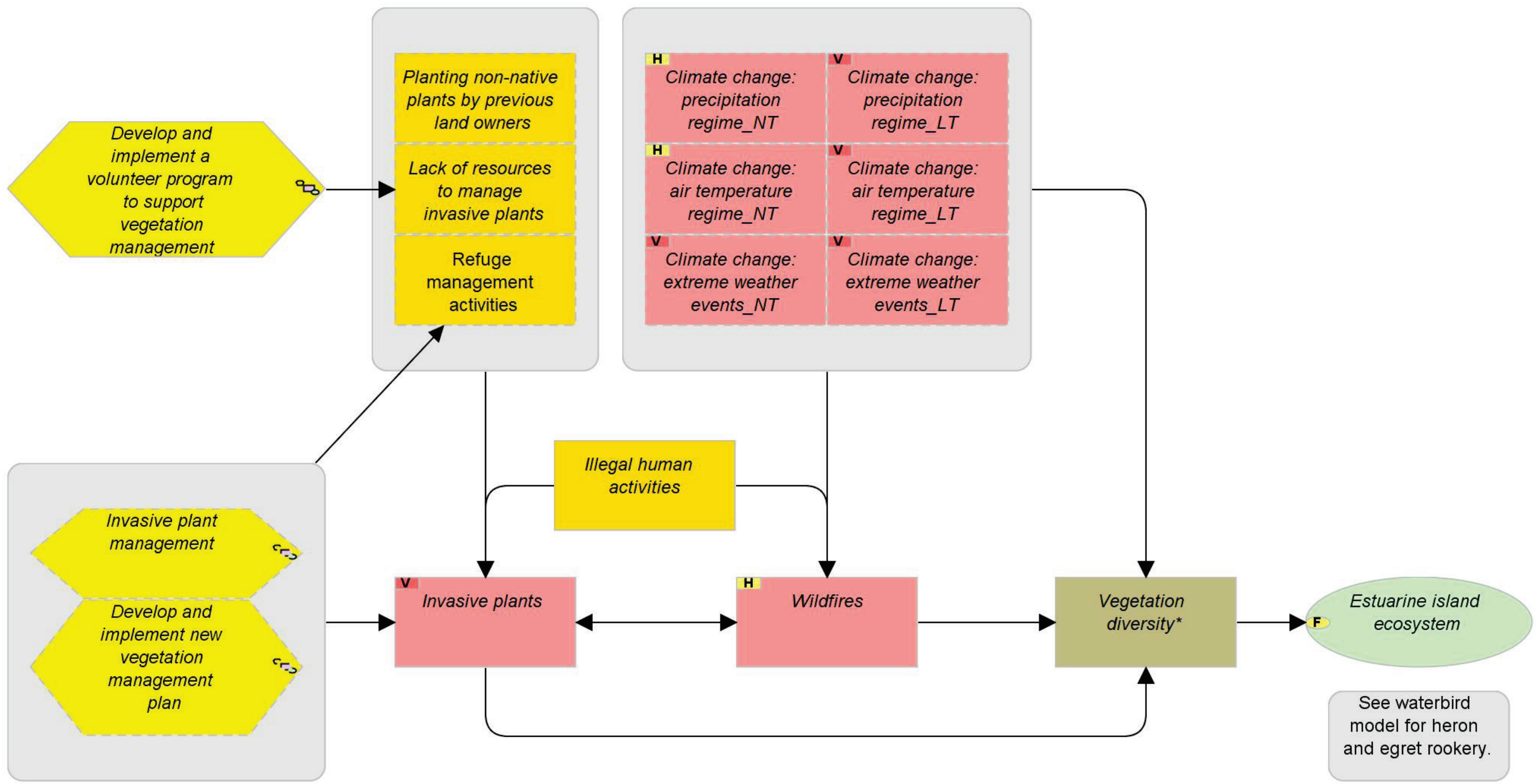


Figure 7. Conceptual model of the estuarine island ecosystem at Marin Islands National Wildlife Refuge.

Notes: Only Very High or High threats to the ecosystem are depicted here. Legend: green oval = natural resource conservation target; olive box = biophysical or human well-being attribute; pink box = direct threat; orange box = contributing factors; yellow hexagon = conservation strategy. The letters in the upper left portion of threats (pink boxes) represent the summary threat ranking across the seven refuges of the San Francisco National Wildlife Refuge Complex (L=low, M=moderate, H=high, VH=very high).

4.2.5 Conservation Strategies

Conservation strategies for the estuarine island ecosystem are focused on reducing the threat of invasive plant species. Each strategy is briefly described in the following in order of priority to implement. Threats addressed by each strategy and expected outcomes (objectives) are summarized in table 13. Results chains visually depicting the assumptions behind these strategies (how they work) and expected outcomes are stored in the Miradi file associated with this NRMP (see appendix B for a link to this file).

Develop and Implement a Volunteer Program to Support Vegetation Management

With the guidance and assistance from the Refuge Complex's visitor services and education program, develop and implement a long-term, dependable volunteer program to conduct weed management and native plant restoration activities on East Marin Island. Volunteers are essential for increasing Marin Islands NWR's capacity to control invasive plants, restore native plants, and conduct vegetation monitoring. Work under this strategy will be guided by Marin Islands NWR's vegetation management plan. Ideally, attain at least 10 regular volunteers, with at least one volunteer training and leading volunteer workdays.

Develop and Implement a New Vegetation Management Plan

This strategy includes revision of a 2005 vegetation management plan (Baye 2005). Revisions will focus on refining what actions to take, where, and when. Activities under this strategy will include prioritizing invasive plant species and areas for management, conducting a baseline inventory of invasive plants (2018), and utilizing this information to update the Marin Islands NWR's vegetation management plan (Baye 2005) to reflect current vegetation conditions, priorities, and available resources. The plan will encompass an integrated pest management approach to invasive plant control by identifying a range of methods (manual, mechanical, chemical, cultural). It will also prioritize actions and refine objectives to allow flexibility as resource conditions change.

Invasive Plant Management

Annually control the top three priority weeds—French broom, oxalis pes-capre, and italian thistle—using herbicide and hand pulling. Efforts will be focused in areas where previous work has occurred (based on 2017 treatment maps). As resources allow, expand control efforts to increase areas of control for the top three priority weeds, and include the control of more priority species based on the 2017 prioritization of invasive plants. Once the vegetation plan and subsequent inventory are completed (previous strategy), this strategy will be removed because it will encompass invasive plant management activities.

Table 13. Marin Islands National Wildlife refuge management strategies and associated objectives, in order of priority to implement over the next 5 years to conserve the estuarine island ecosystem.

Strategy Title	*Threat Addressed*	*Expected Outcome (Objectives)*
Develop and implement a volunteer program to support vegetation management	Invasive plants	EIE_O01. Within 6 months of active volunteer recruitment, the San Francisco Bay National Wildlife Refuge Complex has identified at least two volunteers who are regularly (at least 4 hours per month on island) carrying out invasive plant management and native plant restoration at Marin Islands NWR.
Revise and implement the Marin Islands vegetation management plan	Invasive plants	EIE_O02. By the end of 2018, the Service understands the distribution and abundance of priority invasive plants at Marin Islands NWR. EIE_O03. By the end of 2021, a vegetation management plan for Marin Islands NWR is completed and identifies optimal strategies and associated SMART objectives for reducing the threat of priority invasive plants and restoring native plants given limited resources. EIE_O04. Over the next 15 years (2018–2032), areas of East Marin Island documented as free (0% cover) of priority invasive plants are maintained as such. Clean areas will be identified during an invasive plant inventory (in 2018).
Invasive plant management	Invasive plants	EIE_O05. By 2032, French broom is reduced by 60% within existing management areas (baseline = 2017 control area map, 2018 inventory) on East Marin Island of Marin Islands NWR.

4.2.6 Natural Resource Surveys

Natural resource surveys to assess estuarine island ecosystem health (goals) and effectiveness of Marin Islands NWR management strategies (objectives) are presented below (table 14). Surveys are listed in order of priority to conduct based on survey prioritization in 2017.

Table 14. Natural resource surveys to inform progress in achieving estuarine island ecosystem goals and objectives (Marin Islands National Wildlife Refuge).

Survey Name	*PRIMR ID*	*Status*	*Survey Frequency*	*Goal or Objective Informed by Survey*	*Survey Coordinator*
Invasive plant inventory: Marin Islands NWR	FF08RMRI00-003	Current	2018	EIE_O02	USFWS, San Francisco Bay NWR Complex
Vegetation monitoring: Marin Islands NWR	FF08RMRI00-004	Expected	1–2 years	EIE_G01-G03, EIE_O04-O05	USFWS, San Francisco Bay NWR Complex

Notes: For survey status, current = survey is currently implemented on the refuge; expected = survey will likely be implemented. For expected surveys, the survey frequency is an estimate and may change once a protocol is developed.

4.3 Marine Island Ecosystem

Information sources used to describe the marine island ecosystem are presented in the following. Any other sources are cited in-text.

- *Farallon National Wildlife Refuge Final Comprehensive Conservation Plan and Environmental Assessment* (USFWS 2009)
- *San Francisco Bay NWR Complex Climate Assessment* (CALCC et al. 2018)

4.3.1 Overview

The marine island ecosystem encompasses the native flora, fauna, and ecosystem processes found at Farallon Islands NWR (figure 8), established in 1909 to protect breeding birds, particularly seabirds. The rocky islands that make up the refuge contain the largest seabird nesting colony south of Alaska; they hold the largest colony of western gulls in the world; and they support half the world's population of Ashy storm-petrels (*Oceanodroma homochroa*). The marine island ecosystem found at Farallon Islands NWR is tightly linked to the surrounding marine environment (such as ocean tides, currents, and fog). The islands are adjacent to the California Current, the biologically rich eastern boundary current that runs southwardly along the west coast. Here, the health of the surrounding ocean has a strong influence on the health of the refuge's marine island ecosystem, especially seabirds and pinnipeds who depend on the ocean, especially for food. The refuge supports the largest seabird nesting colony in the contiguous United States and was recognized as a Globally Important Bird Area in 2001 by the American Bird Conservancy. The Farallon Islands are also designated as a State Ecological Reserve and a Golden Gate Biosphere Reserve.

Nested Targets of the Marine Island Ecosystem:

- Breeding seabirds
- Pinnipeds
- Farallon camel cricket
- Arboreal salamander
- Maritime goldfields

Located within the Greater Farallones National Marine Sanctuary approximately 28 miles west of San Francisco, the refuge is composed of four island groups: the North Farallones, Middle Farallon Island, the South Farallon Islands (SFI), and Noonday Rock (figure 8). SFI consists of West End, Southeast Farallon Island (SEFI), and adjacent outcrops and islets (figure 8). Together, these islands comprise 0.85 square kilometers (211 acres) of a mostly rocky landscape that is terraced and rises 60–70 meters above the sea floor. The North and Middle Farallones and Noonday Rock were designated as the Farallon Refuge by President Theodore Roosevelt in 1909. SFI was given refuge status in 1969 and is the largest of the four groups. In 1974, Congress designated all these islands except SFI as the Farallon Wilderness Area (Public Law 93-550).

As early as 1539 (USDOI 1970) and prior to refuge establishment, humans exploited the island for food (seals and birds, especially eggs) and navigational purposes. With San Francisco becoming a major seaport in the early 1800s, the islands became a navigation point, and a lighthouse was constructed in 1855. Lighthouse keepers and their families occupied the islands until these functions were turned over to the U.S. Coast Guard in 1939 (White 1995). These uses put stress on the native island flora and fauna and ultimately resulted in degradation of species habitat and populations. Today, the islands and surrounding waters are protected by the Greater Farallones National Marine Sanctuary and refuge designations.

4.3.2 Ecology

The marine island ecosystem of Farallon Islands NWR comprises four groups of small islands: SFI, North Farallones, Middle Farallon, and Noonday Rock. These islands are beside the cold California Current that originates in Alaska and flows north to south; they are also surrounded by waters of the Greater Farallones National Marine Sanctuary. Farallon Islands NWR lies along the western edge of the continental shelf. This area of the ocean plunges to 6,000-foot depths. Cold, upwelling water brought from the depths as the wind blows surface water westward from the shoreline and the California Current flowing southward past the islands provide an ideal biological mixing zone along the continental shelf and around the San Francisco Bay area, which in turn, provides food resources for the wildlife that inhabits this ecosystem.

Vegetation

The natural diversity of flora on the refuge is low relative to the mainland given its rocky nature, poor soil development, and harsh marine climate. The dominant native plant species on SEFI (and likely of the other surrounding islands) is maritime goldfields (*Lasthenia maritima*). Maritime goldfields is an annual plant endemic found on many offshore seabird nesting islands and sea stacks from Central California to the northern tip of Vancouver Island, British Columbia (Ornduff 1961, Crawford et al. 1985, Vasey 1985). This species provides important habitat for some of the islands' wildlife. For example, cormorants and gulls use maritime goldfields for ground nest building material (Ainley and Boekelheide 1990), and the native Farallon arboreal salamander (*Aneides lugubris farallonensis*) is primarily associated with native plant-dominated areas of SFI (Gerry McChesney, refuge manager—pers. comm. 2018).

Farallon Islands NWR. Credit: USFWS

Vegetation mapping conducted in 2013 and 2014 (Hawk 2015) led to the documentation of six vegetation types on SEFI, including two native plant assemblages (*Spergularia macrotheca* type and *Lasthenia maritima* type) and three invasive species-dominated plant assemblages (*Tetragonia tetragonioides* type, *Plantago coronopus* type, and mixed vegetation type). Human settlement and use of the island have contributed greatly to the introduction and continued spread of invasive plant species on the refuge (see section 4.3.4, "Critical Threats," for details).

Wildlife

The marine island ecosystem supports a variety of wildlife including seabirds, pinnipeds, arboreal salamanders, and the endemic Farallon camel cricket. Two of the most globally significant natural resources of the refuge are seabirds and pinnipeds. Historically, it is estimated that several hundred thousand seabirds and pinnipeds relied on the Farallon Islands prior to human occupation. These numbers sharply declined in the 1800s due to egg collecting, commercial hunting, environmental contaminants, commercial fisheries and oil spills.

Common murre (*Uria aalge*). Credit: USFWS

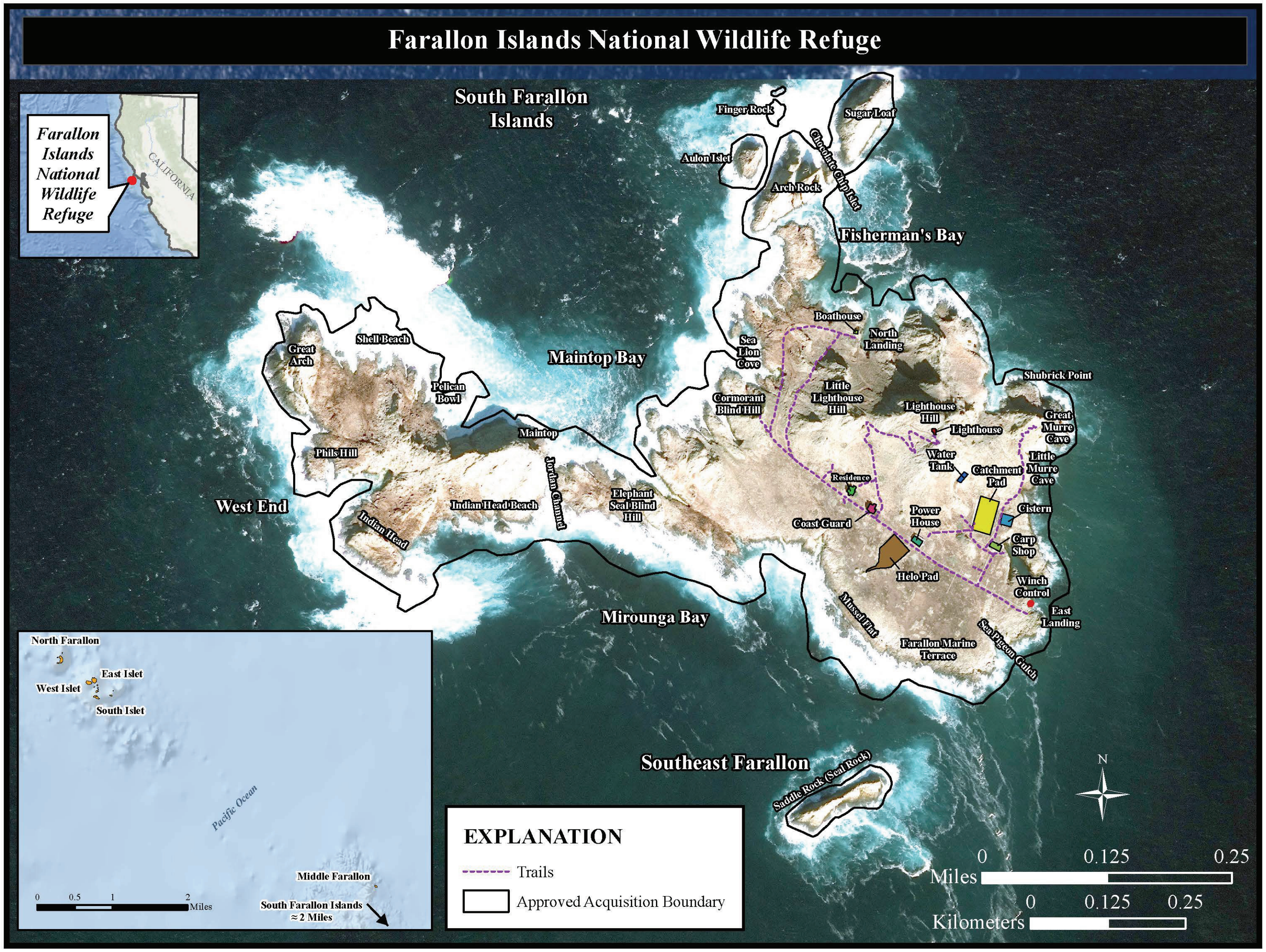
The refuge supports 13 breeding seabird species and approximately 25% of the breeding seabird population in California. The refuge also hosts the single largest seabird breeding colony in the contiguous 48 United States. Located along the Pacific Flyway, the Farallon Islands are an ideal breeding and roosting location for wildlife off the California coast. The seabird species that occur on the refuge represent a diversity of nesting habitat needs (such as surface slopes, burrow/crevice, and cliff ledges) and foraging guilds (offshore schooling fish, nearshore reef fish, zooplankton).

Historically, it is estimated that several hundred thousand birds relied on the Farallon Islands prior to human occupation. These numbers sharply declined in the 1800s due to egg collecting, commercial hunting, environmental contaminants, commercial fisheries, and oil spills. The refuge supports an estimated 328,592 breeding seabirds out of 507,262 based on 2010–2012 data for the North Central Coast Study Region (Point Arena to Pigeon Point) (McChesney et al. 2013).

The Farallon Islands are also an important breeding site for pinnipeds. Five species of marine mammals breed or haul-out on the refuge: northern fur seal (*Callorhinus ursinus*), Steller sea lion, California sea lion (*Zalophus californianus*), harbor seal (*Phoca vitulina*), and northern elephant seal (*Mirounga angustirostris*). In addition, the rare Guadalupe fur seal (*Arctocephalus townsendi*) has recently been recorded around the Farallon Islands. There are no accurate historical estimates available for most species. Historic accounts, however, suggest that pinnipeds numbered in the tens to hundreds of thousands or more prior to human occupation.

Although the focus of conservation on the refuge has historically been on seabirds and marine mammals, other wildlife has conservation significance such as the Farallon arboreal salamander and Farallon camel cricket (*Farallonophilus cavernicolus*). Arboreal salamanders were first noted on the Farallon Islands by Boulenger (1882). There were no multiyear studies to determine salamander population status and trends until late 2006, when the first-ever mark recapture study was conducted (Lee 2008, unpub. report). Since November 2006, a total of 251 unique salamander individuals has been documented. The Farallon camel cricket is endemic to the Farallon Islands where occurs in caves and possibly in seabird burrows (Rentz 1972). The species is believed to be among the most primitive members of its tribe, the Ceuthophilini (Rentz 1972).

Research and long-term surveillance monitoring of the refuges' wildlife has been coordinated, in large part, by Point Blue Conservation Science through a cooperative agreement with the Service. Point Blue Conservation Science (previously Point Reyes Bird Observatory) began studying the refuges' wildlife in 1968; its continued work has contributed a wealth of knowledge about refuge resources and the surrounding ocean ecosystem.



Map Projection: North American Datum 1983 Universal Transverse Mercator Zone 10; Map Production Date: 11/20/2017; Source Data: Refuge boundaries from U.S. Fish & Wildlife Service Cadastral Data, August 2017; Structures provided by refuge; Place names created by Region 8 Inventory & Monitoring using materials from refuge; Imagery from Digital Globe, October 24, 2014.

Figure 8. Geographic setting of Farallon Islands National Wildlife Refuge.

4.3.3 Target Status, Trends, and Goals

Four KEAs were selected to represent the health of the marine island ecosystem at Farallon Islands NWR: 1) ashy storm-petrel population size, 2) seabird population size, 3) native plant cover and composition, and 4) pinniped population size. Based on the best available information about the status of these KEAs and their associated indicators, the health of the marine island ecosystem is considered Fair. Indicator scales used to evaluate the status (Poor to Very Good) of the marine island ecosystem is detailed in the Refuge Complex conservation target viability database (appendix B).

KEA 1: Ashy-Storm Petrel Population Size

Ashy storm-petrel population size was selected as a KEA because the refuge supports the world's largest colony and approximately 50% of the world population (Warzybok et al. 2016). Further, the species has unique food requirements, exploiting more pelagic foraging grounds than most other California seabird breeding species and feeds on deep-dwelling fish and invertebrates that migrate to the surface at night. They also have unique breeding habitat requirements, using small rock crevices in talus slopes and artificial rock walls. Point Blue Conservation Science and the Service have monitored ashy storm-petrel and other seabird species on the refuge since the early 1970s, making this dataset particularly useful for examining trends such as response of seabirds to climate change. Refer to Point Blue reports and research papers for species-specific status and trends in population size and reproductive success (such as Warzybok et al. 2016).

The ashy storm-petrel is endemic to the California Current System and breeds on islands and coastal rocks along coastal California and northwestern Baja California, Mexico (Carter et al. 2016). The global breeding population is currently thought to be about 5,000 pairs, concentrated at five main breeding areas in central and southern California. One of these concentrated breeding sites is located on the refuge where it is estimated that 50% of the world's population of ashy storm-petrel breeds (Warzybok et al. 2016).

The refuge breeding populations of ashy storm-petrel have undergone population fluctuations in recent decades (Warzybok et al. 2016) (figure 9). The indicator of ashy storm-petrel population trends is based on time-dependent models of storm-petrel capture-recapture data. Status and trends of ashy storm-petrel at the refuge is presented in the following (source: Warzybok et al. 2016).

> "Sydeman et al. (1998) reported a 35% decline in their population between 1972 and 1992 while analysis of a population index derived from catch per unit effort during netting suggests alternating periods of growth and decline (Nur et al. in review). Integrating ASPE capture-mark-recapture data into new Jolly Seber modelling methods has provided insights into recent changes in Farallon storm petrel survival, populations, and predation by burrowing owls (Nur et al. in review). From 2001 to 2007, the population displayed a strong increase in population size (increasing at 17.5% per year, $P < 0.015$). From 2007 to 2012 the population decreased by 7.0% per year ($P < 0.1$), this decrease coinciding with the period of increase in burrowing owl overwinter attendance. However, from 2012 to 2015 the population showed some stability (figure 2): the estimated change in size is less than 0.1% per year (a reduced decline). Thus, the time series indicates that, after 2011 (the year of peak burrowing owl attendance), the population trend changed from decline to stability, just as the level of burrowing owl changed from high to moderate. This change in trend was consistent with the observed pattern of survival for the storm petrels over this time period. It is important to note that results of the statistical analysis provided low confidence in the estimates for any single year. The power of the results of these statistical analysis lies in estimates based on multiple years of data, rather than basing comparison on any single year."

Point Blue Conservation Science continues to refine and improve the index for ashy storm-petrel population trends.

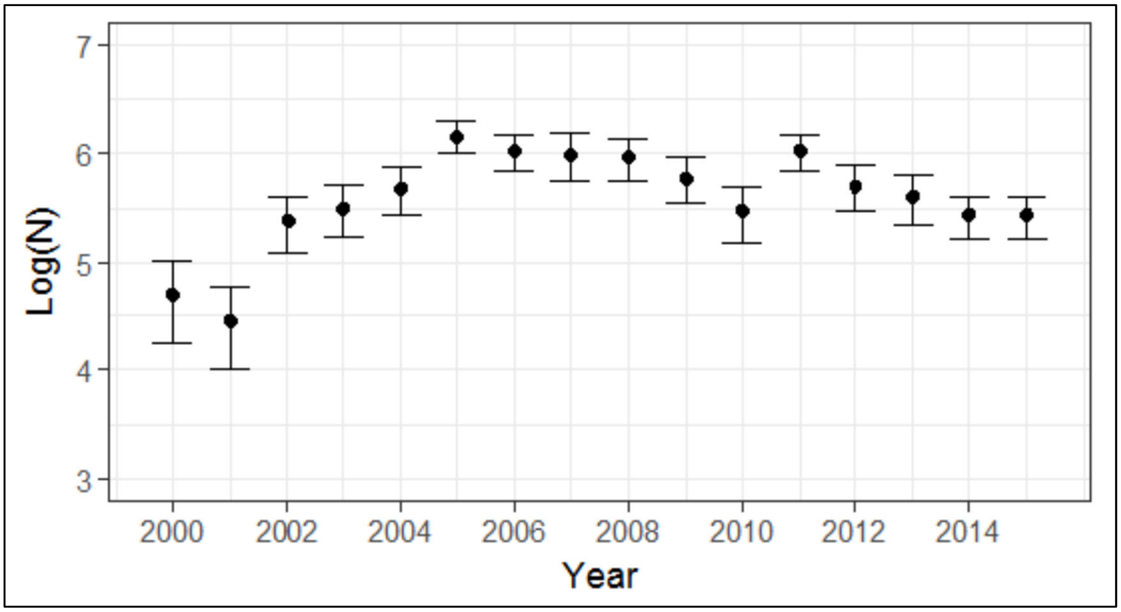


Figure 9. Change in estimated population size index of ashy storm-petrels over time at Farallon Islands National Wildlife Refuge, based on captures of individually-banded ashy storm-petrels, 1999–2016.

Notes: The index reflects estimated population size on a log-scale. Shown is each year's estimate ± 1 Standard Error of the estimate. 2016 was the last year of capture in the dataset, so population size could not be estimated for that year. Source: Warzybok et al. (2016).

KEA 2: Seabird Population Size

Seabird population size is evaluated by an index of breeding population trends of five representative seabird species (breeding adults). The index is based on species-specific population trends: increasing, stable, or decreasing. Species evaluated are Cassin's auklet (*Ptychoramphus aleuticus*), rhinoceros auklet (*Cerorhinca monocerata*), common murre (*Uria aalge*), Brandt's cormorant (*Phalacrocorax penicillatus*), and Pelagic cormorant (*Phalacrocorax pelagicus*). These species represent the diversity of seabird habitat requirements (breeding, food) on and off the refuge. Further, they are identified as priority monitoring target in the USFWS California Current Seabird Monitoring Plan. All species can be monitored concurrently but methods of assessing population trends varies (see table 14; Warzybok et al. 2016).

During 2016, all seabird populations decreased from the previous year except double-crested cormorants (*halacrocorax auritus*) (Warzybok et al. 2016: figure 7, 11). A summary of 5-year population trends (2012–2016) for each of five indicator species at SEFI and West End Islands is presented in table 15.

Table 15. Population trend (2012–2016) of five breeding seabird species at Southeast Farallon Island and West End Island, Farallon Islands National Wildlife Refuge (2012–2016).

Source: Warzybok et al. 2016: figures 7, 11).Species	*Measure*	*Trend (5-Year)*
Brandt's cormorant	Ground and boat count	Decreasing
Pelagic cormorant	Boat count	Increasing
Cassin's auklet	Burrow count	Increasing
Rhinoceros auklet	Mean index plot count	Increasing
Common murre	Mean index plot count	Increasing

KEA 3: Native Plant Cover and Composition

Vegetation composition and structure is an important indicator of island ecosystem health. Although not well-understood, terrestrial vegetation influences native wildlife species of the refuge. For example:

- The native maritime goldfields are used by cormorants and gulls for ground nest building material (Ainley and Boekelheide 1990).
- The native Farallon arboreal salamander is primarily associated with native plant–dominated areas of SEFI (Gerry McChesney, Refuge Manager—pers. comm., 2018)
- Vegetation affects the quality of seabird nesting habitat—some non-native plant species may block access by burrow nesting seabirds (Hornung 1981, USFWS 2005, Cadiou et al. 2010).

Human use and settlement on the SEFI have contributed to the introduction and spread of non-native plants, some of which are invasive (non-native and harmful; see section 4.3.4, "Critical Threats," for details). The health of the native plant community of the marine island ecosystem is indicated by the percentage of vegetative cover at SEFI comprising native plants (= % native plants / [% native plants + % non-native plants]). A 2018 vegetation survey showed native plants comprised 63% of the vegetative cover and is stable when compared to measures taken in 2013 (Holzman 2018).

KEA 4: Pinniped Population Size

The refuge supports a unique assemblage of five pinniped species, and like seabirds and native flora, these species are an important component of the marine island ecosystem. There are no accurate historical estimates available for most species. However, historical accounts suggest that pinnipeds numbered in the tens to hundreds of thousands or more prior to human occupation. Trends in pinniped populations have been monitored since the 1970s through a cooperative partnership between the USFWS and Point Blue Conservation Science.

Because of their size and concentrations, pinnipeds have a strong influence on island vegetation and wildlife habitats. The health of pinnipeds, like seabirds, is representative of the health of the ecosystems upon which they depend, including both the terrestrial islands and the surrounding ocean ecosystem. Like seabirds, changes in pinniped populations are sensitive to changes in prey abundance, ocean conditions, and related environmental threats (such as human disturbance and climatic changes; Berger 2017). Point Blue Conservation Science and the Service have monitored pinnipeds on the refuge since 1970. Refer to Point Blue annual pinniped reports for species-specific status and trends in population size and reproductive success (such as Berger 2017).

Pinniped population size is indicated by the number of pinniped species (out of five) with stable or increasing populations of adults and pups (5-year trend). Target species are California and Steller sea lions, northern elephant seal, northern fur seal, and harbor seal. Surveys show trends in population size over the last 5 years have been stable or increasing for all five species except for stellar sea lions (Berger 2017). This is also consistent with long-term trends (figure 3).

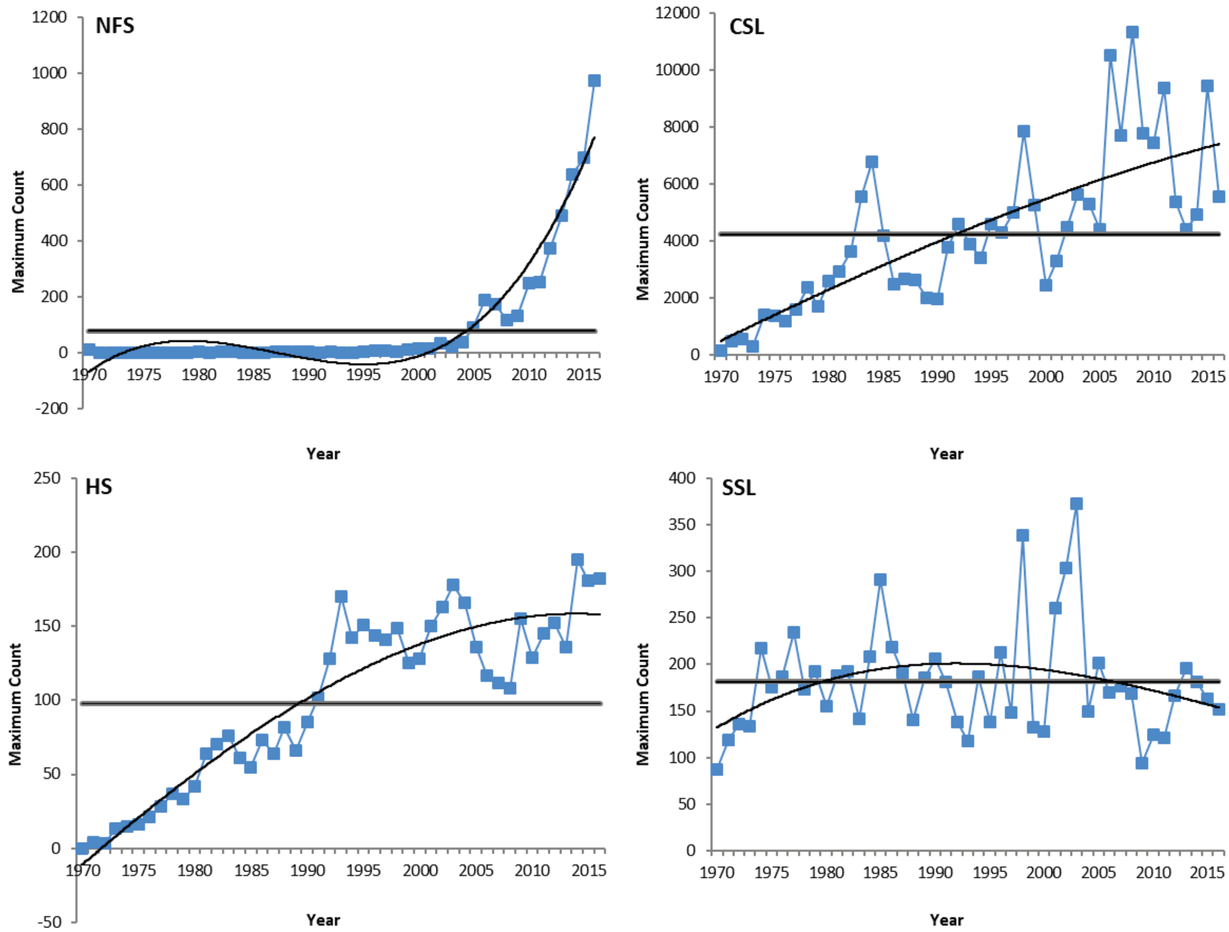


Figure 10. The maximum total count of northern fur seals (NFS), harbor seals (HS), California sea lions (CSL), and stellar sea lions (SSL), 1970–2015.

Notes: Data are summarized from weekly pinniped surveys conducted from the Farallon Island's lighthouse. We fitted a third polynomial trend line (in black) for each species to help illustrate long term trends. The solid gray line is the long term mean from 1970 to 2015 (except for NFS who recolonized the island in 1996). Note the difference in scale on the Y-axis. Maximum total counts in 2016 for NFS, HS, CSL and SSL are: 976, 182, 5,555 and 152. Long term means for NFS, HS, CSL and SSL are: 78, 98, 4,237 and 182. Source: Berger 2017.

Table 16. Current status and desired future state (goals) of the marine island ecosystem at Farallon Islands National Wildlife Refuge in terms of key ecological attributes and indicators.

Key Ecological Attribute	*Indicator*	*Status*	*Status Source*	*Goal*
Ashy-storm petrel population size	Index of ashy storm-petrel population trend based on time-dependent models of storm-petrel capture-recapture data	Fair: <0.1%/year, 2010–2015	Warzybok et al. (2016), Bradley (2017)	MIE_G01. Over the next 5 years, ashy storm-petrel population size at Farallon Islands NWR is stable or increasing (based on 5-year running trend).
Seabird population size	Index of breeding seabird population trends for Cassin's and Rhinoceros auklets, Common murre, Brandt's and Pelagic cormorants	Good: four of five seabird species are stable or increasing	Warzybok et al. (2016)	MIE_G02. Over the next 5 years, indices of population size for Cassin's auklet, rhinoceros auklet, common murre, Brandt's cormorant, and pelagic cormorant population trends at Farallon Islands NWR are stable or increasing (based on 5-year running trend).
Native plant cover and composition	% relative cover native plants (of vegetation cover)	Fair: 63%	Holzman et al. 2018 (tier 1 methods)	MIE_G03. By 2027, >85% of the vegetative cover on Southeast Farallon Island is comprised of native plants.
Pinniped population size	Number of species with stable or increasing populations (adults and pups): California and Steller sea lions, northern elephant seal, northern fur seals, harbor seal	Good: four of five species with stable or increasing populations of adults and pups (declining only for northern elephant seal)	Berger (2017)	MIE_G04. Over the next 5 years, 5 pinniped species at South Farallon Islands exhibit stable or increasing populations of adults and pups (based on 5-year running trend).

Note: Status designations: red = Poor, yellow = Fair, light green = Good, dark green = Very Good. Refer to the San Francisco Bay National Wildlife Refuge Complex viability database for additional details (appendix B).

4.3.4 Critical Threats

A variety of human-induced threats cause stress to the marine island ecosystem (table 17). The most critical threats (classified as High or Very High threats) are climate change, invasive plants, avian and mammalian predators, and oil spills. Medium or Low threats included boat and aircraft disturbance, pollution, refuge management activities (includes monitoring and research), marine debris, commercial fisheries, and disease. A conceptual model depicting threats to the marine island ecosystem, relationships with biophysical factors of the ecosystem, and strategies aimed at reducing the most critical threats is depicted in figure 11. The most critical threats (High to Very High) to the marine island ecosystem are summarized below.

Climate Change (High–Very High Threat)

Anticipated changes in ocean, climate, and coastal weather patterns are expected to significantly impact the physical habitat on offshore islands, reducing the amount of habitat available to seabird and marine mammals for breeding and resting. Other important potential impacts include disruptions in the marine-based food web, erosion, and changes in vegetation communities on the islands. Key findings from the *San Francisco Bay National Wildlife Refuge Complex Climate Assessment* (CALCC et al. 2018) are presented in the following (see this reference for additional details on impacts on seabirds):

- Sea Level Rise. Future sea level rise off northern and central California has the potential to significantly alter island habitats and cause a redistribution of wildlife populations. Models have demonstrated that a rise of 0.5 meter would result in permanent flooding of 23,000 square meters of habitat at SFI (Largier et al. 2010). This represents approximately 5% of the island surface area and would include much of the intertidal areas where pinnipeds haul out as well as pocket beaches and gulches around the island. As a result, these areas would become inaccessible, forcing the animals to move higher up onto the marine terrace or to abandon the colony. This redistribution of pinnipeds would, in turn, impact seabird habitat by reducing the available nesting areas and causing the destruction of nest sites, particularly for burrow nesting species such as the Cassin's auklet (*Ptychoramphus aleuticus*). Furthermore, during extreme high tides and storm events, waves would be expected to extend higher still, leading to increased erosion, flooding, and loss of habitat. Examples of these changes can be seen during El Niño events when alongshore winds decrease and warm water floods into the area from the tropical Pacific, leading to higher sea level off the coast of California. During the El Niño events of 1983 and 1992, higher water and increased storm activity resulted in significant erosion of elephant seal breeding areas and the destruction of important beach access routes at the Farallones (Sydeman and Allen 1999). This in turn made it more difficult for them to access their primary breeding areas and led to local population declines and reduced breeding success (Sydeman and Allen 1999). The distribution of pinnipeds was also significantly altered during El Niño events, resulting in greater numbers of animals hauled out high on the marine terrace, habitat normally occupied by breeding seabirds (Largier et al. 2010). Similar consequences would be expected with rising oceans, particularly if coupled with more extreme weather events, which are also projected to occur as a result of climate change.
- Changes in Precipitation Patterns. Intensified winter precipitation and more significant rainfall later in the season may alter physical habitat in many ways. Increased erosion of the hillsides can alter vegetation structure, increase the frequency of rockslides, and degrade nesting habitat, particularly for species that rely on rock crevices, such as auklets and storm petrels. Flooding of low-lying areas on the marine terrace will also decrease suitable habitat for burrow nesting species and carry away the thin layer of soil in which they dig their burrows (Largier et al. 2010).
- Rising Air Temperatures. Average annual air temperature at the Farallones has exhibited an increasing trend over a 36-year period, from 1971 to 2007 (Largier et al. 2010). Scientists expect this trend to continue, leading to overall changes in the climate of the islands. While warmer temperatures would not necessarily alter the physical structure of the islands, they may affect habitat by altering the vegetation structure on the island and facilitating the proliferation of more heat-tolerant non-native species such as grasses. Increasing air temperatures will also have important implications for island wildlife. Many of these species are adapted to cold and windy conditions and quickly become stressed when conditions change. During unusually warm weather, seabirds may abandon their nests, neglect dependent offspring, and die of heat stress (Warzybok and Bradley 2011). Marine mammals are expected to spend less time hauled out and may abandon young in the rookeries if temperatures become too warm.
- Ocean Condition Changes. Projected changes in the marine environment associated with climate change are expected to have substantial impacts on breeding seabird populations. These changes include rising sea surface temperatures, ocean acidification, and changes in timing and strength of upwelling and ocean circulation patterns.

Invasive Plants (High Threat)

If left uncontrolled, invasive plants will become dominant on the island and could lead to extirpation or near extirpation of some native plant species and harm to wildlife such as nesting seabirds and arboreal salamanders. Invasive plant management was initiated at SEFI in the late 1980s, primarily in response to the establishment and spread of two non-native plants, New Zealand spinach (*Tetragonia tetragonioides*) and cheeseweed (*Malva parviflora*). New Zealand spinach was first recorded on SEFI in 1968 by Malcom Coulter (Coulter and Irwin 2005) and has since spread to several parts of the island (USFWS 2004, Coulter and Irwin 2005). Cheeseweed was first recorded on SEFI in 1996. Although many other non-native plant species have been recorded on the refuge (Coulter and Irwin 2005), New Zealand spinach and cheeseweed have been the focus of invasive plant management efforts because of the direct impact they have on nesting seabird species. For example, observational evidence suggests impenetrable mats of New Zealand spinach (*Tetragonia tetragonioides*) eventually blocks burrow entrances and annual grasses decrease auklet mobility, subsequently increasing predation risk by gulls (Pete Warzybok, biologist, Point Blue Conservation Science—pers. comm. 2015). Other plants of concern on the refuge are non-native grasses (such as *Avena fatua*, *Bromus diandrus*, and *Hordeum murinum*) and plantain (*Plantago coronopus*). Thick mats of these species may hinder burrowing by nesting auklets and compete with native plants (USFWS 2009). Lastly, invasive plants may impact arboreal salamanders, which are nearly absent in invasive-dominated parts of SFI.

Factors that contribute positively (+) or negatively (-) to the invasive plant threat include:

- **Lack of prevention/biosecurity (-).** When seeds arrive in cargo or on personnel (such as on clothing, shoes, or field equipment), this leads to the introduction and spread of invasive plants.
- **On-island activities (-).** On-island activities, such as wildlife monitoring or infrastructure maintenance, can lead to introduction and spread of invasive plants. Holzman (2018) found that the spatial distribution of non-native species on SEFI shows a pattern of increased numbers in and around trails and structures indicating a human component to the spread of invasive plants on the refuge.
- **Vector: birds (-).** Birds can transport/spread invasive plant seeds by consumption and defecation of undigested seeds, as well as from dropping seeds caught in feathers.

Avian Predators (High Threat)

Burrowing owls (*Athene cunicularia*) predate upon ashy storm-petrels. Fall migrant burrowing owls arrive at the islands each year, just as the invasive house mouse (*Mus musculus*) population is at its peak. With the abundant prey supply, owls overwinter on the refuge. Once the mouse population is depleted, owls switch to feeding primarily on ashy storm-petrels (Nur et al. 2013, USFWS 2013, Chandler et al. 2016). As a result, storm-petrel adult survivorship and population size are reduced (Nur et al. 2013, Bradley 2017). If mice were not present on the islands, it is assumed burrowing owl predation pressure would decrease and affected seabird populations would increase. Evidence for this relationship is described in Warzybok et al. 2016:

> Burrowing owl occurrence and activity at the Farallon National Wildlife Refuge reached a peak in 2010/2011. During that same year, ashy storm-petrel survival reached its lowest level in the last decade, having shown a multi-year decline; population size was also declining during this same period that show a steep increase in burrowing owl attendance, 2007 to 2011. Thus, the evidence points to the increased abundance and activity of burrowing owl leading to predation of ashy storm-petrels, thus decreasing survival and contributing to the observed population decline. However, since 2011, fall/winter burrowing owl numbers have been 40% lower in recent years (2011/2012 to 2014/2015) compared to the previous 2 years (2009/2010 and 2010/2011). Average storm-petrel survival for the four most recent year period (2011/2012 to 2014/2015) was greater than the estimate of survival for 2010/2011 by 6.0%. However, survival of ashy storm-petrels for 2014/2015, the year of markedly low burrowing owl attendance, was indistinguishable from survival observed in the previous 3 years, when burrowing owl attendance was on average 68% higher than it was in 2014/2015.

Western gulls (*Larus occidentalis*) also prey upon auklet and storm-petrel populations (Ainley and Boekelheide 1990, Sydeman et al. 1998, Carter et al. 2008). Unlike burrowing owls, they are a natural predator. Gull populations may be higher because of increased populations on the mainland (as a result of abundant food from human sources such as landfills).

Factors that contribute positively (+) or negatively (-) to the avian predator threat include:

- Landfills (-). Food supplied by landfills result in greater gull populations, which then prey upon other species, such as ashy storm-petrels and Cassin's auklets.

Mammalian Predators (High Threat)

European hares (now extirpated) once decimated native vegetation and competed with burrow nesting seabirds for nesting burrows (Ainley and Lewis 1974). Today, invasive house mice cause harm to the marine island ecosystem by preying upon native plants and plant seeds, native invertebrates (including the endemic camel cricket), and possibly on juvenile salamanders, as well as competing with salamanders for invertebrate prey (USFWS 2013).

House mice also attract fall migrant burrowing owls, who prey upon seabirds once house mouse populations are depleted (Nur et al. 2013, USFWS 2013, Chandler et al. 2016).

Factors that contribute positively (+) or negatively (-) to the mammalian predator threat include:

- Lack of prevention/biosecurity (-). This can result in the introduction and spread of introduced mammals (such as rodents) when they arrive in cargo or shipwreck.

Oil Spills (High Threat)

Oil pollution dramatically reduced Farallon seabird populations in the first half of the 20th century (Ainley and Lewis 1974; Carter et al. 2003). Since the early 1970s, several large oil spills have killed tens or hundreds of thousands of Farallon seabirds, especially common murres (Carter 2003, Cosco Busan Oil Spill Trustees 2012, Hampton et al. 2003). Because of heavy shipping traffic in the region, the risk of large oil spills, and associated risk to seabirds, is considered a critical threat to refuge wildlife, including seabirds and pinnipeds, and the ocean resources they depend on. A large spill close to the islands could result in severe oiling of the island's shorelines, impacting intertidal communities and habitats for birds and marine mammals.

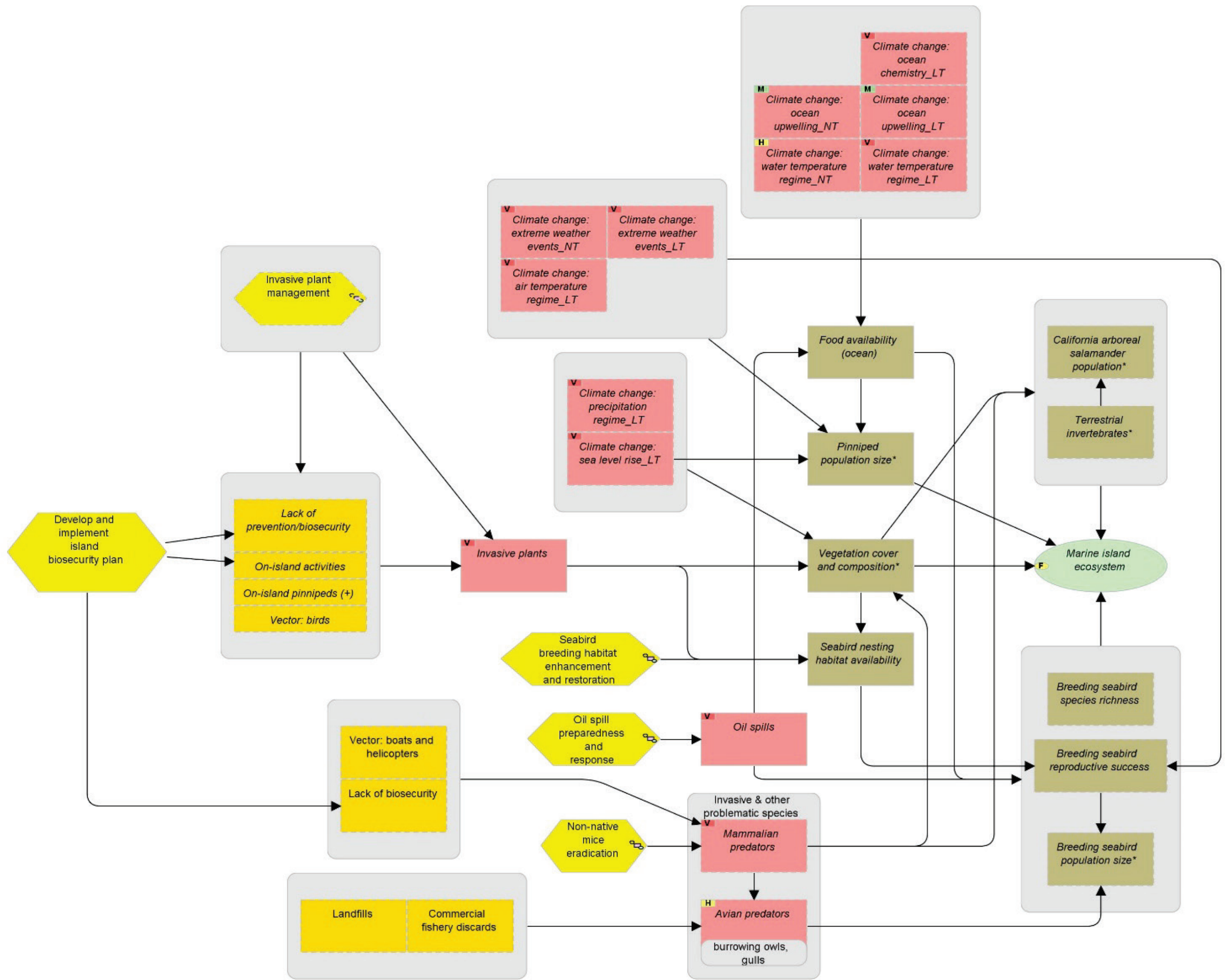


Figure 11. Conceptual model of the marine island ecosystem at Farallon Islands National Wildlife Refuge.

Notes: Only Very High or High threats to the ecosystem are depicted here. Legend: green oval = natural resource conservation target; olive box = biophysical or human well-being attribute; pink box = direct threat; orange box = contributing factors; yellow hexagon = conservation strategy. The letters in the upper left portion of threats (pink boxes) represent the summary threat ranking across the seven refuges of the San Francisco National Wildlife Refuge Complex (L=low, M=moderate, H=high, VH=very high).

4.3.5 Conservation Strategies

Conservation strategies for the marine island ecosystem are focused on reducing or mitigating the most critical threats: invasive plants, predation, climate change, and human disturbance. Threats addressed by each strategy and expected outcomes (objectives) are summarized in table 16. Each strategy is briefly described in the following and presented in order of management priority. Results chains visually depicting the assumptions behind these strategies (how they work) and expected outcomes are stored in the Miradi file associated with this NRMP (see appendix B for a link to this file).

Non-Native Mice Eradication

This strategy is aimed at eradicating house mice from SFI. Mice attract overwintering burrowing owls, which switch to feeding on storm-petrels when the mouse population crashes. Mice compete for food with salamanders by preying on insects and possibly other invertebrates. Mice likely contribute to reductions in native plant cover by seed and plant consumption. Mouse eradication will benefit the marine island ecosystem by removing a high threat to the nested targets of this ecosystem including ashy storm-petrels, salamanders, crickets, other invertebrates, and native plants. Activities include working with contractor and multiple partners to complete the environmental impact statement (USFWS 2013) and implementing the eradication through rodenticide application (proposed).

Invasive Plant Management

The invasive plant management strategy involves continuation of current invasive plant management practices laid out in the 2008 refuge weed management plan (USFWS 2009) as well as adaption of these strategies using new vegetation abundance and distribution survey results (Holzman et al. 2016, Holzman 2018). The new strategy will also encompass monitoring to assess whether strategies are working or not. Over time, such an approach is expected to reduce invasive plant cover, benefit native plant species (such as maritime goldfields), and benefit seabirds by providing habitat (e.g., nesting crevice availability).

The first refuge weed management plan was prepared in 2004 and updated in 2008 (USFWS 2008). The plan focuses solely on SEFI and highlights New Zealand spinach and cheeseweed as priorities for management. Since the late 1980s, the primary tool for managing these two species has been a summer application of glyphosate-based herbicides and hand pulling (Gerry McChesney, refuge manager—pers. comm. 2017). In 2013, the refuge added a second glyphosate treatment in late March. Qualitative refuge observations suggest spring treatments have reduced the abundance of mature, seed-producing plants. In 2013, the refuge piloted the use of imazapyr (tradename Habitat) to control invasive plants. Qualitative refuge observations suggest imazapyr is not effective at controlling target species and limits colonization by native plants for at least 2 years following application (creates "dead zones"). Observations also suggest that the native maritime goldfield and non-native grasses (such as *Bromus diandrus, Avena barbata, A. fatua*) are the primary species that colonize treatment areas.

Develop and Implement Island Biosecurity Plan

This strategy involves updating and implementing the existing draft biosecurity plan with the goal of preventing new introductions of invasive species to the refuge. Measures in the biosecurity plan will help prevent introduction or spread of invasive species on the islands and will have rapid response measures to quickly eradicate newly introduced species. Biosecurity will be conducted both on the mainland (e.g., staging areas, transport vessels, packing materials) and on island (inspection, cleaning, etc.). Prevention/rapid response is much less costly than control or eradication of infestations of introduced species. This strategy is a critical component once mice are eradicated from SEFI in order to prevent future introductions.

Seabird Breeding Habitat Enhancement and Restoration

Much seabird habitat was lost due to historical building construction. Talus slopes used by crevice-nesting storm-petrels, auklets, guillemots, and puffins were altered when rocks were removed for construction of walls and early buildings. Although most buildings have been removed, many of the concrete foundations still remain, thereby rendering habitat unusable for nesting seabirds. This strategy involves conversion of historical human features to provide additional crevice-nesting habitat for burrowing-nesting species, or removal when reuse is not possible. By removing and converting concrete foundations to new habitat for crevice-nesting seabirds such as ashy storm-petrels, additional breeding sites for this target species can be added, resulting in increased population size. Other activities include maintaining existing seabird breeding habitat and shielding breeding areas that are closed to trails that provide island access. In addition, artificial nest boxes both provide additional auklet nesting habitat and provide easily accessible nest sites for monitoring. By developing artificial habitat that more closely replicates natural burrows, auklets will be less impacted by extreme heat events (climate smart adaptation project) and populations benefit.

Oil Spill Preparedness and Response

Certain species of seabirds, especially alcids (and more specifically, common murres) and cormorants, are directly affected by oil spills. In order to reduce threats to seabirds, staff would continue to be trained to respond to oil spills, document impacts of oil spills to island resources, and coordinate with partners (USFWS NRDAR staff, CDFW, U.S. Coast Guard, Oiled Wildlife Care Network). Assistance with response may lead to a reduction of impacts on island resources (e.g., seabirds, pinnipeds) from oil spills as well as a better understanding of impacts on resources, which may then result in restoration funds.

Table 17. Farallon Islands National Wildlife Refuge management strategies and associated objectives, in order of priority to implement over the next 5 years to conserve the marine island ecosystem.

Strategy Title	*Threat Addressed*	*Expected Outcome (Objectives)*
Non-native mice eradication	Mammalian predators	MIE_O01. By FY 2020, non-native house mouse eradication at the Farallon Islands National Wildlife Refuge is underway. MIE_O02. Within 2 years of implementation of mouse eradication at Farallon Islands National Wildlife Refuge, non-native mice are declared eradicated (2 years of monitoring with no mice detection). MIE_O03. Within 5 years of implementation of mouse eradication at Farallon Islands National Wildlife Refuge, statistically significant increases in ashy storm-petrels (2001–current baseline data), Farallon arboreal salamander (2013–2015 baseline data), Farallon camel cricket (2013–2015 baseline data, in prep.), and maritime goldfields (2018 baseline data) are detected. MIE_O04. After the first year of mouse eradication, overwintering burrowing owls are reduced by 50% of pre-eradication 10-year average at Farallon Islands National Wildlife Refuge.

Strategy Title	*Threat Addressed*	*Expected Outcome (Objectives)*
Invasive plant management	Invasive plants	MIE_O08. By FY 2023, % cover of New Zealand spinach (*Tetragonia tetragonioides*) decreases by 10%, Malva species (*Malva parviflora, Malva neglecta,* and *Malva pseudolavatera*) decrease by 25%, narrowleaf plantain (*Plantago coronopus*) by 10%, and Erharta erecta by 30% (based on 2018 baseline) on Southeast Farallon Island of the Farallon Islands National Wildlife Refuge. MIE_O09. By FY 2023, an invasive plant management plan is completed for Farallon Islands National Wildlife Refuge. MIE_O10. By FY 2033, eradicate New Zealand spinach (*Tetragonia tetragonioides*); three species of Malva including cheeseweed (*Malva parviflora, Malva neglecta,* and *Malva pseudolavatera*; narrowleaf plantain (*Plantago coronopus*); and Ehrharta erecta on the South Farallon Islands of the Farallon Islands National Wildlife Refuge.
Develop and implement island biosecurity plan	Invasive plants, mammalian predators	MIE_O13. Within 3 years of the implementation of the Farallon Islands Biosecurity Plan, no new establishments of non-native plant or animal species are detected on the Farallon Islands National Wildlife Refuge.
Seabird breeding habitat enhancement and restoration	All threats	MIE_O05. By FY 2023, 75% of new (since FY 2018) climate smart nest boxes are occupied by Cassin's and rhinoceros auklets at Southeast Farallon Island. MIE_O06. By FY 2023, at least 40 ashy storm petrel active nests are detected annually in artificial rock wall nesting habitat on Southeast Farallon Island. MIE_O07. No human disturbance events at Sea Lion Cove seabird colony are detected on the Farallon Islands National Wildlife Refuge.
Oil spill preparedness and response	Oil spills	MIE_O11. By FY 2022, the San Francisco Bay NWR Complex understands how to respond to an oil spill (an oil spill response plan for the Refuge Complex) is completed and understood by staff involved with managing marine-influenced conservation targets of the Refuge Complex. MIE_O12. Over the next 15 years (FY 2018–2032), at least one refuge staff member associated with each of the marine-influenced conservation targets of the Refuge Complex understands how to respond to an oil spill that affects the Refuge Complex. For example, that person would have current certifications in HAZWOPER (hazardous waste operations and emergency response).

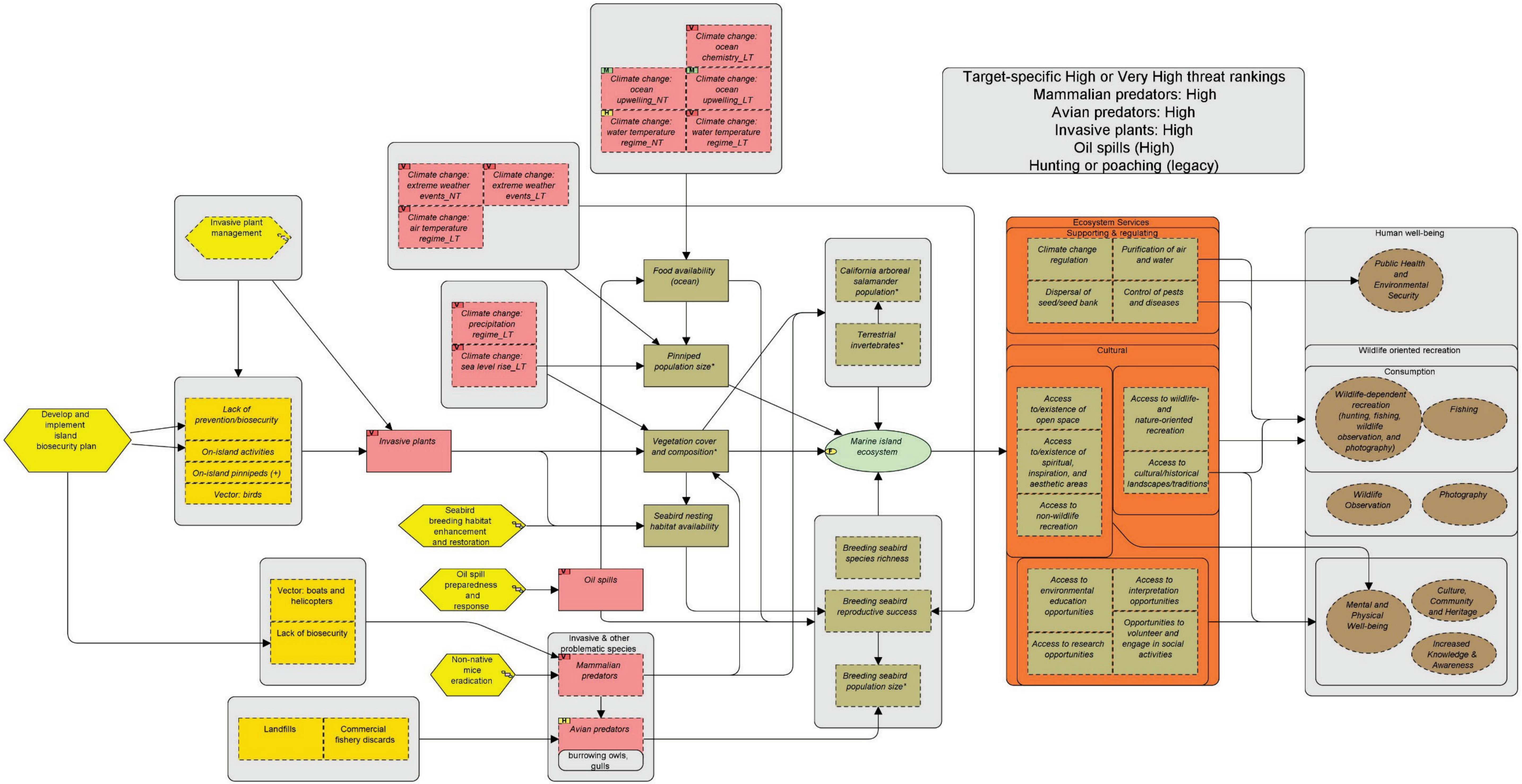


Figure 12. Conceptual model of the marine island ecosystem at Farallon Islands National Wildlife Refuge depicting the most critical threats and strategies aimed at addressing them.

Notes: Legend: green oval = natural resource conservation target; olive box = biophysical or human well-being attribute; pink box = direct threat; orange box = contributing factors; yellow hexagon = conservation strategy. Biophysical factors the refuge expects to monitor are donated with an asterisk (*) after the name. The letters in the upper left portion of threats (pink boxes) represent the summary threat ranking across the seven refuges of the San Francisco National Wildlife Refuge Complex (L=low, M=moderate, H=high, VH=very high).

4.3.6 Natural Resource Surveys

Natural resource surveys to assess marine island ecosystem health (goals) and effectiveness of refuge management strategies (objectives) are presented below (table 18). Surveys are listed in order of priority (USFWS 2019).

Table 18. Natural resource surveys to inform progress in achieving marine island ecosystem goals and objectives (Farallon Islands National Wildlife Refuge).

Survey Name	*PRIMR ID*	*Status*	*Survey Frequency*	*Goal or Objective Informed by Survey*	*Survey Coordinator*
Ashy and Leach’s storm-petrel reproductive performance survey	FF08RFRL00-021	Current	Annual	MIE_O06	Point Blue Conservation Science
Capture-recapture of ashy and Leach's storm-petrels	FF08RFRL00-004	Current	Annual	MIE_G01	Point Blue Conservation Science
Burrowing owl population monitoring	FF08RFRL00-026	Current	Annual	MIE_O04	Point Blue Conservation Science
Non-native small mammal presence-absence surveys*	FF08RFRL00-037	Expected	Annual	MIE_O02	USFWS, San Francisco Bay NWR Complex
Vegetation monitoring: Farallon Islands NWR	FF08RFRL00-049	Current	Every 5 years	MIE_G03, MIE_O08, MIE_O10	USFWS, San Francisco Bay NWR Complex
Cassin’s Auklet Reproductive Performance	FF08RFRL00-031	Current	Annual	MIE_G02, MIE_O05	Point Blue Conservation Science
Rhinoceros auklet reproductive performance	FF08RFRL00-045	Current	Annual	MIE_O05	Point Blue Conservation Science
Weekly pinniped census	FF08RFRL00-012	Current	Weekly	MIE_G04	Point Blue Conservation Science
Cassin’s auklet and rhinoceros auklet capture-recapture survey	FF08RFRL00-028	Current	Annual	MIE_G02	Point Blue Conservation Science
Farallon camel cricket survey*	FF08RFRL00-034	Current	Annual	MIE_O03	Point Blue Conservation Science
Arboreal salamander long term monitoring*	FF08RFRL00-007	Current	Annual	MIE_O03	Point Blue Conservation Science
Brandt’s Cormorant, Pelagic Cormorant, and Common Murre Population Size	FF08RFRL00-025	Current	Annual	MIE_G02	Point Blue Conservation Science

Notes: * = survey also meets a regulatory permit requirement.

For survey status, current = survey is currently implemented on the refuge; expected = survey will likely be implemented. For expected surveys, the survey frequency is an estimate and may change once a protocol is developed.

4.4 Pajaro Valley Watershed

Information sources used to describe the Pajaro Valley Watershed are presented in the following. Any other sources are cited in-text.

- *Draft Revised Recovery Plan for the Santa Cruz Long-Toed Salamander* (USFWS 1999)
- *Ellicott Slough National Wildlife Refuge Final Comprehensive Conservation Plan and Environmental Assessment* (USFWS 2010)
- *Recovery plan for the California red-legged frog (Rana aurora draytonii)* (USFWS 2002)
- *Recovery Plan for the Central California Distinct Population Segment of the California Tiger Salamander (Ambystoma californiense)* (USFWS 2017)
- *San Francisco Bay National Wildlife Refuge Complex Climate Assessment* (CALCC et al. 2018)
- *Water Resources Inventory and Assessment, Ellicott Slough National Wildlife Refuge* (USFWS 2015)

4.4.1 Overview

The Pajaro Valley watershed (watershed) occurs in Santa Cruz County, along the central coast of California and spans 13,000 acres (figure 13). The watershed was chosen as a priority conservation target of the Refuge Complex because it supports one of the largest remaining freshwater wetlands in the California coastal zone. It provides critical habitat for state and federal endangered species, is an important rest stop for migratory birds along the Pacific Flyway and provides breeding and year-round habitat for over 200 species of waterfowl, songbirds, and raptors. Although the Service does not have management jurisdiction over the watershed, it was selected as a target because biodiversity at Ellicott Slough NWR is dependent on health of the watershed in which it occurs. The refuge therefore supports conservation efforts on the refuge and in the larger watershed.

Nested Targets of the Pajaro Valley watershed:

- California tiger salamander (CTS)
- Santa Cruz long-toed salamander (SCLTS)
- Ephemeral (seasonal) ponds
- Oak woodlands

The Pajaro Valley watershed includes a mix of urban, industrial, rural residential, agricultural, and open space land uses. The 800-acre Watsonville Slough System is a key feature of the lower watershed. The system was once an extensive brackish and freshwater wetland and estuarine complex but over time has been altered for human uses such as agriculture and urban development. The refuge occurs in the lower northwest portion of the watershed, 0.5 mile inland from Monterey Bay and 4 miles west of Watsonville (figures 1, 2). The refuge was established to conserve and protect native biodiversity found in the watershed, including federally threatened and endangered species and migratory birds (figures 13 and 14). Ellicott Slough NWR is one of the few refuges in the Refuge System established for amphibians:

- Santa Cruz long-toed salamander (*Ambystoma macrodactylum croceum*) (SCLTS)—federally listed as endangered
- California tiger salamander (*Ambystoma californiense*) (CTS)—federally listed as threatened
- California red-legged frog (*Rana aurora draytonii*)—federally listed as threatened

The refuge consists of three non-contiguous management units totaling approximately 316 acres: Ellicott Unit (168 acres), the Calabasas Unit (31 acres), and the Harkins Slough Unit (116 acres) (figure 13). Replace with 'In addition, the refuge assists with the management of the 289-acre area known as the Buena Vista property, owned by CDFW.

4.4.2 Ecology

Santa Cruz long-toed salamander (*Ambystoma macrodactylum croceum*).
Credit: S. Ruth and E.F. Katibah

The Pajaro Valley watershed falls within the central California foothills and coastal mountains ecoregion (Griffith et al. 2016). This ecoregion consists of mountains, hills, valleys, and plains in the southern Coast Ranges of central California. Elevation of the watershed ranges from sea level to 3,800 feet. The refuge Harkins Slough Unit, Calabasas Unit, and the eastern portion of the Buena Vista Property lie within the larger Watsonville Slough system. This system flows southwest and then south before confluence with the Pajaro River, Monterey Bay, and the Pacific Ocean. The region surrounding Watsonville Slough system used to contain a much more extensive wetland and estuarine complex, but it has since been modified for agricultural and urban land uses.

The watershed supports a mix of vegetative types including San Andreas coastal live oak woodland, riparian woodlands, California coastal plant communities, coastal grasses, coastal shrub, northern coastal shrub, San Andreas Maritime Chaparral, freshwater marshes, and closed-cone coniferous forests (considered invasive). The dominant types found at Ellicott Slough NWR are coastal shrub, San Andreas coastal live oak woodland, riparian woodland, closed-cone coniferous forest, and coastal grassland. Seasonal ponds, wetlands, and vegetation communities at Ellicott Slough NWR and the larger watershed within which it occurs, are critically important for native amphibian species. These environments are dependent on rainfall captured by and transported through the watershed. Water quality in the watershed is equally important and is heavily influenced by agricultural practices in the surrounding landscape as well as the plant community itself.

Sensitive Amphibian Species

Santa Cruz Long-Toed Salamander

SCLTS is distributed over a relatively small geographic area, all within Santa Cruz and Monterey Counties in central California. The species was first listed by the federal government as endangered in 1967 due habitat loss and fragmentation. The species exists in six metapopulations. The refuge encompasses the Ellicott-Buena Vista and Larkin Valley metapopulations. SCLTS spends most of its life underground in small mammal burrows and along the root systems of plants in chaparral and oak-woodland areas (where it is protected from heat and sun exposure). Adult salamanders leave their underground habitat with the onset of the rainy season in late October and November and begin their annual migration to a breeding pond, where they establish pairs, court, and breed. Ponds are an essential habitat component because after eggs hatch, SCLTS larvae spend 3-7 months in the pond before becoming terrestrial. As breeding ponds begin to dry, juvenile salamanders seek underground habitat in adjacent areas. The juveniles disperse to upland vegetation communities (such as chaparral, oak woodlands, willow riparian) during the first fall rains, normally in September. Juvenile salamanders will not return to the pond until they are sexually mature (3–4 years).

California Tiger Salamander (Central California Distinct Population Segment)

The Central California Distinct Population Segment of CTS was federally listed as threatened in 2004 as a result of habitat loss similar to SCLTS. This population segment is restricted to disjunct populations that form a ring along the foothills of the Central Valley and Inner Coast Range from San Luis Obispo, Kern, and Tulare Counties in the south, to Sacramento and Yolo Counties in the north. CTS has a similar life cycle as SCLTS in that it utilizes both aquatic and terrestrial habitats. Although CTS larvae develop in the ponds and vernal pools in which they were born, once a metamorph leaves its natal pond and enters a burrow, they spend the vast majority of life underground. Adult CTS of this distinct population segment engage in mass migrations during a few rainy nights per year, typically from November through April, although migrating adults have been observed as early as October and as late as May. During these rain events, adults leave their underground burrows and return to breeding ponds to mate. Upland environments surrounding known breeding pools are usually dominated by grassland, oak savanna, or oak woodland. Large tracts of these upland environments, preferably with multiple breeding ponds, are necessary for this distinct population segment of CTS to persist.

California Red-Legged Frog

The California red-legged frog is endemic to California and Baja California, Mexico. The species was federally listed as threatened in 1996. The species has been extirpated from 70% of its historic range as a result of human-induced impacts similar to SCLTS and CTS. The species breeds in a variety of aquatic environments including streams, deep pools, backwaters within streams and creeks, ponds, marshes, ponds, and lagoons. Breeding adults are often associated with deep (>0.7-meter) still or slow-moving water and dense, shrubby riparian or emergent vegetation. Critical habitat designated for California red-legged frog includes refuge lands although abundance and distribution of this species on the refuge is not well understood.

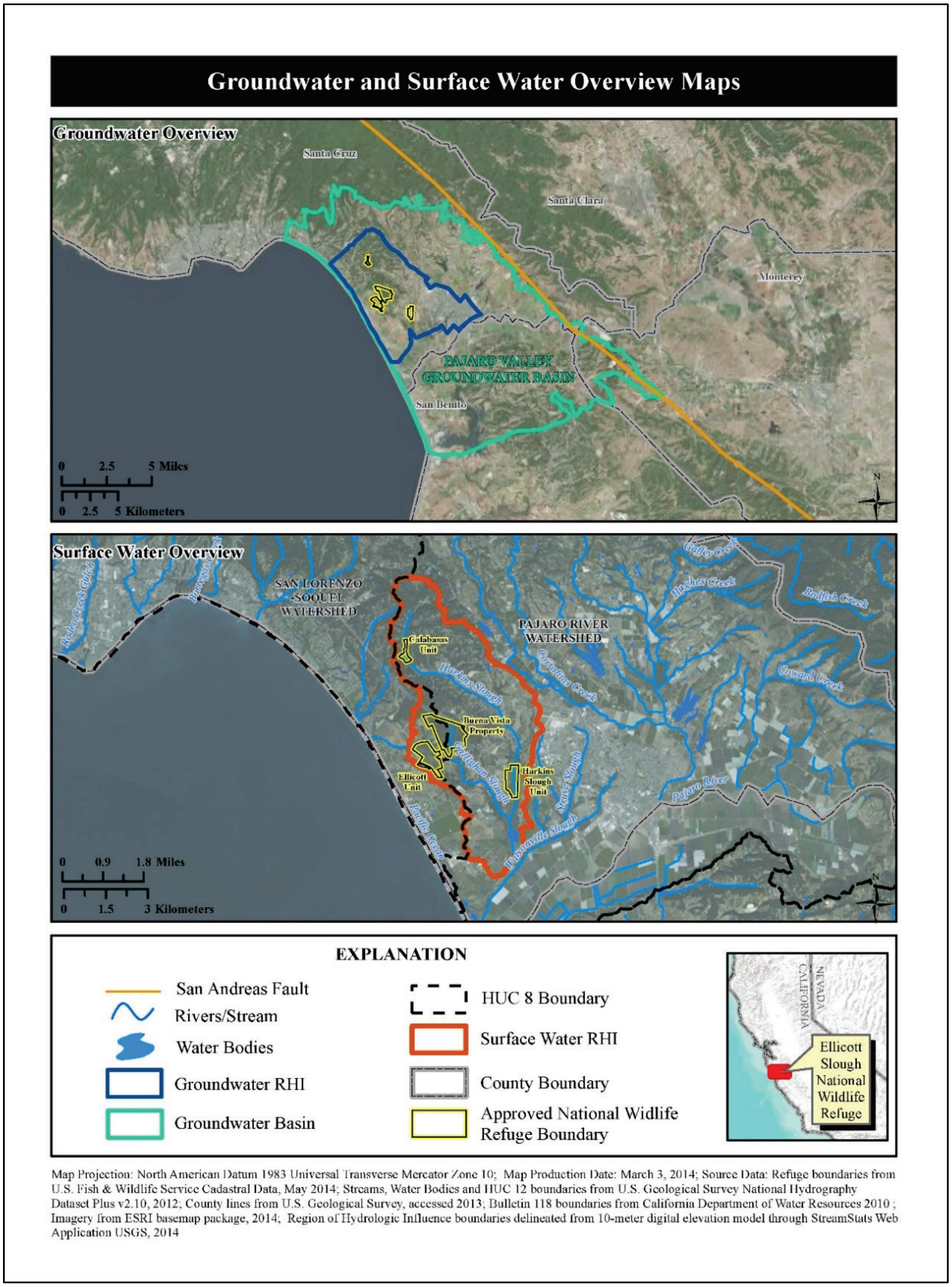


Figure 13. Map depicting location and hydrological features of the Pajaro Valley watershed and Ellicott Slough National Wildlife Refuge.

Source: USFWS 2015.

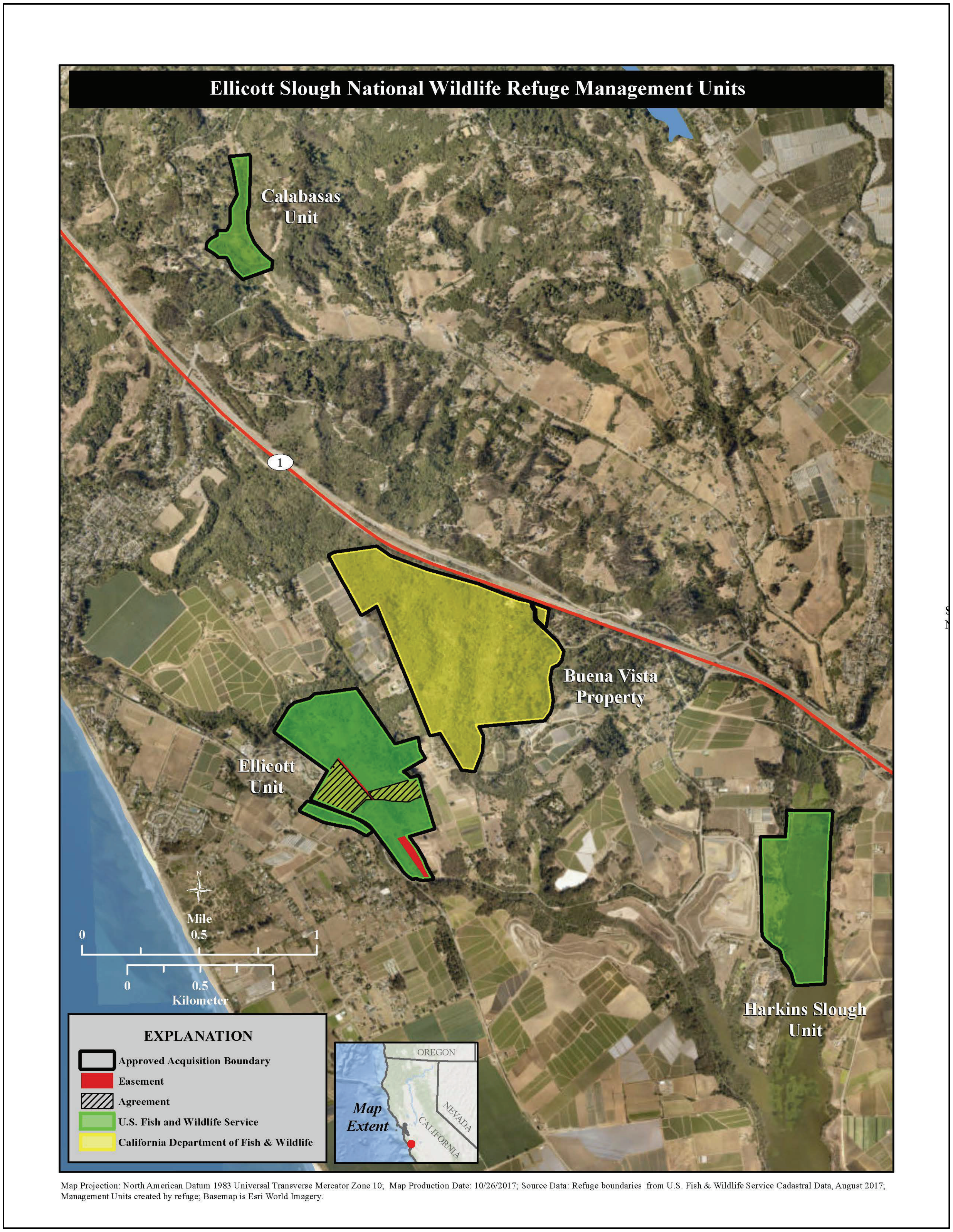


Figure 14. Geographic setting of Ellicott Slough National Wildlife Refuge and associated management units, Santa Cruz County, California.

4.4.3 Target Status, Trends, and Goals

Four KEAs were selected to indicate the health of the Pajaro Valley watershed, in terms of Ellicott Slough NWR: 1) population size of the SCLTS and CTS, 2) salamander reproductive success, 3) pond hydroperiod, and 4) grassland and woodland extent. Although surveys conducted by the Refuge Complex are focused at Ellicott Slough NWR, they are representative of the overall health of the watershed because this particular refuge is hydrologically linked and heavily influenced by the health of the larger watershed (see figure 13). Further, these indicators collectively represent habitat needs of native species in the watershed, including sensitive amphibian species as well as many other native wildlife and plant species. Based on current knowledge of the status and trends of the four KEAs and associated indicators, the health of the watershed—in terms of Ellicott Slough NWR—is considered Fair. The relationship between indicator measures and status (Poor to Very Good) is detailed in the Refuge Complex conservation target viability database (appendix B). A summary of KEAs, associated indicators, indicator status and trends, and desired future conditions (SMART goals) is presented in table 18.

KEA 1: Santa Cruz Long-Toed Salamander and California Tiger Salamander Population Size

SCLTS and CTS population sizes are indicative of the health of the watershed because these species depend on aquatic (breeding) and upland (migration, over-summering) environments representative of the watershed. If salamander populations are stable or increasing, it is assumed the health of environments at Ellicott Slough NWR and the larger watershed are also stable or increasing. Salamanders are dependent on and sensitive to the state of many ecological attributes of the watershed, including hydrological regimes, vegetation community composition and cover, and habitat connectivity.

Since 1990, general trends in salamander populations at Ellicott Slough NWR have been assessed using dip-net surveys (see KEA 2 below), night-time migration surveys, and drift fence surveys (2013–2015). A salamander capture-recapture study was conducted at Ellicott Slough NWR from 2013 to 2015 to estimate salamander population size using drift fencing. The study resulted in a population estimate of 2,405 (+/- 222) breeding SCLTS adults at the Buena Vista Unit and 9,913 (+/- 844) breeding SCLTS adults at the Ellicott Unit (BioSearch Associates 2016). Although CTS were detected during this study, numbers were to low too generate a population estimate. In the future, refuge staff hope to develop an effective and efficient population survey technique. If successful, this survey will replace the current salamander reproductive success survey (see KEA 2). The status of salamander populations at Ellicott Slough NWR is considered Fair (table 18), but this assessment is highly uncertain given the lack of long-term monitoring data.

KEA 2: Salamander reproductive success

Salamander reproductive success is indicated by presence of SCLTS and CTS larvae in refuge ponds (Ellicott Pond, Calabasas Pond, and Buena Vista Pond). The Service has conducted annual larval salamander dip-net surveys since 1990 to assess breeding success and general trends in salamander populations. Dip-net surveys for larval salamanders are conducted before the pond dries out, but late enough that there are no eggs still present (typically April–May). The indicator is also used to assess health of larvae; captured larvae are examined for signs of disease and malformations. A comprehensive analysis and summary of dip-net monitoring data (1990–present) is needed to assess long-term trends in salamander reproductive activity at Ellicott Slough NWR. The status of salamander reproductive success in terms of SCLTS and CTS larval presence in the refuge ponds is Good (SCLTS larvae are present in four of four ponds; CTS larvae are present in three of three ponds; table 18).

KEA 3: Pond Hydroperiod

Calabasas pond at Ellicott Slough NWR.
Credit: Rachel Tertes, USFWS

Pond hydroperiod is indicated by the average annual number of continuous weeks all ponds at Ellicott Slough NWR (N=4) hold ≥1-foot water between December 1 and June 30. Characteristics of pond hydroperiod and depth strongly influence salamander reproductive success because they depend, in part, on aquatic systems to survive and reproduce (egg stage through metamorphosis). The amount and periodicity of pond water is driven by annual precipitation patterns and movement of water through the watershed, which in turn affects watershed biodiversity. However, water level can be managed in three of the four ponds via water control structures and/or wells. Pond hydroperiod can also be used to evaluate success of refuge efforts to actively manage pond water levels when needed. Long-term hydrological data can also indicate how climate changes are affecting pond hydroperiod and inform what actions to take, if any, to alleviate inadequate hydrological conditions. As of 2015–2016 season, pond hydroperiod is considered Good (table 19) for the year. A four-year running average will be calculated when enough staff gauge data is collected to determine long-term trend.

Water management and infrastructure are used to help control water levels to promote recruitment. According to refuge staff, excessive interannual fluctuation of pond levels may increase the risk that emergent vegetation will dry or be inundated; emergent vegetation is required for successful amphibian recruitment. In 2015, ponds were equipped with staff gauges that measure to 0.01 foot so that refuge personnel can estimate the depth of water in the ponds to ensure that adequate pond water levels are maintained. Prior to 2015, pond water levels were estimated informally, and approximate timing of dry down was noted.

KEA 4: Grassland and Woodland Extent

Grassland and woodland extent is indicated by percent landcover of grassland and woodland at Ellicott, Buena Vista, and Calabasas management units of Ellicott Slough NWR. Both CTS and the SCLTS spend most of their time underground in these upland habitats. CTS use small mammal burrows, such as those of ground squirrels and pocket gophers, found in open grasslands. The SCLTS prefers small mammal burrows found in woodlands and will also burrow along the root systems of oaks and willows. This indicator is representative of the overall biodiversity at Ellicott Slough NWR because many wildlife and plant species, in addition to salamanders, likely benefit from the continued persistence of these native landcover types. Changes in the extent of these landcover types are also likely representative of changes in the larger watershed due to shifts in climate, hydrology, fire regimes, plant disease, and other factors. The long-term trend in the extent of grasslands and woodlands at Ellicott Slough NWR and the larger watershed are unknown. The status, as of 2016, if this indicator is estimated as Fair (≤25% woodland, ≤25% grassland, table 18), and the trend is unknown.

Table 19. Current status and desired future state (goals) of the Pajaro Valley watershed at Ellicott Slough National Wildlife Refuge in terms of key ecological attributes and indicators.

Key Ecological Attribute	*Indicator*	*Status: Measure (Trend)*	*Status Source*	*Goal*
Santa Cruz long-toed salamander and California tiger salamander population size	Estimated number of adult Santa Cruz long-toed salamander by refuge unit (Buena Vista, Ellicott, and Calabasas) and estimated number of adult California tiger salamander at Buena Vista Unit and Ellicott Unit (California tiger salamander does not occur at the Calabasas Unit)	Fair: Santa Cruz long-toed salamander = 9,913 +/- 884 adults at Ellicott Unit, 2,405 +/- 222 adults at Buena Vista Unit (unknown trend)	Refuge research (BioSearch Associates 2016)	PVW_G01. Over the next 15 years (2018–2032), the estimated population size of Santa Cruz long-toed salamanders at Ellicott Slough NWR is >9,000 at the Ellicott Unit and >2,000 at the Buena Vista Unit.
Salamander reproductive success	Presence/absence of Santa Cruz long-toed salamander and California tiger salamander larvae in refuge ponds (California tiger salamander does not occur at the Calabasas Unit)	Good: Santa Cruz long-toed salamander larvae present in four ponds, California tiger salamander larvae present in three ponds (increasing)	Refuge monitoring data	PVW_G02. Over the next 15 years (2018-2032), Santa Cruz long-toed salamander larvae are present in all ponds (N=4), and California tiger salamander larvae are present in all ponds known to support CTS breeding (N=3) at Ellicott Slough NWR
Pond hydroperiod	Average annual number of weeks all four ponds at Ellicott Slough NWR have ≥1 foot of water between December 1 and June 30 over the last 4 years	Good: All four ponds retained water for 21–24 weeks on average over the last 4 years (2014–2017 (increasing)	Refuge monitoring data	PVW_G03. Over the next 15 years (2018–2032), the average annual number of weeks all ponds (N=4) at Ellicott Slough NWR have ≥1 foot of water in a given year is ≥21 weeks, and no pond has <15 weeks for 3 consecutive years.
Grassland and woodland extent	% grassland and % woodland landcover by management unit (Ellicott, Buena Vista, and Calabasas). Woodland is defined as willow, shrub, or oak vegetative cover. Grassland is not an indicator at Calabasas Unit, because no California tiger salamanders are present.	Fair: Ellicott Unit = 11–25% grassland, 26–40% woodland; Buena Vista = <10% grassland, 26–40% woodland; Calabasas = 26–40% woodland (unknown)	Expert opinion	PRW_G04. Over the next 15 years (2018–2032), the proportion of landcover occupied by grassland and woodland at Ellicott Slough NWR is (1) Calabasas Unit, woodland maintained at 26–40%; (2) Buena Vista Unit, increase grassland to 11–25% and maintain 26-40% woodland; (3) Ellicott Unit, increase grassland to 26–40% and maintain 26–40% woodland.

Note: Status designations: red = Poor, yellow = Fair, light green = Good, dark green = Very Good. Refer to the San Francisco Bay National Wildlife Refuge Complex viability database for additional details (appendix B).

4.4.4 Critical Threats

The most critical threats (classified as High or Very High threats) to Ellicott Slough NWR and the Pajaro Valley watershed are climate change, invasive plants, wildfire, roadways/rails/levees, and landcover conversion (legacy or current). Invasive aquatic wildlife is a Medium threat. Low threats are mosquito control activities, agricultural pesticides, disease, native nuisance species, and illegal activities by humans. A conceptual model depicting threats, their relationship to KEAs of the Pajaro Valley watershed, and strategies aimed at reducing the most critical threats or restoring the watershed is depicted in figure 15. The most critical threats (High to Very High) to the Pajaro Valley watershed and Ellicott Slough NWR are summarized below.

Climate Change (High to Very High Threat)

Some of the key findings from the *San Francisco Bay National Wildlife Refuge Complex Climate Assessment* (CALCC et al. 2018) and the *Water Resources Inventory and Assessment, Ellicott Slough National Wildlife Refuge* (USFWS 2015) are presented below.

Climate change models for 2100 suggest that mean temperatures will increase from 0.3 to 6.3 °F, and potential evaporation will increase from 0 to 8.2%. These factors could result in an increase of climatic water deficit (water demand required to meet existing habitat needs) by 144.1 to 477.1 acre-feet per year by 2100. This issue is of greatest concern for the Buena Vista, Ellicott, and Calabasas Units, which require specific water supplies to maintain amphibian breeding ponds, although the impacts of these changes are unknown because refuge water quantity requirements have not been determined. Determining a water budget for refuge ponds would be helpful for determining whether predicted increases in climatic water deficit pose a problem for breeding pond management.

Precipitation projections are highly variable, but drought frequency and intensity are expected to increase as a result of increased air temperatures regardless of precipitation amount. California is already experiencing increased drought conditions; drought years in California have occurred twice as often in the last 20 years compared to the preceding century (Diffenbaugh et al. 2015).

Drought and increased air temperature can completely prevent ponding and/or reduce the ponding hydroperiod (Bauder 2005). Loss of pools or reduction of hydroperiod at critical times reduces salamander breeding opportunities (Barry and Shaffer 1994). Early pond drying caused by drought conditions can also lead to death of larval-stage salamanders. However, relatively long adult lifespans help salamander populations weather short-term drought (Barry and Shaffer 1994), but longer drought durations would likely negatively affect CTS and other salamander species by limiting breeding opportunities and reducing survival Paired with naturally low recruitment (Trenham et al. 2001), drought could threaten CTS persistence. In addition to reduction in hydroperiod, drought and decreased rainfall can cause a reduction in pond depth, which increases egg and larva exposure to ultraviolet radiation. Increased ultraviolet exposure has been shown in many salamander species to lead to egg mortality or embryo deformities (Blaustein et al. 2011). Ultraviolet exposure has also been shown in multiple salamander species to increase time spent under refugia and in deeper waters (Garcia et al. 2004).

Invasive Plants (Very High Threat)

Invasive plants can decrease native biodiversity of the Pajaro Valley watershed in multiple ways, including changes in vegetation structure and composition (DiTomaso et al. 2013) and altered hydrology. Of particular concern is reduced quantity of quality of over-summering or migration habitat used by salamanders (USFWS 2009). Invasive non-native plants such as eucalyptus trees (*Eucalyptus* sp.), jubata grass, and pampas grass (*Cortaderia selloana*) compete with native vegetation and reduce the availability of salamander habitat resources (USFWS 1999). Invasive plants may reduce the availability of root systems that are preferred by SCLTS for underground refuge. Additionally, the presence of non-native invasive plants may alter the invertebrate community, which in turn could negatively impact salamander food availability (USFWS 2009). Invasive plants may also affect the viability of ephemeral amphibian breeding ponds either directly by altering pond hydrological characteristics or indirectly by changing the hydrology of the watershed (water supply).

Factors that contribute positively (+) or negatively (-) to the invasive plant threat include:

- Surrounding source populations (-). Ellicott Slough NWR, the Pajaro Valley watershed, and surrounding lands contain source populations of many invasive plant species. If new invasions are not prevented or existing populations are not managed, invasive plant populations will continue to spread.

- Human and animal vectors (-). Visitors to the refuge, staff, migrating wildlife, and birds are potential vectors (agents of spread) of invasive plant species, resulting in new introductions or increased spread of existing populations.

Land Conversion (High Threat)

The loss, degradation, and fragmentation of wildlife habitat as the result of human activities is a critical threat to Ellicott Slough NWR and the larger watershed. Conversion of open spaces to high intensity uses such as agriculture or other high intensity human uses eliminates habitat for many native wildlife species. The loss, degradation, and fragmentation of habitat as a result of land conversion are cited as one of the primary threats to CTS (USFWS 2017) and SCLTS (USFWS 2009). CTS populations occur in scattered and increasingly isolated breeding sites, reducing opportunities for inter-pond dispersal (USFWS 2009). Similarly, land conversion has reduced habitat availability to the SCLTS and has isolated subpopulations (USFWS 2009).

Roads, Railways, and Levees (High Threat)

Transportation corridors such as roads can create barriers to wildlife movement or result in direct mortality. For example, roads and highways can create permanent physical barriers to salamander migration between breeding and over-summering habitats and can eliminate genetic exchange between subpopulations, thereby increasing the risk of local extirpations (USFWS 2009, 2017). Transportation corridors can also cause mortality directly through vehicle strikes (Shaffer et al. 1993). Both CTS and SCLTS have been reported to be killed by vehicular traffic while crossing roads (Twitty 1941; Barry and Shaffer 1994; Launer and Fee 1996; C. Caris, Wildlife Biologist, USFWS—pers. comm. 2014).

Wildfires (High Threat)

Uncontrolled wildfires and alteration of fire regimes (fire suppression) can reduce carrying capacity of upland habitats and possibly cause direct mortality to SCLTS and CTS. Fire has been excluded from the Pajaro Valley watershed for decades to protect residential neighborhoods, orchards, and agriculture fields. This has multiple, if not conflicting problems for the entire watershed. As fire is suppressed, fuel loads increase, and the risk of catastrophic fires increases. Catastrophic fires can result in direct mortality of wildlife and plants and alteration of wildlife habitat through erosion or introduction of invasive plant cover (Keeley 2006). Another byproduct of altered fire regimes is the conversion plant communities. Sensitive and rare plant communities of the watershed, such as coastal shrub and San Andreas coast live oak are converted to a later successional stage due to a lack of fire. Invasive Monterey pine trees have moved into many woodland areas of the Pajaro Valley watershed (such as the Buena Vista Unit) and are shading out these increasingly rare native plant communities. A lack of fire is also resulting in a conversion of grasslands to scrub habitat (Caris and Kodama, pers. obs.).

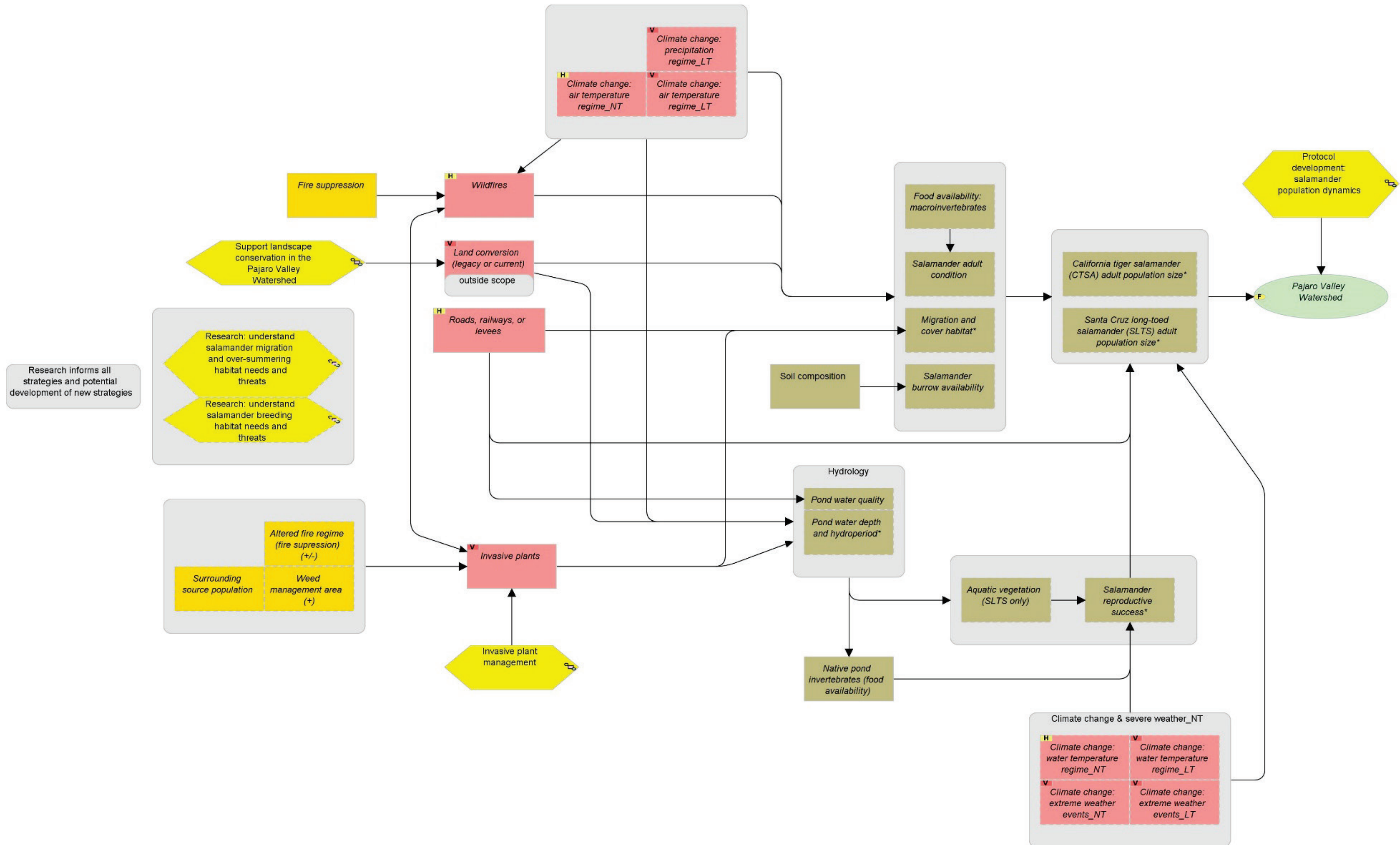


Figure 15. Conceptual model of the Pajaro Valley watershed.

Notes: Only Very High or High threats to the ecosystem are depicted here. Legend: green oval = natural resource conservation target; olive box = biophysical or human well-being attribute; pink box = direct threat; orange box = contributing factors; yellow hexagon = conservation strategy. The letters in the upper left portion of threats (pink boxes) represent the summary threat ranking across the seven refuges of the San Francisco National Wildlife Refuge Complex (L=low, M=moderate, H=high, VH=very high).

4.4.5 Conservation Strategies

Conservation strategies for Ellicott Slough NWR and the Pajaro Valley watershed are focused on reducing or mitigating the most critical threats. Threats addressed by each strategy and expected outcomes (objectives) are summarized in table 20. Each strategy is briefly described below in order of priority to implement. Results chains visually depicting the assumptions behind these strategies (how they work) and expected outcomes are presented in the Miradi file associated with this NRMP (appendix B).

Research: Understand Salamander Migration and Over-Summering Habitat Needs and Threats

Design and implement research at Ellicott Slough NWR to assess over-summering and migration corridor upland habitat requirements for SCLTS and CTS. Determine amphibian dependence on small mammal burrows. Results will be used to evaluate and adapt (if necessary) existing management strategies (fire, invasive plants, restoration) or inform new management strategies. Information gained from this research, along with better estimates of salamander population size and aquatic breeding habitat needs, will allow the Service to identify factors that are limiting salamander recruitment at each refuge unit and may have management implications for sensitive amphibian species recovery throughout the Pajaro Valley watershed.

Research: Understand Salamander Breeding Habitat Needs and Threats

Develop and implement research at Ellicott Slough NWR to better understand pond characteristics that influence SCLTS and CTS recruitment success (from egg to aquatic larvae to terrestrial metamorph). Factors include water quality, soil characteristics, predator populations, aquatic vegetation, and food availability. Information gained form this research will inform enhancement and restoration of refuge ponds or how to build new ponds (if deemed necessary).

Protocol Development: Salamander Population Dynamics

Develop a protocol to feasibly monitor status and trends in SCLTS and CTS population size, age structure, and sex ratios. Current salamander monitoring methods (dip-netting and night-time migration surveys) can provide general salamander trends but do not provide population estimates. Development of a monitoring protocol will be accomplished by through partnerships with salamander experts. Salamander population trends will better inform management of uplands and ponds at Ellicott Slough NWR and can inform management strategies in the larger watershed.

Support Landscape Conservation in the Pajaro Valley Watershed

Work with existing conservation partners and develop new partnerships to expand SCLTS and CTS recovery efforts throughout the Pajaro Valley watershed. This work encompasses activities aimed at increasing connectivity of salamander metapopulations through habitat restoration and acquisition, breeding pond enhancement and development, road projects (to create salamander pass-throughs). This work is critical to ensuring genetic exchange and long-term viability of salamander populations. Partners include the Resource Conservation District of Santa Cruz County, CDFW, The Land Trust of Santa Cruz County, the Trust for Public Land, the Open Space Alliance, and the California Landscape Conservation Cooperative. The role of Ellicott Slough NWR is to support partners in their efforts to protect and restore lands of the watershed.

Invasive Plant Management

Continue to implement activities at Ellicott Slough NWR aimed at reducing the abundance and distribution of invasive plant threats such as eucalyptus, jubata grass, pampas grass, and those identified by Santa Cruz County as priorities. Native upland and aquatic, emergent vegetation are essential to the survival of native plants and wildlife, including listed species such as SCLTS, CTS, and robust spineflower (*Chorizanthe robusta* var. *robusta*). Over 20 years of work have been put into removing eucalyptus and jubata grass at Ellicott Slough NWR.

This strategy also includes activities to refine and focus the integrated pest management approach at Ellicott Slough NWR by 1) identifying the most harmful invasive plant species (current and potential future); 2) assessing the status of priority invasive plant threats (inventory); 3) refining and documenting invasive plant management strategies (integrated pest management plan) using information from the baseline inventory, invasive plant ecology, and current science; and 4) implementing strategies, monitoring effectiveness of strategies, and adapting strategies as needed. Evaluation and documentation of the refuge invasive plant management strategy will be conducted using a standardized Refuge Complex–level approach and is discussed in more detail in section 3.6, "Management Strategies." This strategy is expected to benefit the Pajaro Valley watershed by preventing or reducing future harm to biodiversity caused by invasive plants as well as reducing the risk of wildfire.

Table 20. Ellicott Slough National Wildlife Refuge management strategies and associated objectives, in order of priority to implement over the next 5 years (2018–2022) to help conserve the Pajaro Valley watershed.

Strategy Title	*Threat Addressed*	*Expected Outcome (Objectives)*
Research: understand salamander breeding habitat needs and threats	All threats	PVW_O01. By 2022, a study design for assessing salamander (Santa Cruz long-toed salamander and California tiger salamander) upland habitat needs at Ellicott Slough NWR is completed. PVW_O02. Within 3 years of initiating the salamander upland habitat needs study, the Service understands salamander (Santa Cruz long-toed salamander and California tiger salamander) upland habitat needs and uses this information to review and refine its conservation strategies for upland habitat management at Ellicott Slough NWR.
Research: understand salamander breeding habitat needs and threats	All threats	PVW_O03. By 2020, the Service has secured funding to conduct a native salamander (Santa Cruz long-toed salamander and California tiger salamander) recruitment study at Ellicott Slough NWR. PVW_O04. Within 3 years of initiating the native salamander recruitment study, the Service understands (1) priority aquatic threats to salamanders, (2) aquatic habitat variables driving population recruitment, and (3) uses this information to review and refine management strategies at Ellicott Slough NWR.
Protocol development: salamander population dynamics	All threats	PVW_O05. By 2020, a feasible protocol for estimating Santa Cruz long-toed and California tiger salamander population size at Ellicott Slough NWR is completed.
Landscape conservation planning in the Pajaro Valley watershed	All threats	PVW_O06. Over the next 15 years (2018–2032), the Service is aware of seasonal pond, grassland, and oak woodland protection and restoration opportunities in the Pajaro Valley watershed and continues to support these efforts with conservation partners.
Invasive plant management	Invasive plants	PVW_O07. By 2023, eucalyptus trees with <14-inch diameter at breast height are eradicated from Ellicott Slough NWR.

4.4.6 Natural Resource Surveys

Natural resource surveys to assess the health of Pajaro Valley watershed health (goals) and effectiveness of refuge management strategies (objectives) are presented below (table 21). Surveys are listed in order of priority (USFWS 2019).

Table 21. Natural resource surveys to inform progress in achieving Pajaro Valley watershed goals and objectives (Ellicott Slough National Wildlife Refuge).

Survey Name	*PRIMR ID*	*Status*	*Survey Frequency*	*Goal or Objective Informed by Survey*	*Survey Coordinator*
Pond hydrology survey: Ellicott Slough NWR	FF08RELS00-007	Current	Annual	PRW_G03	USFWS, San Francisco Bay NWR Complex
Salamander population dynamics: Ellicott Slough NWR	FF08RELS00-009	Expected	Annual	PRW_G01	USFWS, San Francisco Bay NWR Complex
Landcover survey: woodland and grassland	FF08RELS00-010	Expected	Every 5 years	PRW_G04	USFWS, San Francisco Bay NWR Complex
Vegetation monitoring: Ellicott Slough NWR	FF08RELS00-006	Expected	Every 5 years	PRW_O07	USFWS, San Francisco Bay NWR Complex
Dip-net survey: special status amphibian species	FF08RELS00-005	Current	Annual	PRW_G02	USFWS, San Francisco Bay NWR Complex
Visual encounter survey: special status amphibian species	FF08RELS00-004	Current	Annual	PRW_G01*	USFWS, San Francisco Bay NWR Complex

Notes: Visual encounter survey will be replaced by salamander population dynamics once the survey is implemented.

For survey status, current = survey is currently implemented on the refuge; expected = survey will likely be implemented. For expected surveys, the survey frequency is an estimate and may change once a protocol is developed.

4.5 Riverine Sand Dune Ecosystem

Information sources used to describe the riverine dune ecosystem are presented below. Any other sources are cited in-text.

- *Antioch Dunes National Wildlife Refuge Climate Inventory and Summary* (USFWS 2015)
- *Antioch Dunes National Wildlife Refuge: Comprehensive Conservation Plan* (USFWS 2002)
- *Lange's Metalmark Butterfly, Antioch Dunes Evening Primrose, and Contra Costa Wallflower 5-year Review: Summary and Evaluation* (USFWS 2008)
- *Revised Recovery Plan for Three Endangered Species Endemic to Antioch, California* (USFWS 1984)
- *San Francisco Bay NWR Complex Climate Assessment* (CALCC et al. 2018)
- *Synthesis of Threats to Lange's Metalmark Butterfly at Antioch Dunes National Wildlife Refuge* (Campos et al. 2018)

4.5.1 Overview

The riverine sand dune ecosystem occurs at Antioch Dunes NWR. The refuge was established in 1980 to protect plants and insects federally listed as endangered: LMB, Contra Costa wallflower (*Erysimum capitatum* var. *capitatum*) (CCW), and Antioch Dunes evening primrose (*Oenothera deltoides* var. *howellii*) (ADEP). The refuge's riverine dune ecosystem is the only known location in the world where LMB is found. Once part of an extended riverine sand dune ecosystem, the dunes of the refuge hosted a variety of endemic plants and insects (USFWS 2002). During the last 150 years, the dune ecosystem was seriously degraded by sand mining (removal), invasive plants, and other threats (USFWS 1984). Today, the riverine sand dune ecosystem of the refuge represents one of the last remaining riverine sand dune environments in the Sacramento–San Joaquin Delta.

Nested Targets of the Riverine Sand Dune Ecosystem:

- Lange's metalmark butterfly (LMB)
- Contra Costa wallflower (CCW)
- Antioch Dunes evening primrose (ADEP)

The 55-acre refuge is located on the northern border of the city of Antioch in Contra Costa County, California, along the south shore of the San Joaquin River (figure 16). The scope of this NRMP also includes 12 acres owned by Pacific Gas and Electric and managed by the refuge under a cooperative agreement. The refuge encompasses an area that was once part of a larger expanse of riverine sand dunes. Several decades before the acquisition of the refuge, the Antioch Dunes covered approximately 500 acres. Heavy industrialization, sand mining, and urbanization led to >80% loss of the dune ecosystem. Today, only 60 acres of highly altered dunes remain and are located within the bounds of the refuge. Historic sand dunes surrounding the refuge are now occupied by industrial facilities and the Georgia-Pacific gypsum plant. Changes in land use on and off the refuge, including sand mining and agriculture, resulted in degradation or outright loss of sand dunes.

The goals, objectives, critical threats, management strategies, and surveys outlined here support and align with the *Recovery Plan for the Three Endangered Species Endemic to Antioch Dunes* (LMB, ADEP, and CCW) (USFWS 1984).

4.5.2 Ecology

The Antioch Dunes were once a large, ancient, aeolian (wind-blown) sand dune ecosystem extending along the southern bank of the San Joaquin River just east of the city of Antioch. According to a 1908 U.S. Geological Survey topographic map, the dunes occurred primarily along a 2-mile stretch of the San Joaquin River, averaged approximately one-sixth of a mile wide, and totaled roughly 190 acres. The aeolian sand at the refuge is contiguous with the sheer aeolian sand underlying much of the flat lands between the Mount Diablo foothills and the western margin of the Sacramento–San Joaquin Delta. Most of the exposed aeolian sand near Antioch accumulated between 10,000 and 40,000 years ago, during the late Pleistocene period.

Below is a brief overview of the vegetation and wildlife of the riverine sand dune ecosystem found on the refuge, with a focus on dune-associated species of greatest conservation concern. Additional details about the ecology of sand dunes and other natural resources of the refuge can be found in the *Antioch Dunes National Wildlife Refuge Comprehensive Conservation Plan* (USFWS 2002).

Lange's Metalmark Butterfly

The species of greatest conservation concern associated with the riverine dune ecosystem is LMB, which is federally listed as endangered. LMB was first discovered in 1933. In June 1976, this local subspecies was one of the first insects to be federally listed as endangered. Since 1953, LMB has only been documented within and immediately adjacent (within 150 meters) to the refuge, although the historical range may have included an area of dunes as far east as Oakley (8 kilometers east of the refuge) (Arnold and Powell 1983). Much of what is known about LMB biology and ecology came from early research by Richard A. Arnold and Jerry A. Powell from 1978 to 1986 (Arnold and Powell 1983; Arnold 1986). They provided the first known estimates of LMB population size (1977–1985), the period during which mining was ceased and the refuge was established (figure 17). Little is known about the size of the LMB population prior to sand mining. The primary factors limiting LMB population size is the availability of native plants used for reproduction and food (USFWS 1984)

Lange's metalmark butterfly (*Apodemia mormo langei*).
Credit: USFWS

The continued existence of this species is dependent upon the health of the riverine dune ecosystem because the entire lifecycle of the butterfly occurs here. The species relies upon sand dune–associated plant species such as naked stem buckwheat (*Eriogonum nudum* var. *psychicola*) for reproduction and food (nectar) plants including Douglas ragwort (*Senecio douglasii*), divergent snakeweed (*Gutierrezia divergens*), and California matchweed (*Gutierrezia californica*). The decline in the LMB population is due to a variety of factors that have either resulted in loss or degradation of the riverine sand dune ecosystem, such as legacy human uses (mining, agriculture), wildfire, invasive plants, climatic changes, and contaminants (figure 17).

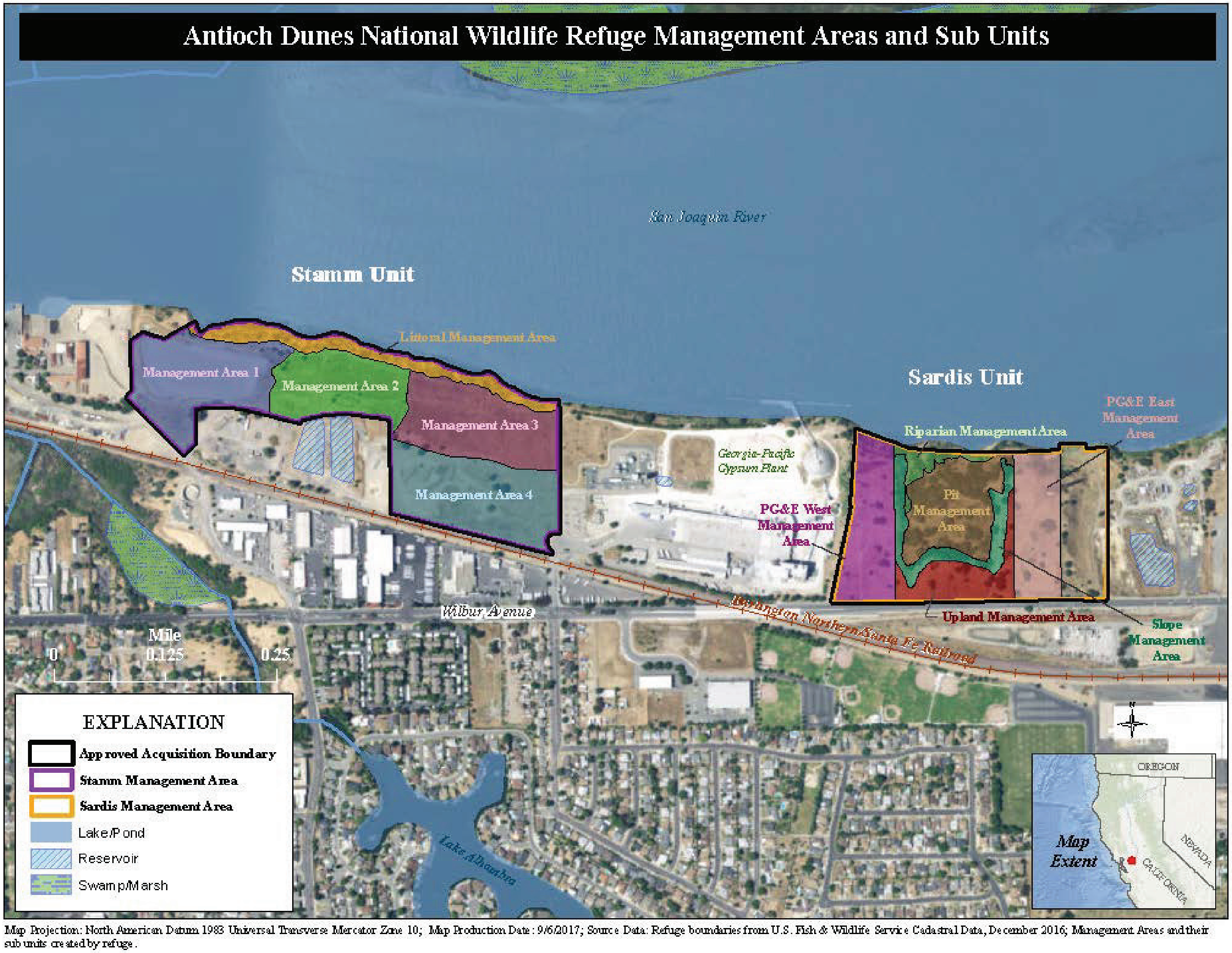


Figure 16. Geographic setting of Antioch Dunes National Wildlife Refuge, Contra Costa County, California.

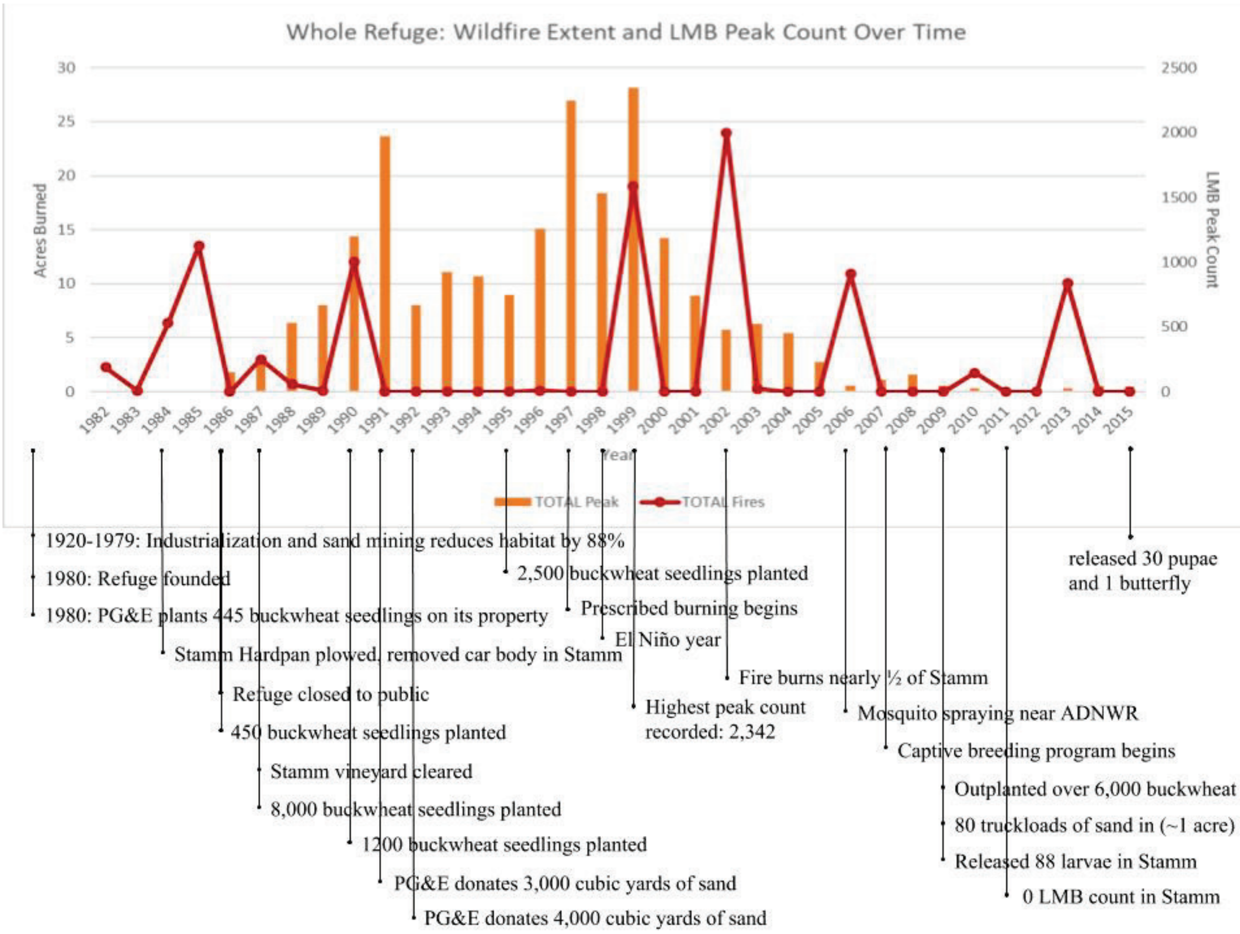


Figure 17. Timeline of events and trends in peak Lange's metalmark butterfly counts and fire at Antioch Dunes National Wildlife Refuge, 1982–2015.

Source: (Campos et al. 2018).

Vegetation

In the early 1900s, lands encompassed by the refuge were characterized as "rolling dunes with large open sand areas and scattered oaks" (Arnold and Powell 1983). Today, dominant vegetation communities of the refuge are characterized as littoral, riparian, and unique upland stands (Sawyer and Keeler-Wolf 1995, USFWS 2002):

- The unique upland stands, the current focus of conservation as part of the riverine sand dune ecosystem, consist of scattered forbs and grasses on stabilized or partially stabilized dunes.
- The littoral vegetation community bordering the San Joaquin River. This community hosts a state listed rare plant, Mason's lilaeopsis (*Lilaeopsis masonii*) as well as other several other rare plant species (USFWS 2002).
- The riparian vegetation community characterized by coast live oak, narrow-leaved willow (*Salix exigua*), arroyo willow (*Salix lasiolepis*), toyon (*Heteromeles arbutifolia*), and elderberry (*Sambucus mexicana*).

The highest proportion of native plant species on the refuge, including ADEP, CCW, and the butterfly's host plant, the naked stem buckwheat (*Eriogonum nudum* var. *psychicola*), are found in remnant dune areas of the refuge's Stamm Unit (USFWS 2002). A 2017 vegetation inventory showed dune-associated native plant species, including host, nectar, and perching plants for LMB were present throughout the refuge (Mathers and USFWS 2018). However, non-native herbs, grasses, shrubs, and trees dominate vegetation cover on refuge lands.

Antioch Dunes Evening Primrose

Federally listed as endangered, ADEP is associated with the riverine sand dune ecosystem. The largest known population of this species occurs on the refuge. ADEP prefers sandy to sandy-loamy, well-drained, and weed-free soil. Ground disturbance appears to benefit the species, especially to reduce competition with weeds. Dick Arnold (pers. comm. 1999) believes that bees are the primary pollinators, but ADEP may need a diverse variety of pollinators. As of 2017, ADEP occurs in both the Stamm and Sardis Units of the refuge and occupies approximately 0.14 acre (Mathers and USFWS 2018).

Antioch Dunes evening primrose (*Oenothera deltoides ssp. howellii*). Credit: USFWS

Contra Costa Wallflower

CCW is federally listed as endangered species and is endemic to the riverine dune habitat found within and immediately adjacent to the refuge (USFWS 2008). Like ADEP, the wallflower prefers sandy to sandy-loamy, well-drained, and weed-free soil. Ground disturbance appears to benefit the species, especially to reduce competition with weeds. Wind is important for seed dispersal, and pollinators are not thought to be species-specific although little is known about the invertebrates that pollinate this plant. Vegetation surveys conducted in 2017 estimate wallflower coverage on the refuge at 0.13 acre (Mathers and USFWS 2018).

Contra Costa wallflower (*Erysimum capitatum var. angustatum*). Credit: USFWS

4.5.3 Target Status, Trends, and Goals

Two KEAs and associated indicators (N=3) were chosen to represent the biodiversity and health of the riverine sand dune ecosystem: (1) sand dune vegetation cover and composition and (2) LMB population size. Based on the best available information about the status of these KEAs and their associated indicators, the health of the riverine dune ecosystem at the refuge is considered Poor. The relationship between indicator measures and the overall health of the riverine sand dune ecosystem is detailed in the Refuge Complex conservation target viability database (appendix B). The database contains scales used to assess target status in terms of indicator measures.

KEA 1: Sand Dune Vegetation Cover and Composition

Sand dune vegetation cover and composition is indicated by 1) percent cover open sand (non-vegetated) and 2) percent cover desirable native plant species (dune-associated and beneficial to LMB). Understanding the status and trends of dune vegetation is important because changes in vegetation cover and composition have a strong influence on the biodiversity of the sand dunes. For example, LMB relies on several dune-adapted species for reproduction and food. This includes the LMB host plant, naked stem buckwheat, as well as LMB nectar plants such as Douglas ragwort, divergent snakeweed, and California matchweed. A healthy dune-associated plant community depends on ecological processes such as sand dune formation and movement. Without such processes, the health and continued existence of dune plants and wildlife are at risk. Lastly, it is important to understand the status and trends of endangered species such as ADEP and CCW. Results from a 2017 vegetation inventory of the refuge (Mathers and USFWS 2018) showed the following:

- The estimated proportion of bare ground on the refuge is <20%. It is unknown what proportion of bare ground is dominated by sand. This value is well below what is desired on the refuge (>40% open sand, non-vegetated).
- Native dune-associated plant species comprise approximately 5.8 acres or 8.2% of the land cover on the refuge.
- LMB nectar and perching plant species are concentrated on the higher elevation PG&E parcels of the Sardis Unit, where there is limited cover of coast live oak (*Quercus agrifolia*) and non-native trees. In the Stamm Unit, nectar plants were denser in the western portion of the unit, where recent sand deposition appeared to stimulate the growth of telegraph weed (*Heterotheca grandiflora*).
- The largest zones supporting a combination of dense cover of buckwheat, nectar, and perching plants are the eastern portion of Stamm Management Area 2, the western portion of Stamm Management Area 3, and the PG&E Eastern Management Area of the Sardis Unit.

Based on the 2017 inventory, status of sand dune vegetation cover and composition is Poor (Poor defined as <20% open sand [>80% vegetated] and ≤20% cover desirable species) (table 22).

KEA 2: Lange's Metalmark Butterfly Population Size

Population size for LMB was selected as a KEA of the riverine sand dune ecosystem because the continued existence of the species is dependent, in part, on the health and integrity of the riverine dune ecosystem. The entire lifecycle of the butterfly occurs only in the remnant dunes found on the refuge. LMB relies on dune-associated plant species to survive, such as naked stem buckwheat and other nectar plants (USFWS 2002). It is unknown whether a small LMB population size is creating a genetic bottleneck and limiting the ability of the species to recover, even if many components of the ecosystem are restored.

Annual 1-day refuge peak count of adult LMB is used as an annual index of the relative size of the population. Surveys are initiated each year when butterflies emerge, are then conducted weekly, and conclude when counts reach zero. The *refuge peak count* (peak count) is defined as the highest number of butterflies counted on the refuge during a single week. Annual monitoring of LMB peak count by the USFWS began in 1985. Peak counts of LMB reached a high of 1,200 to 2,300 in the late 1990s but has not exceeded 50 butterflies since 2009 (USFWS 2017). No butterflies have been observed on the Stamm Unit since 2010. The current status of the LMB population is Poor (a peak LMB count <150), with the most recent peak count in 2016 yielding 24 butterflies observed (USFWS 2017) (table 22).

Small populations of organisms such as LMB are at a greater risk of extinction because they are subject to inbreeding (mating between closely related individuals) and subsequent a loss of genetic diversity (USFWS 2008). A more extensive discussion of genetic issues and minimum effective population size needed to protect LMB from extinction is presented in the *Lange's Metalmark Butterfly, Antioch Dunes Evening Primrose, and Contra Costa Wallflower 5-year Review* (USFWS 2008).

Table 22. Current status and desired future state (goals) of the riverine dune ecosystem at Antioch Dunes National Wildlife Refuge in terms of key ecological attributes and indicators.

Key Ecological Attribute	*Indicator*	*Status: Measure (Trend)*	*Status Source*	*Goal*
Sand dune vegetation cover and composition	% cover open sand (non-vegetated)	Poor: Stamm Unit = 23.4% bare ground, Sardis Unit = 11.4% bare ground[2] (decreasing)	Mathers and USFWS (2018)	RDE_G01. By FY 2028, the Stamm Unit of Antioch Dunes NWR contains at least 30% open sand (or <70% vegetated) and at least 46% of the vegetative cover comprises native dune-associated plant species (Arnold and Powell 1983, Mathers and USFWS 2018). RDE_G02. By FY 2031, the Sardis Unit of Antioch Dunes NWR contains at least 20% open sand (<80% vegetated) and at least 21% of the vegetative cover comprises native dune-associated plant species (Arnold and Powell 1983, Mathers and USFWS 2018).
Sand dune vegetation cover and composition	% cover native desirable plant species (beneficial to Lange's metalmark butterfly)	Poor: Stamm Unit = 8.5% sand dune native plants, Sardis Unit = 8.1% sand dune native plants[2] (decreasing)	Mathers and USFWS (2018)	See above: RDE_G01, RDE_G02
Lange's metalmark butterfly population size	Lange's metalmark butterfly annual refuge peak count	Poor: Sardis Unit = 24, Stamm Unit = 0 (decreasing)	USFWS (2017)	RDE_G03. By 2031, Lange's metalmark butterfly is re-established in the Stamm Unit (species is present for 3 consecutive years through natural recruitment) and the annual refuge peak count is ≥151 individuals over 3 consecutive years at Antioch Dunes NWR.

4.5.4 Critical Threats

A variety of human-induced threats cause stress to the riverine dune ecosystem. The most critical threats (classified as High or Very High threats) are climate change, land conversion (historic sand mining), invasive plants, wildfire (figure 18), and mosquito control pesticides. Medium or Low threats include refuge management activities (includes monitoring and research), gypsum deposition, poaching, and disease. A conceptual model depicting threats to the marine island ecosystem, relationships with biophysical factors of the ecosystem, and strategies aimed at reducing the most critical threats is depicted in figure 19. The most critical threats (High to Very High) to the riverine dune ecosystem are summarized below.

Land Conversion (Very High Threat)

Mining of sand for brickmaking occurred on lands encompassed by the refuge area as early as the late 19th century and continued until the 1970s (USFWS 2002). Though discontinued, mining significantly altered dune topography and sand dune formation processes, resulting in changes in the native dune plant community and subsequent declines in dune-associated wildlife such as LMB. Further, much of the pure sand was removed, forever altering the soil composition of the dunes. Today, the last remnants of the dunes are surrounded by a former shipyard, a gypsum plant, and a former sewage treatment plant and vary from 0 to 50 feet high (USFWS 2002). The conversion of historic dunes on neighboring sites into industrial facilities removes the potential for sand migration from other sources.

Invasive Plants (Very High Threat)

Invasive plants are noted in the earliest refuge annual narratives (1981–1982) as "diluting the refuge" and altering "the physical and chemical nature of the sand." In the late 1990s, refuge LMB survey reports suggest the decline in the LMB population may be related to the encroachment of invasive plants such as tree of heaven (*Ailanthus altissima*), black locust (*Robinia pseudoacacia*), yellow star-thistle (*Centaurea solstitialis*), and rip-gut brome (*Bromus diandus*) (Fernandez 1997, Slowick 1998). These species, along with winter vetch (*Vicia villosa*) and Russian thistle (*Salsola tragus*), continue to be a problem today. In 2006, LMB experts (Jerry Powell, University of California, Berkeley; Travis Longcore, The Urban Wildlands Group) visited the refuge to assess LMB habitat conditions. Both suggested LMB population declines were likely due, in large part, to invasive grasses and other invasive plants that suppress native plants, particularly by winter vetch (USFWS 2008).

Stress caused to the riverine dune ecosystem as a result of invasive plants include:

- Stabilization of sand dunes. Colonization and spread of non-native plants (such as annual grasses) increase the vegetative cover of sand dunes and reduce the natural process of sand dune movement and formation, a process which many sand dune–associated plant species depend on (such as ADEP, buckwheat, and CCW)
- Increased fire frequency. Invasive plants provide fuel for wildfires; as a result, they can increase the frequency and intensity of wildfires and can lead to mortality of native plant species or wildlife not adapted to fire.
- Sand dune nutrient enrichment. Invasive plants, especially those which fix nitrogen such as vetch, add nutrients to sand dunes, which are typically low in nutrients. This enrichment can provide resources for further establishment and spread of invasive plants. Pickart et al. (1998) studied the ecological effects of introduced yellow bush lupine on coastal sand dunes and concluded that the invasion of this species resulted in both direct soil enrichment and indirect soil enrichment as a result of the associated encroachment of other non-native species, particularly grasses. Lupine directly resulted in soil enrichment, particularly of ammonium, during both growth and decay.

Factors that contribute positively (+) or negatively (-) to the invasive plant threat include:

- Neighboring seed sources (-). Lands adjacent to the refuge, such as the neighboring city property used as a way station for fill removed from other city properties, harbor uncontrolled populations of invasive plants and act as a source for new infestations.
- Human and animal vectors (-). Visitors to the refuge, including refuge staff, can serve as vectors and result in new introductions or continued spread of invasive plants.
- Propagule bank (-). In some cases, propagules (such as seeds) of invasive plants can remain in the environment for long periods of time (years) and can act as a source for re-establishment following control efforts or disturbance events such as fire or active sand movement.
- Refuge management (-). Refuge management activities can result in introduction and spread of invasive plants via tools, vehicles, and restoration planting materials.
- Roads, railways (-). Adjacent roads and a train track serve as pathways to spread seed through the refuge's chainlink fence.
- Nitrogen deposition (-). Nitrogen is deposited into the soil from the nearby power plants and generally from human activities including motor vehicles, electric utilities, and industrial boilers. Nitrogen deposition into the soil can negatively affect native and endangered plants that require low soil nitrogen to survive/thrive, including the host plant for the endangered butterfly. Nitrogen deposited into these typically nutrient-poor soils also make it hospitable

for invasive plants to thrive and outcompete native vegetation. Further, invasive vegetation can also fix nitrogen into sand.

Climate Change (High to Very High Threat)

Global climatic changes can result in changes to climate in the Antioch Dunes NWR area and result in stress to the riverine sand dune ecosystem. Climatic factors of particular concern include alteration of temperature and precipitation regimes and extreme events (heat waves, drought). Increases in air temperatures, extreme events (such as drought), and changes in precipitation patterns may stress the riverine dunes ecosystem directly or exacerbate other threats such as invasive species and wildfire. Warmer air and soil temperatures (especially in winter), changes in precipitation, and an earlier spring transition of weather and ocean patterns have been shown to result in changes in phenological processes in plants and insects, potentially causing the temporal decoupling of conditions important for survival of species such as LMB; these include insect reproductive events mistimed with peak food availability (driven by plants). Furthermore, more frequent and prolonged drought and periods of extreme heat could cause direct mortality or prevent or delay germination of plants and impact insect life cycles. Increased aridity or changes in precipitation patterns may favor different plant species, annual or biennial versus perennial reproductive cycles, increased hybridization, changes in arthropod herbivory, and vernalization (the process of cold winter soil temperatures signaling some species' seeds to germinate).

Wildfires (High Threat)

Historically, fire would not have been part of the riverine sand dune ecosystem because of the sparse distribution of vegetation. Today, the high density of vegetation such as annual grasses results in high fire risk.

Wildfires have likely contributed to the continued decline in LMB populations on the refuge and may have resulted in the extirpation of this species from the Stamm Unit (figure 18). From 1997 to 2002, a total of 92 acres in Stamm burned due to a combination of wildfires (43 acres) and prescribed fires (49 acres). Prescribed burns have been used to control invasive plants in the late 1990s and early 2000s. In May 1999, wildfire burned 18 acres of the Stamm Unit, including areas containing LMB habitat. The Stamm LMB peak count never recovered to pre-1999 levels. The largest recorded wildfire on the refuge occurred in 2002, burning 24 acres of Stamm, accounting for nearly half of the unit. The LMB peak count subsequently fell in 2002. A slight recovery occurred the year after, but the population continued to decline. After the 10.9-acre fire in 2006, the LMB peak count never rose above 10; starting in 2011, peak count has stayed at 0 in the Stamm Unit. In June 2013, a wildfire burned another 10.1 acres of the Stamm Unit, including area suitable for LMB.

Factors that may reduce (+) or contribute to (-) to the wildfire threat include:

- Invasive plants (-). Wildfires are exacerbated by the presence of invasive plants such as annual grasses.
- Illegal activities by humans (-). Sparks or smoking from cars parked (loitering) at a pullout on the boundary of the refuge, and trespassers starting illegal campfires on the refuge, have likely contributed to wildfires on the refuge.
- Insufficient law enforcement (-). Limited budget and law enforcement hampers ability to provide regular presence on this refuge to deter trespassing and related risk of wildfires.

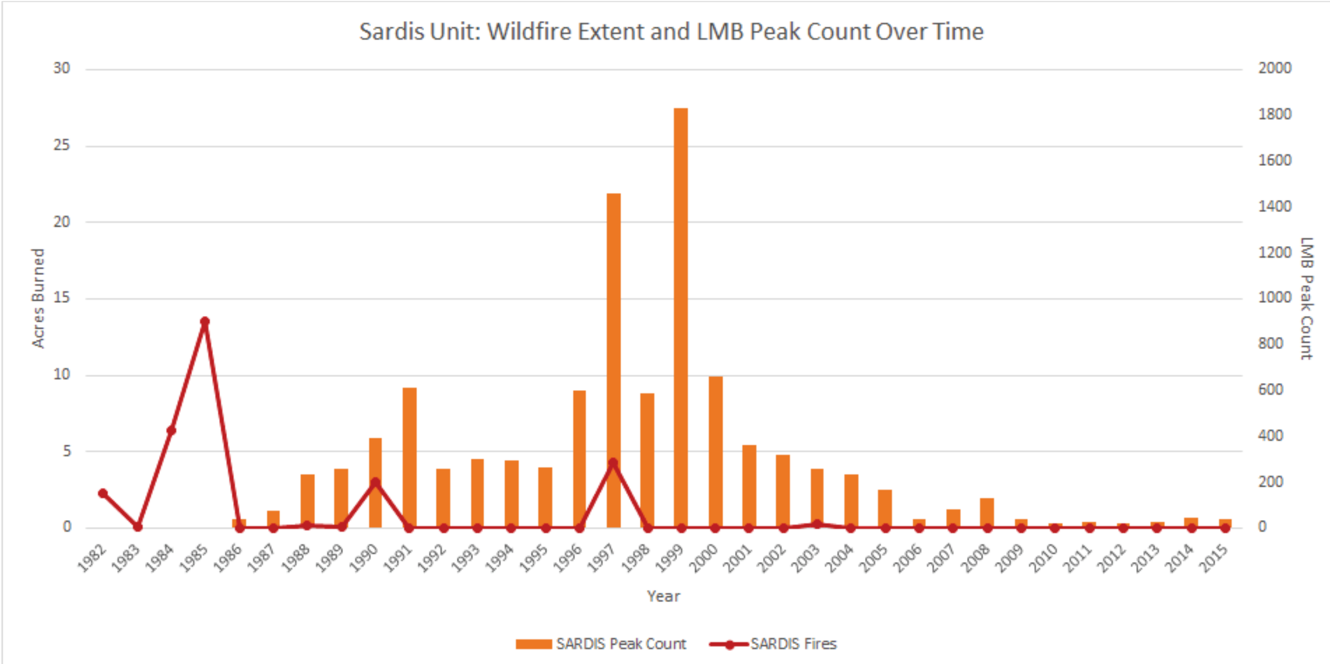
Mosquito Control Pesticides (High Threat)

The Contra Costa Mosquito and Vector Control District uses a variety of methods, including application of insecticides (such as adulticides), to reduce mosquito populations and protect human health (from mosquito–borne disease such as West Nile virus). Although no application of mosquito adulticides have occurred on the refuge, there is concern that use of adulticides to kill adult mosquitos on lands adjacent to the refuge may inadvertently harm LMB. Mosquito adulticides may cause LMB mortality directly, through uptake of nectar or pollen exposed to adulticides, or through LMB's contact with or feeding on treated foliage or flowers (Thompson 2001). Oberhauser et al.

(2009) have also shown increased mortality of monarch butterflies downwind of spray path. Oberhauser et al. (2009) showed that exposure to field application doses of resmethrin (a type of synthetic pyrethroid/adulticide) resulted in monarch butterfly larval mortality that was higher than control mortality up to 120 meters downwind of the spray path. These studies and adjacency of mosquito control activities to the refuge suggest there is some risk of harm to LMB via exposure to adulticides.

Factors that contribute positively (+) or negatively (-) to the mosquito control pesticide threat include:

- Nearby waterway (-). A stagnant waterway adjacent to the refuge results in breed mosquitoes and increases the likelihood of mosquito control activities involving application of pesticides.



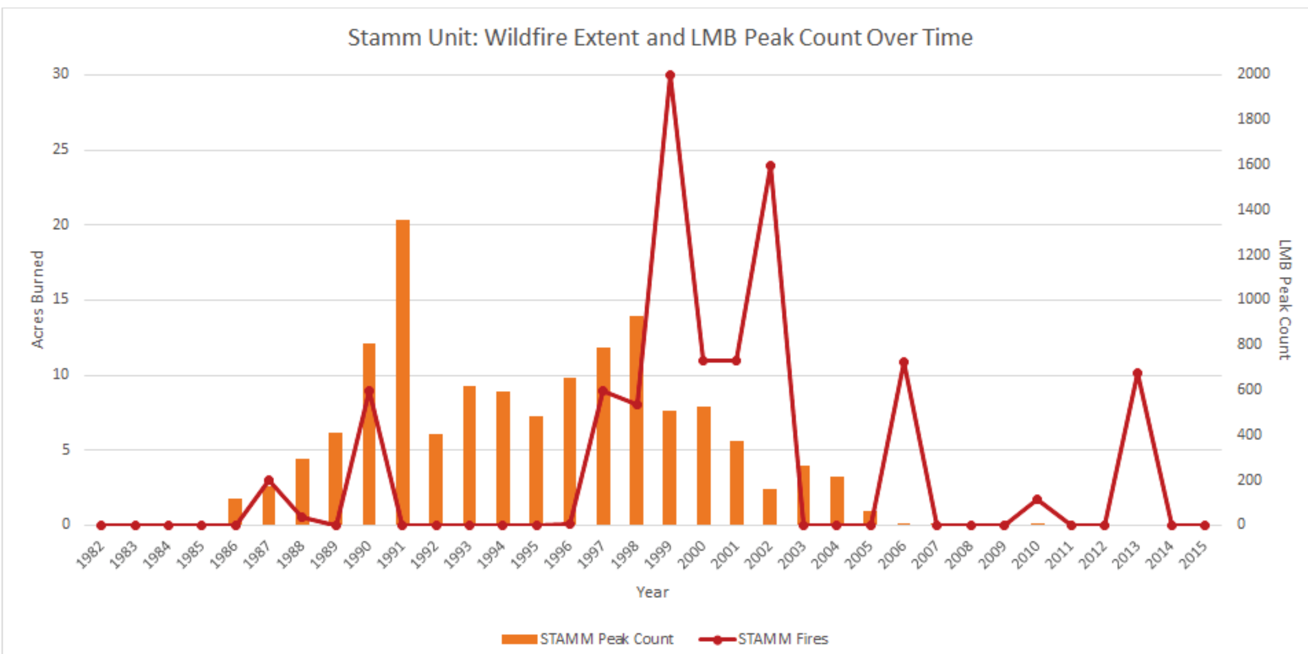


Figure 18. Acres burned by fire (red line) and LMB peak counts (orange bars) over time in the Sardis and Stamm Units.

Notes: The Sardis counts are a total of the Sardis Pit, PG&E West, and PG&E East subunits.

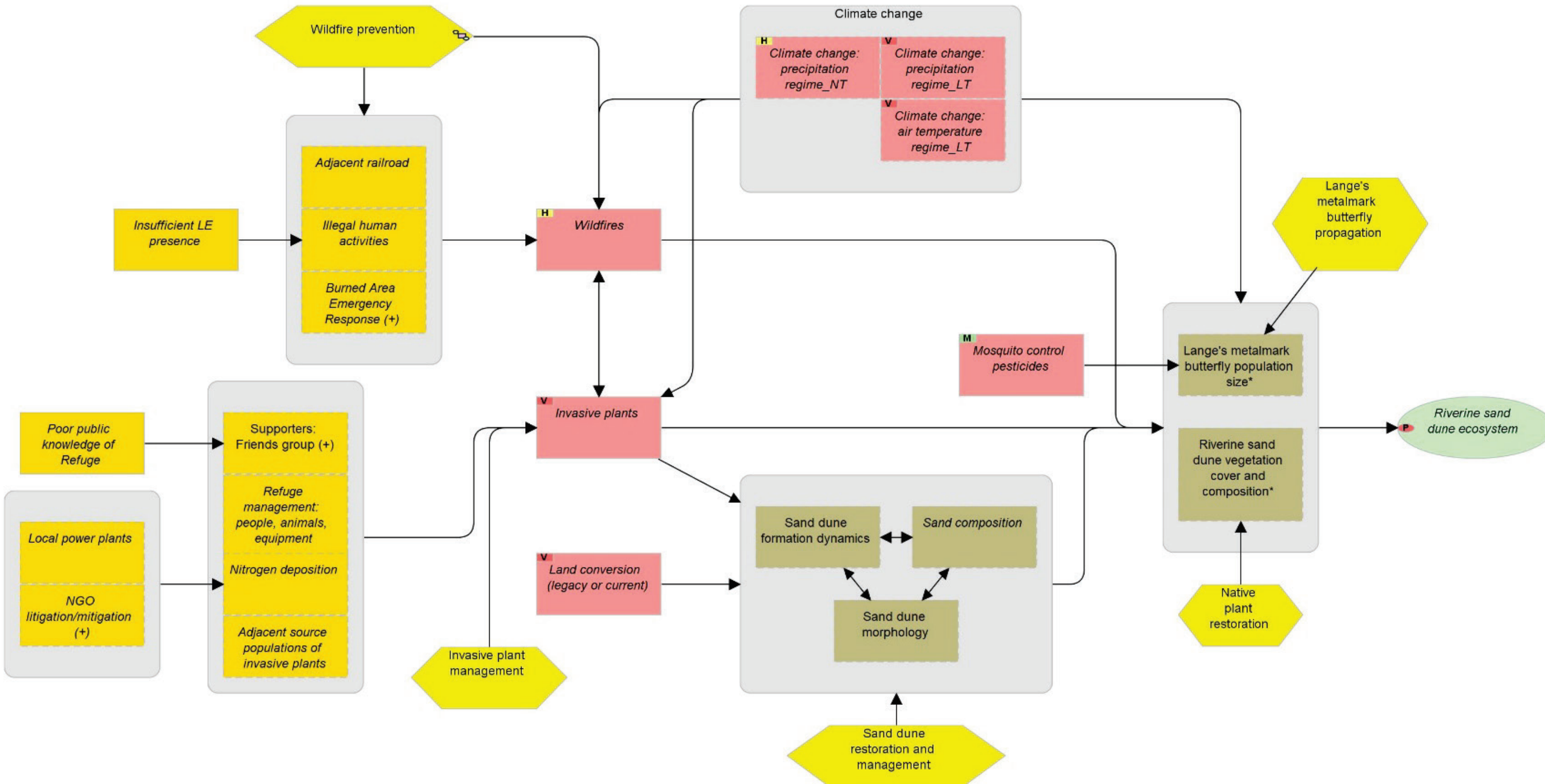


Figure 19. Conceptual model of the riverine dune ecosystem at Antioch Dunes National Wildlife Refuge.

Notes: Only Very High or High threats to the ecosystem are depicted here. Legend: green oval = natural resource conservation target; olive box = biophysical or human well-being attribute; pink box = direct threat; orange box = contributing factors; yellow hexagon = conservation strategy. The letters in the upper left portion of threats (pink boxes) represent the summary threat ranking across the seven refuges of the San Francisco National Wildlife Refuge Complex (L=low, M=moderate, H=high, VH=very high).

4.5.5 Conservation Strategies

Conservation strategies for the riverine dune ecosystem are focused on reducing or mitigating the most critical threats of climate change, land conversion, invasive plants, and wildfire. No formal strategies were developed for mosquito control pesticides, but the refuge will continue to coordinate with the local mosquito abatement districts. Threats addressed by each strategy and expected outcomes (objectives) are summarized in table 23. Each strategy is briefly described below and presented in order of management priority. Results chains visually depicting the assumptions behind these strategies and expected outcomes are presented in the Miradi file associated with this NRMP (appendix B).

Sand Dune Restoration and Management

This strategy is aimed at developing and implementing an action plan to restore the dune ecosystem on the Stamm Unit through active placement of dredged sand and restoration of the native dune plant community. Once adequate amounts of sand are received, active management of the sand will occur to mimic dune formation and movement. This strategy addresses the historical loss of sand dunes as a result of sand mining and will help reduce the threat of invasive plants and wildfire.

Activities include conducting a literature review to inform restoration of the sand dunes (such as optimal sand dune depth and topography) and to inform native plant restoration and development of the sand dune restoration plan. Plan components will include communication with partners and the public, site preparation, sand delivery and management, native plant restoration (optimal methods to be determined, such as passive restoration, seeding, or out-planting), and reintroducing LMB. Deposition of sand over the entire unit is expected to create an open sand environment favorable to dune-adapted native plants, the nested target species, and the naked stem buckwheat, which is host plant to LMB.

Lange's Metalmark Butterfly Propagation

The recovery plan for LMB, ADEP, and CCW (USFWS 1984) recommended that controlled rearing of LMB should be performed to safeguard against extinction, especially following severe population declines in 2006–2007. A captive propagation program for LMB began in 2007 and is expected to continue. This strategy involves the permitting, management and coordination between refuge staff, the USFWS Endangered Species Division and conservation contractors. Wild egg-bearing female butterflies are captured by an entomologist at the Sardis Unit of refuge to propagate pupae at an offsite facility to be released back on the refuge. Although the intent of this strategy is to augment the LMB population, it is unknown whether released individuals actually survive. Therefore, survey methods must be developed to determine effectiveness of this strategy.

Invasive Plant Management

This strategy, in concert with other refuge management strategies, is focused on preventing, containing, and suppressing invasive plants that harm the riverine dune ecosystem. In the short-term, this includes 1) assessing the status of invasive and native dune plants on the refuge (inventory), 2) conducting a literature review of priority invasive plants to understand the best available methods of prevention and control, and 3) continue priority invasive plant treatment activities until a comprehensive strategy is developed. Results from the inventory will then be used to refine what, when, where, and how invasive plant management should be implemented on the refuge. The inventory will also serve as a baseline for evaluating outcomes, learning, and adapting. The literature review will ultimately inform development of an invasive plant management strategy (activities laid out in the Refuge Complex invasive plant management strategy). If implemented as planned, the refuges' invasive plant management strategy is expected to result in a reduction of vegetative cover and extent of harmful invasive plants. If successful, this will also reduce the risk of wildfires.

Native Plant Restoration

This strategy is focused on active restoration of ADEP, CCW, and naked stem buckwheat. Seeds for these three plants would be collected from the refuge; naked stem buckwheat would be propagated annually. ADEP and CCW seeds will be collected annually for later propagation and outplanting. Seed collection would also be conducted for seed banking in the event of a catastrophic event (e.g., fire). At this time all planting would occur at the Sardis Unit only, since the Stamm Unit is undergoing sand augmentation. These activities will continue until the native plant restoration portion of the sand dune restoration plan (see above) is completed. At that time, activities aimed at restoring native plants, such as direct seeding, may change. These activities are expected to increase the distribution and abundance of ADEP, buckwheat, and CCW in the Sardis Unit.

Wildfire Prevention

This strategy is focused on updating and implementing a fire management plan for the refuge. The plan will lay out specific activities (what, when, where, how) to reduce threat of wildfires in the riverine dune ecosystem. A variety of methods will continue to be used, such as mowing, scraping, and treatment with herbicide to maintain fuel breaks between roads and rail lines passing by the Sardis and Stamm Units. Other fire management activities may be identified through assessing refuge fire history and consulting with fire experts. Sand dune restoration and invasive plant management are also expected to reduce fire incidence on the refuge.

Table 23. Antioch Dunes National Wildlife Refuge management strategies and associated objectives, in order of priority to implement over the next 5 years (2018–2022) to help conserve the riverine dune ecosystem.

Strategy Title	*Threat Addressed*	*Expected Outcome (Objective)*
Sand dune restoration and management	Land conversion (legacy)	RDE_O01. By 2019, a long-term sand dune restoration and management plan is completed for the Stamm Unit of Antioch Dunes NWR. RDE_O02. Over the next 15 years (2018–2032), invasive plants occupy <5% of the landcover where sand placement has occurred in the Stamm Unit of Antioch Dunes NWR. RDE_O03. Contra Costa wallflower and Antioch Dunes evening primrose occupy ≥20% of the vegetative cover and naked stem buckwheat composes at least 20% of the vegetative cover at the Stamm Unit once desired sand depths are attained in dune restoration areas (per Antioch Dunes NWR sand dune management plan). RDE_O04. Naturally occurring Lange's metalmark butterfly larvae are documented in dune restoration areas of the Stamm Unit of Antioch Dunes NWR within 5 years of attaining desired sand depths (per Antioch Dunes NWR sand dune management plan).
Lange's metalmark butterfly propagation	Mitigates all threats by directly restoring target	RDE_O05. Over the next 15 years (2018–2032), the number of Lange's metalmark butterfly pupae and adults propagated for Antioch Dunes NWR is ≥20 per field-collected female. RDE_O06. Over the next 5 years (2018–2022), ≥80% of propagated Lange's metalmark butterfly pupae eclose (hatch) following release at Antioch Dunes NWR. RDE_O07. Refuge staff maintain USFWS 10(a)(1)(A) permit for the Lange's metalmark butterfly propagation program, including capture, propagation, transfers, releases, data management, and annual reporting.

Strategy Title	*Threat Addressed*	*Expected Outcome (Objective)*
Invasive plant management	Invasive plants	RDE_O08. By FY 2019, an Antioch Dunes NWR integrated pest management plan is complete and implementation has begun. The plan identifies priority invasive weeds for control, optimal strategies, and associated SMART objectives. RDE_O09. By 2033, cover of ripgut brome, vetch, yellow starthistle, and Russian thistle is reduced by at least 50% and Himalayan blackberry is reduced by at least 80% (baseline = 2017 inventory) at the Stamm Unit of Antioch Dunes NWR. RDE_O10. By 2033, cover of tree of heaven is reduced by 75% (baseline = 2017 inventory) at the Sardis and PG&E West Units of Antioch Dunes NWR. RDE_O11. By 2033, oak cover is <20% at the Sardis Unit of Antioch Dunes NWR.
Native plant restoration	Mitigates all threats by directly restoring target	See objectives for *Sand dune restoration and management.*
Wildfire prevention	Wildfires	RDE_O12. Over the next 15 years (2018–2032), the number of wildfires at Antioch Dunes NWR is <6 or the average number of fires per year is <0.4 (0.80 wildfire per year for the period 1980–2013) and <20 acres are burned (105 acres burned for the period 1980–2013).

4.5.6 Natural Resource Surveys

Natural resource surveys to assess the health of the riverine dune ecosystem health (goals) and effectiveness of refuge management strategies (objectives) are presented below (table 24). Surveys are listed in order of priority (USFWS 2019).

Table 24. Natural resource surveys to inform progress in achieving riverine dune ecosystem goals and objectives (Antioch Dunes National Wildlife Refuge).

Survey Name	*PRIMR ID*	*Status*	*Survey Frequency*	*Goal or Objective Informed by Survey*	*Survey Lead*
Vegetation monitoring: Antioch Dunes NWR	FF08RATD00-006	Expected	Every 5 years	RDE_G01, RDE_G02 RDE_O02, RDE_O03, RDE_O09, RDE_O10, RDE_O11	USFWS, San Francisco Bay NWR Complex
Lange's metalmark butterfly survey	FF08RATD00-002	Current	Annual	RDE_G03, RDE_O04	USFWS, San Francisco Bay NWR Complex
Lange's metalmark pupae release success survey	FF08RATD00-012	Expected	Annual	RDE_O06	USFWS, San Francisco Bay NWR Complex

Note: As of 2018, the vegetation monitoring survey will replace annual surveys focused on Contra Costa wallflower and Antioch Dunes evening primrose. The survey now encompasses all plant species, including non-native plant species.

For survey status, current = survey is currently implemented on the refuge; expected = survey will likely be implemented. For expected surveys, the survey frequency is an estimate and may change once a protocol is developed.

4.6 Tidal Marsh Ecosystem

Primary information sources used to describe the tidal marsh ecosystem are presented below. Any other sources are cited in-text.

- *Baylands Ecosystem Habitat Goals* (Goals Project 2000)
- *Don Edwards San Francisco Bay National Wildlife Refuge Final Comprehensive Conservation Plan and Environmental Assessment* (USFWS 2012)
- *Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California* (USFWS 2013)
- *San Francisco Bay NWR Complex Climate Assessment* (CALCC et al. 2018)
- *San Pablo Bay National Wildlife Refuge Climate Adaptation Plan* (Veloz et al. 2016)
- *San Pablo Bay National Wildlife Refuge Final Comprehensive Conservation Plan and Environmental Assessment* (USFWS 2011)
- *Site-specific Protocol for Monitoring Marsh Birds: Don Edwards San Francisco Bay and San Pablo Bay National Wildlife Refuges* (Wood et al. 2017)
- *The Baylands and Climate Change: What We Can Do. Baylands Ecosystem Habitat Goals Science Update 2015* (Goals Project 2015)

4.6.1 Overview

Nested Targets of the Tidal Marsh Ecosystem:

- Ridgway's rail (RIRA)
- Salt marsh harvest mouse (SMHM)
- Marsh zones: upland transition, low marsh, mid-marsh high marsh
- Native tidal marsh songbirds (common yellowthroat, song sparrow), plants, and fish
- Harbor seal

The tidal marsh ecosystem occurs at two refuges in Refuge Complex: San Pablo Bay NWR and Don Edwards San Francisco Bay NWR (figures 20 and 21). These refuges were established, in part, to conserve and protect migratory birds and species federally listed as endangered and associated with the larger Estuary. The Estuary is one of the largest estuaries along the Pacific Coast (Takekawa et al. 2013). It provides essential migrating and wintering habitat for over a million waterbirds (shorebirds, waterfowl) each year to overwinter or to refuel during their migration along the Pacific Flyway. Tidal marsh of the Estuary also provides year-round habitat for a variety of tidal marsh–dependent species such as the RIRA and SMHM, which are federally listed as endangered.

San Pablo Bay NWR occurs along the north shore of San Pablo Bay in Sonoma, Solano, and Napa Counties. The refuge supports one of the largest contiguous expanses of tidal marsh in the Estuary (Takekawa et al. 2013) and provides habitat for federally and state-listed species, such as the salt marsh harvest mouse (*Reithrodontomys raviventris*), the California black rail (*Laterallus jamaicensis*), and RIRA. The refuge also provides critical migratory and wintering habitat for waterfowl and shorebirds. Unlike many parts of the Estuary, the refuge is surrounded by open space, including wetlands owned and managed by CDFW. Don Edwards San Francisco Bay NWR is situated in the San Francisco Bay, in the southern part of the Estuary. Like San Pablo Bay, the refuge encompasses tidal marsh and other estuarine environments which support a wide variety of estuarine dependent species, including SMHM and RIRA, as well as wintering and migratory waterbirds. Don Edwards San Francisco Bay NWR differs from San Pablo Bay NWR in several ways but most notable is the presence of former salt ponds that support breeding populations of waterbirds such as the SNPL and tern species. Don Edwards San

Francisco Bay NWR also lies adjacent to other protected lands but, unlike San Pablo Bay NWR, human developments surround much of the protected estuarine lands. This fact creates many additional pressures on the refuges' wildlife and plant populations (such as increased predation pressure and disturbance).

Human activities have negatively altered and dramatically reduced the tidal marsh ecosystem throughout the Estuary, decreasing its quantity and quality. It is estimated that 190,000 acres of tidal marsh occurred in the Estuary in the mid-1800s and before substantial impacts from European settlers began around the Gold Rush (mid-1800s; Goals Project 1999, 2015). Approximately 80% of the Estuary's tidal marsh was subsequently converted to agricultural fields, pasture, salt production ponds, duck clubs, and urban and commercial development (USFWS 2013). Over the last several decades, efforts to enhance or restore historic tidal marsh have led to a partial recovery of tidal marsh in the Estuary, including efforts within the Refuge Complex. Today, approximately 45,000 acres of tidal marsh occur in the Estuary, approximately 25% of which are found in the Refuge Complex.

In addition to supporting a unique biological community, the tidal marsh ecosystem provides humans with many benefits, including flood protection for homes and businesses, filtration of runoff from storm drains, carbon sequestration, prevention of erosion of waterfront properties, outstanding recreational opportunities, and a hatchery for the fish we (and other species) eat.

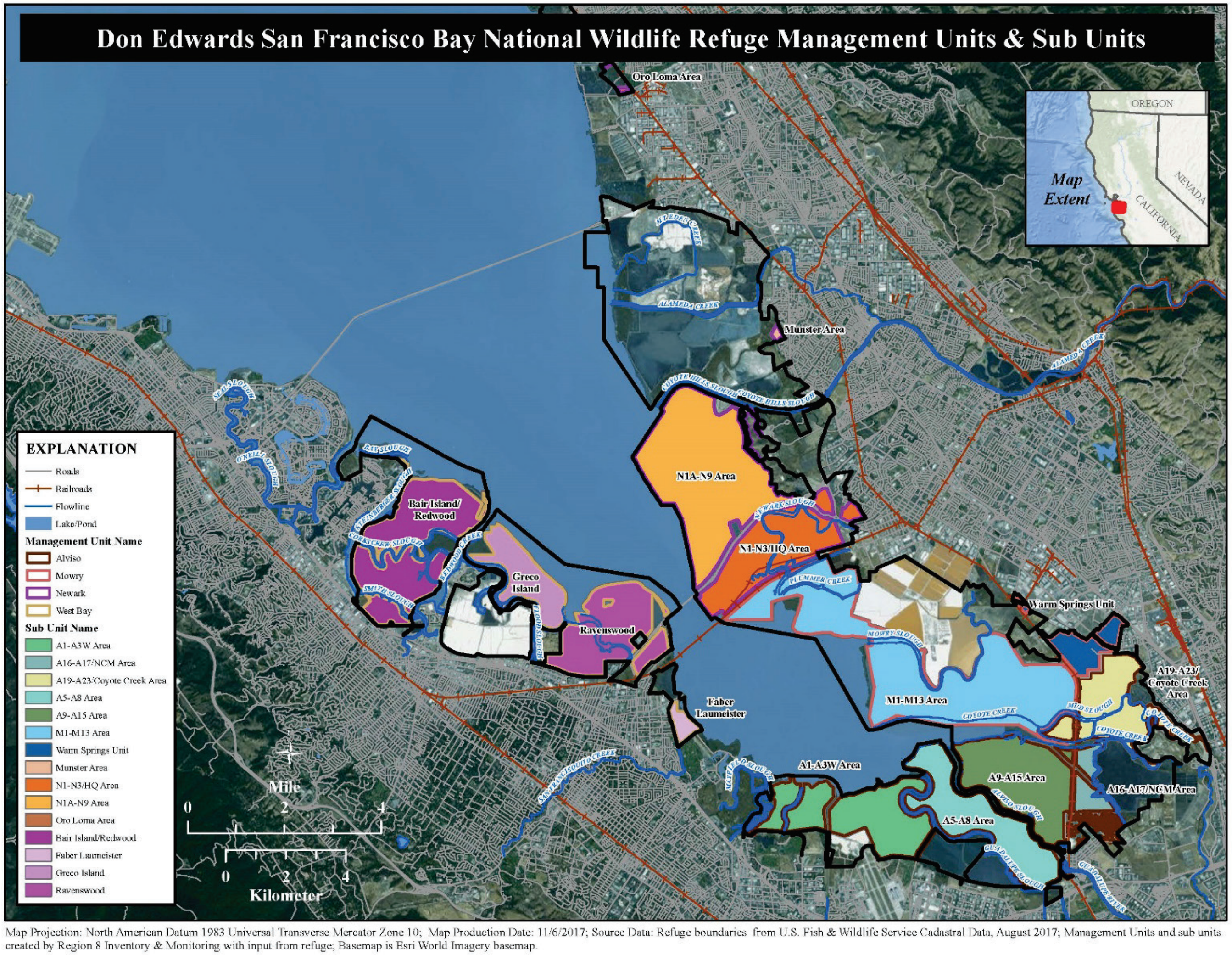
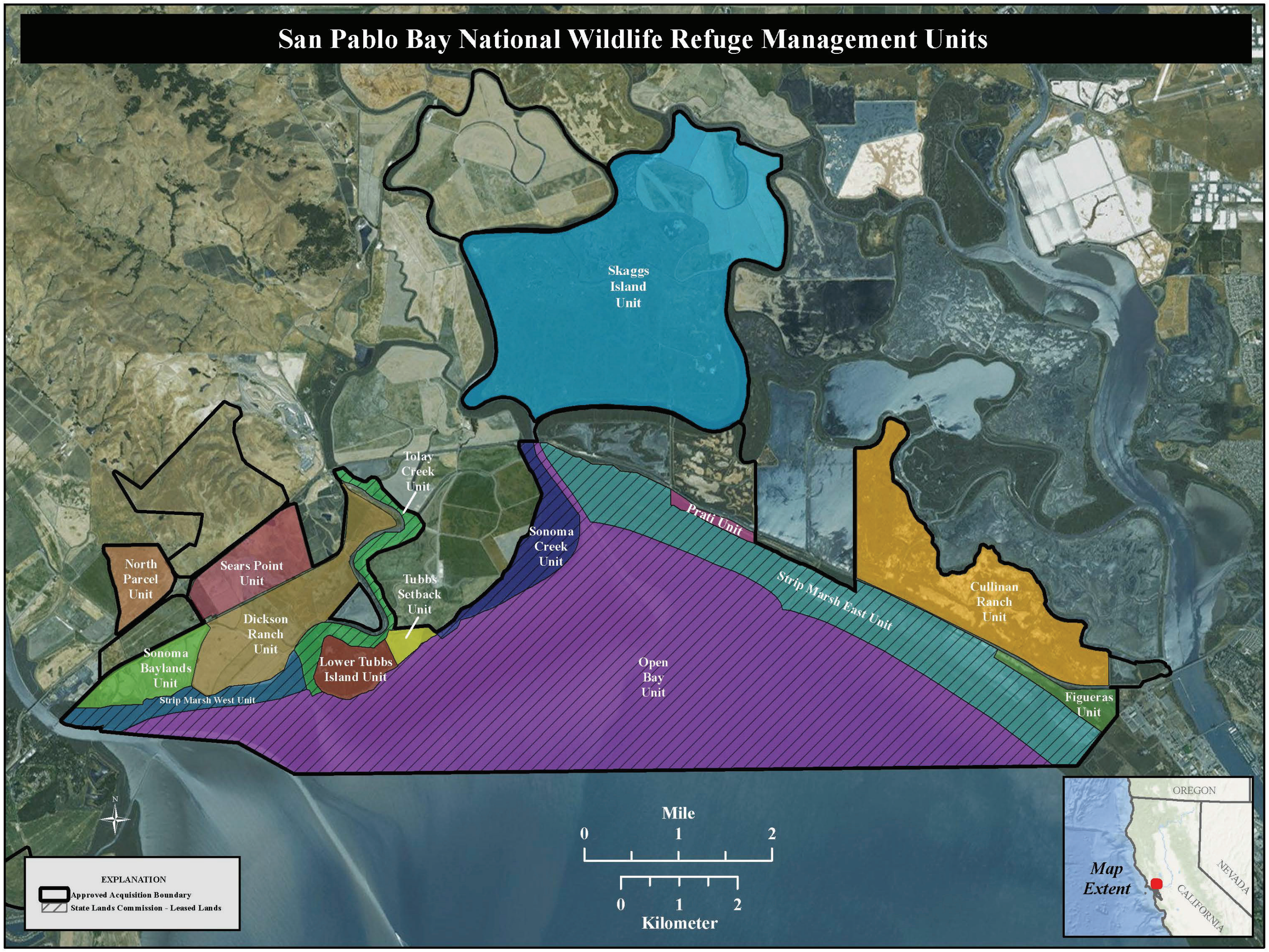


Figure 20. Geographic setting of Don Edwards San Francisco Bay National Wildlife Refuge.



Map Projection: North American Datum 1983 Universal Transverse Mercator Zone 10; Map Production Date: 10/31/2017; Source Data: Refuge boundaries from U.S. Fish & Wildlife Service Cadastral Data, August 2017; Management units created by Region 8 Inventory & Monitoring using input from refuge; Basemap is Esri World Imagery.

Figure 21. Geographic setting of San Pablo Bay National Wildlife Refuge.

4.6.2 Ecology

Tidal marsh at San Pablo Bay NWR. Credit: Judy Irving © Pelican Media

Tidal marsh (also known as *salt marsh*) is a coastal ecosystem in the intertidal zone situated between the uplands and salt or brackish water. The ecological boundaries of tidal marsh ecosystems are elastic; they change depending on the specific component species and the physical processes of the environment. Important physical factors influencing tidal marsh ecosystems include the tides (the rise and fall of sea levels) and elevation relative to the tides (tidal datums), salinity, freshwater inputs, sedimentation, waves, erosion, and soil characteristics. Tides follow a well-marked lunar cycle and also are shaped by local geography. Many other physical factors are closely interrelated with tides and each other. For example, soil salinity is influenced by water salinity, frequency of tidal inundation, evaporation, drainage, and other factors. Even elevation, which would seem primarily derived from geology, is affected by erosional and depositional forces as well as the role of vegetation in trapping sediment and building elevation. Tidal marsh ecosystems can also be affected by landscapes and processes distant from the marsh. For example, the Estuary is the downstream end of the entire Sacramento–San Joaquin watershed, which has profound control over the Estuary's hydrology and salinity.

Tidal marsh of the Estuary is generally stratified in "zones" depending on their elevation relative to the reach of the tides (Hinde 1954, Atwater and Hedel 1976, Peinado et al. 1994). These zones are:

- Low marsh. Low marsh occurs below mean high water (MHW), typically in narrow bands along tidal channel banks and mudflat edges, providing habitat for inundation-tolerant plant species such as California cordgrass (*Spartina foliosa*). At the lowest elevations, low marsh vegetation is inhibited by frequent, prolonged inundation and disturbance by waves or currents.
- Middle marsh. Middle marsh usually is found between MHW and mean higher high water (MHHW). Broad, nearly flat tidal marsh plains are common in the middle marsh zone, dominated mostly by pickleweed (*Sarcocornia pacifica*) and sometimes also dodder (*Cuscuta* spp.; Howell 1949) in young/developing marshes, but consists of a mix of native plant species in established tidal marsh, such as pickleweed, salt marsh dodder (*Cuscuta salina*), *Jaumea carnosa*, saltgrass (*Distichlis spicata*), and alkali-heath (*Frankenia salina*).
- High marsh. The high marsh zone generally occurs above MHHW to the limit of influence of spring tides or storm surges. In the Estuary, high marsh is often confined to natural levees along tidal creek banks and edges of artificial levees. Native plant species found in this zone include marsh gumplant (*Grindelia stricta* var. *angustifolia*), saltgrass, pickleweed, and alkali-heath but can include many other species that have declined or are regionally rare in tidal marshes. The high marsh also includes the transition to upland environments, often referred to as the "transition zone" or "ecotone."

The high marsh then transitions to what is called the transition zone. The transition zone generally occurs between MHW and Extreme High Water or Highest Observed Tide ([Ellis 1978, NOAA 2000] in Goals Project 2015) and extends above high marsh in elevation. It only includes the portion of the marsh wherein the plant community is directly and measurable influenced by terrestrial runoff and other freshwater discharge (BEHGU). It is however, an important component of, and overlaps with, tidal marsh.

The influence of tides, salinity, waves, marsh zonation, and other abiotic conditions of the tidal marsh ecosystem has given rise to a unique collection of tidal marsh–adapted species including invertebrates, plants, fish, mammals, and birds. Two endangered species, California RIRA and SMHM, both year-round residents, represent different aspects of the tidal marsh ecosystem and depend on the tidal marsh ecosystem to survive and reproduce. Both species were federally listed as endangered in 1970 due to loss of tidal marsh in the Estuary over the last century. RIRA is generally associated with low marsh for foraging and high marsh for nesting. It is positively associated with unrestricted daily tidal flows through a network of well-developed channels and large continuous marshes with a low perimeter-area ratio (Overton 2007, Liu et al. 2012). Historically, the range of RIRA may have extended from tidal marshes of Humboldt Bay to Morro Bay, but the Estuary has been the center of its abundance. SMHM is an endemic species of the Estuary and is generally associated with mid- to high marsh zones where pickleweed predominates. Like RIRA, the distribution of SMHM is also likely limited by hydrology, marsh size, and distribution of high tide cover and escape habitat. Recurrent but shallow flooding by saline water is probably needed to maintain habitat that favors SMHM over its potential mammalian competitors. Additional information about tidal marsh biodiversity found in the Estuary can be found in the information sources cited at the beginning of this chapter.

4.6.3 Target Status, Trends, and Goals

Two KEAs and associated indicators were selected to represent the integrity and health of the tidal marsh ecosystem: 1) RIRA density and 2) extent of tidal marsh (interim KEA[4]). Based on current knowledge of the status and trends of KEAs and associated indicators, the health (status) of the tidal marsh ecosystem in the Refuge Complex is considered to be increasing. The relationship between indicator measures and the status of tidal marsh (Poor to Very Good) is detailed in the Refuge Complex conservation target viability database (appendix B). A summary of tidal marsh KEAs, associated indicators, indicator status and trends, and desired future conditions (SMART goals) is presented in table 25.

KEA 1: Ridgway's Rail Density

Ridgway's rail (*Rallus obsoletus obsoletus*). Credit: ©Judy Irving

RIRA density is indicated by 1) the average annual rate of change (%) in RIRA density (number of rails per hectare) and 2) the annual trend in RIRA density (decreasing, stable, increasing). RIRA density was chosen as an indicator of tidal marsh health because the species is a year-round resident of tidal marsh, is sensitive to the quality and extent of this ecosystem to survive, and representative of overall tidal marsh health. Although RIRA is most commonly associated with the low marsh zone, especially for nesting (Harvey 1988, Gould 1973, Foerester et al. 1990, Evens and Collins 1992), higher marsh zones and the transition zone are also necessary for refugia during winter high tides (Harvey 1980, Eddleman et al. 1988). Rail populations are expected to increase as more tidal marsh is enhanced or restored, thus monitoring changes in marsh bird populations can provide evidence for restoration success (or failure) and, ultimately, improve our conservation efforts (such as

[4] We chose the extent of tidal marsh as an interim KEA. Healthy intact marsh ecosystems include a variety of habitats that are beneficial to plants and wildlife, especially where it provides a range of habitats useful in feeding, breeding, or sheltering. This metric allows the refuge to track acreage of tidal marsh as we continue restoring tidal flow to new areas. This is also the standard metric used within San Francisco Bay planning and partnerships. We are currently working with partners in the San Francisco Bay to determine the best method to measure the extent of high-quality tidal marsh. When a Bay-wide method is chosen, we propose to update the KEA.

predator management). In addition, the USFWS *Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California* also established delisting criteria that included rail density (number of rails per Recovery Unit). The Estuary's RIRA population was relatively stable in 2005–2007, declined significantly in 2008 (51%), and was followed by low but relatively stable densities from 2009 to 2011, estimated at 1,167 individuals (range 954–1,426) (Liu et al. 2012). The decline in 2007–2008, primarily associated with the South Bay, was correlated with ongoing control and removal (through chemical and mechanical means) of invasive *Spartina* species. Prior to 2013, RIRA populations in the Estuary maintained a stable to upward trend following the dramatic drop between 2007 and 2008 (Liu et al. 2012). Most sites surveyed in 2014 by Point Blue Conservation Science (PBCS) had numbers comparable to 2012, when the RIRA trend was stable or slightly positive.

In 2017, however, 1,262 individual RIRA (raw survey numbers) were detected in survey transects in the Invasive Spartina Project (ISP) Action Area, which represents only a portion of the total acreage of San Francisco Bay marshes (McBroom 2017, 2018). In 2018, this number increased to 1,415 individual rails. Since both the 2017 and 2018 individual detections within just the ISP sub-areas exceed the extrapolated Bay-wide population estimate of 1,167 from the earlier PBCS study (Liu et al. 2012), the current Bay-wide population is very likely much higher than in 2009–2011 when the previous analysis was conducted. Certainly the 1,415 individual detections in 2018 represent the absolute minimum population of Ridgway's rail that existed in the San Francisco Bay as of spring 2018.

KEA 2: Extent of Tidal Marsh

In response to the Estuary's loss and degradation of tidal marshes and declines in associated biodiversity, state, federal, and private organizations are engaged in tidal marsh restoration throughout the Estuary. It is assumed that increasing extent of high-quality tidal marsh (to be defined in the future; see earlier footnote) will lead to an increase in native tidal marsh biodiversity. The extent of tidal marsh in the Estuary was estimated at approximately 40,000 acres in 2009 (<25% of historic extent). Since 2009, an additional 6,300 acres have been reconnected to the tides. With the help of Measure AA, passed in 2016, an additional 24,000 acres of tidal marsh will likely be added over the next 20–30 years as part of already funded or permitted restoration projects (Goals Project 2015, San Francisco Estuary Partnership 2016). Recent estimates of tidal marsh extent in the Refuge Complex is 11,000 acres (status = Fair) or approximately 25% of total extent of tidal marsh in the Estuary. Given the breadth of current and planned tidal marsh restoration projects in the Refuge Complex, we can reasonably expect the extent of tidal marsh to increase by approximately 4,560 acres at Don Edwards San Francisco Bay NWR and 740 acres at San Pablo Bay NWR by 2030.

Table 25. Current status and desired future state (goals) of the tidal marsh ecosystem at Don Edwards San Francisco Bay and San Pablo Bay National Wildlife Refuges in terms of key ecological attributes and indicators.

Key Ecological Attribute	*Indicator*	*Status: Measure (Trend)*	*Status Source*	*Goal*
Ridgway's rail density	Long-term indicator: Average annual rate of change (%) in Ridgway's rail density (number of rails per hectare)	Unknown	TBD	TME_G01. During the period 2017–2063, achieve an average annual rate of increase in the Ridgway's rail population at Don Edwards San Francisco Bay NWR of at least 4.3% (2.3% during 2017–2032 and 5.5% during 2032–2063); during the period 2017–2063, achieve an average annual rate of increase in the Ridgway's rail population at San Pablo Bay NWR of at least 1.9%.
Ridgway's rail density	Short-term indicator: Annual trend in Ridgway's rail density (decreasing, stable, increasing)	Unknown	TBD	TME_G02. Over the next 15 years (2018–2032), Ridgway's rail density is stable or increasing at Don Edwards San Francisco Bay and San Pablo Bay NWRs.
Extent of tidal marsh	Extent of tidal marsh in the San Francisco Bay NWR Complex	Fair: 11,405 acres (4,615.614 hectares) (increasing)	Database used to categorize tidal marsh for the secretive marshbird protocol, Point Blue Conservation Science sea level rise model	TME_G03. By 2025, extent of tidal marsh within the San Francisco Bay NWR Complex (San Pablo Bay NWR, Don Edwards San Francisco Bay NWR) increases to 14,500 acres (5,900 hectares). This represents a 50% increase in tidal marsh extent. A tidal marsh is defined as a vegetated, intertidal, sedimentary wetland that develops in coastal environments sheltered from high wave energy, with variable ecological influence from marine or estuarine salinity (Adam 1990, USFWS 2013).

Note: Status designations: red = Poor, yellow = Fair, light green = Good, dark green = Very Good. Refer to the San Francisco Bay National Wildlife Refuge Complex viability database for additional details (appendix B).

4.6.4 Critical Threats

The most critical threats (classified as High or Very High threats) to the tidal marsh ecosystem are climate change, land conversion, invasive plants, predators (at Don Edwards San Francisco Bay NWR), transportation infrastructure (roads, railways, and levees), and oil spills (at Don Edwards San Francisco Bay NWR). Lower ranked threats (Low to Medium) are invasive aquatic wildlife mosquito control pesticides, pollution, illegal activities by humans, mosquito management disturbance, marine debris, and human disturbance (from recreation). A conceptual model depicting threats to the tidal marsh ecosystem, their relationship to biophysical factors of the ecosystem, and strategies aimed at reducing the most critical threats is depicted in figure 22. The most critical threats (High to Very High) to the tidal marsh ecosystem are summarized below.

Climate Change (High to Very High Threat)

Persistence of a tidal marsh is a balancing act between processes that increase marsh elevation (sediment accretion, organic matter inputs, tectonic uplift) and decrease marsh elevation (erosion, decomposition, compaction, subsidence) relative to sea level. For example, if sea level rise outpaces sediment accretion and tectonic uplift, marshes will be inundated for longer periods of time. Increased inundation ultimately decreases plant production, and increases compaction and decomposition, or can lead to anoxic soils. Eventually high rates of sea level rise will lead to conversion of marsh to mudflats and the possible expansion of marsh into upland areas. This process will likely result in changes in vegetation and habitat availability for marsh-dependent species (Takekawa et al. 2013). The response of tidal marshes to sea level rise will vary based on local conditions; for example, research suggests that suspended sediment concentration, and thus ability to keep pace with sea level rise, is lower in the North Bay relative to the South Bay (Takekawa et al. 2013). Sea level rise modeling results indicate that San Pablo will not likely keep pace with sea level rise through the 20th century, with much of the *current* footprint of tidal marsh transitioning to mudflat by 2100 (Takekawa et al. 2013, figure L-13) unless the marsh is allowed to migrate inland.

Climate change is also projected to increase the frequency and intensity of extreme weather events such as winter storms. Storms accompanied by large amounts of precipitation and increased wave action could affect tidal marshes in the following ways:

- Storms may provide local suspended sediment to build marsh elevation relative to sea-level rise (Thorne et al. 2013).
- Changes in inundation regimes can alter the biological zonation of plant communities due to inundation and salinity tolerance limitations (Foin et al. 1997, Mendelssohn and McKee 1988, Day et al. 2008, Zedler 2009).
- Vegetation may be buried or covered with sediment or debris which can reduce primary productivity or cause dieback (Callaway and Zedler 2004).
- Storm flushing and sediment influx can increase delivery of nutrients and reduce soil salinity, which are necessary to promote vegetative growth (Zedler et al. 1986, Zedler 2010).
- Unusually low pickleweed cover has been observed after periods of extended inundation from storms (Zedler et al. 1986).
- Storms could lead to episodic flooding that would temporarily decrease the amount of available habitat and displace wildlife and expose them to competition and predation (Zedler et al. 1986).
- Storms during the breeding season have been observed to overtop nests and cause egg failure, reducing fecundity of marsh birds, particularly rails (Takekawa et al. 2013, Masseyet al. 1984).

Invasive Plants (High Threat)

One of the most critical threats to the tidal marsh ecosystem is invasion and modification of the ecosystem by non-native plant species. Non-native plant species capable of living in tidal marshes have invaded and profoundly altered vegetation, or threaten to do so, over extensive areas. Non-native plant species of greatest concern are those that 1) become so abundant that native plant species are diminished significantly in population size or displaced altogether through direct competition; 2) colonize disturbed zones that do not typically receive native propagule recruitment (e.g. sides of levees); 3) colonize habitats naturally lacking in vascular plants, such as tidal flats; or 4) are annuals that thereby provide no escape cover during winter high tides because they are simply a plant skeleton that predators can see through. In addition to altering native plant composition, some invasive plants can lead to altered invertebrate communities or even soil building properties of tidal marsh. Due to limited resources, Don Edwards San Francisco Bay NWR and San Pablo Bay NWR prioritize invasive plant species with the greatest potential to cause harm and therefore should be a focus of management. Descriptions of some of the most critical invasive plant threats to tidal marsh in the Refuge Complex are summarized in the following.

- **Dense-flowered cordgrass (*Spartina densiflora*), English cordgrass (*Spartina anglica*), and smooth cordgrass (*Spartina alterniflora* and its hybrids)**. Over the last 25 years, introduced cordgrass species have spread rapidly, becoming established in numerous wetland habitats and marsh restoration sites throughout the Estuary. These invasive cordgrass species significantly alter marsh composition and structure. For example, smooth cordgrass and its hybrids choke channels used for foraging by RIRA. Dense-flowered cordgrass colonizes middle and upper marsh, displacing native pickleweed marsh, habitat of the endangered SMHM. The native cordgrass species (*Spartina foliosa*) is threatened with local extinction as a result of hybridization with smooth cordgrass. If the hybrid is left unchecked, it is anticipated that native California cordgrass could become the first naturally dominant plant species to go extinct in its own ecosystem since the passage of the Endangered Species Act of 1973.
- **Perennial pepperweed (*Lepidium latifolium*)**. Pepperweed can form monocultures in tidal marsh, excluding native vegetation required by other tidal marsh–dependent species. Areas of active tidal marsh restoration are especially vulnerable to invasion because perennial pepperweed recruitment is accelerated by bare ground (Spenst 2006), potentially affecting several refuge and adjacent restoration projects (such as Sonoma Creek Marsh and Sonoma Baylands). Because of its highly invasive nature, the biological threats it poses to marsh habitat restoration, and the structural and chemical threats it poses to marsh soil accretion and salinity, perennial pepperweed is a high-ranking priority for control efforts at San Pablo Bay NWR and for newly restored marshes on Don Edwards San Francisco Bay NWR.
- **Algerian sea lavender (*Limonium ramosissimum*)**. In 2006, two forms of Algerian sea lavender (ssp. *ramosissimum* and ssp. *provinciale*) were discovered in San Francisco Bay salt marshes. A perennial, salt-tolerant forb of Mediterranean origin, the species has spread to marshes and tidal lagoons in southern California, from San Diego to Santa Barbara. There, the plant displays invasive characteristics including broad salinity tolerance, prolific seed production and the ability to compete with native plants. In the Estuary, Algerian sea lavender has been found in the high marsh and upland transition zone where it forms near-monocultures and competes directly with native salt marsh plant species. At the upper end of this elevational range, sea lavender grows taller and more robustly and produces more seed, competing directly with perennial pickleweed and altering high tide wildlife refugia. At Don Edwards San Francisco Bay NWR, the first discoveries were made on the outer fringes of several marshes though dispersal by Bay water. These sites include the outboard marsh of R1, Coyote Creek Lagoon, Ideal Marsh, Warm Springs Subunit and levees of R1, Greco Island, and N9. The second mechanism has been the mistaken use of Algerian sea lavender in restoration projects. Several different seed mixes from at least one vendor had mistakenly used Algerian sea lavender seeds in place of native California sea lavender (*Limonium californicum*). These sites include the Refuge Complex Environmental Education Center (EEC) restoration area, the levees of SF2, LaRiviere, A6, and the two recently acquired islands in the Cannery exchange. Algerian sea lavender is only known to occur at one location at San Pablo Bay NWR: Guadalcanal Marsh (currently being transferred to the refuge) and its adjacent parking lot belonging to the California Department of Transportation. The total known infestation comprises less than 30 plants and is the focus of an eradication effort.

Factors that contribute to the invasive plant threat include:

- **Infrastructure (levees, boardwalks, power towers, roads,**
- **and railroads)**. These facilities provide additional routes for weed dispersal.
- **Poor public knowledge**. Poor public knowledge can lead to inadvertent invasive seed transport and introduction into protected areas.

Land Conversion (High Threat)

Major alteration of the tidal marsh ecosystem in the Estuary occurred during and after the California Gold Rush era (mid-1800s). The principal causes of tidal marsh loss in the Estuary are diking for agricultural purposes, former solar salt production, and urban and commercial development. By 1989, it is estimated that 79% of tidal marsh that occurred in the Estuary was lost (Goals Project 1999). The habitat structure and quality of remaining marsh also differed from their pre-historical antecedents. This dramatic decline in tidal marsh habitat extent and quality resulted in negative effects on biodiversity and ultimately led to the federal listing of several marsh-dependent species. In addition to loss of biodiversity, tidal marsh conversion decreased water quality and increased local flood risks. In the last several decades, efforts to restore historic tidal marsh have been undertaken. For example, salt production ponds are being restored to tidal marsh at Don Edwards San Francisco Bay NWR and elsewhere in the Estuary. At San Pablo Bay NWR, several tidal marsh restoration projects have been completed (such as Tolay Creek and Tubbs Island), are underway (Cullinan Ranch, Dickson Ranch), or are in the early planning stages (Skaggs Island).

Factors that contribute to the land conversion threat include:

- **Tidal marsh restoration (+)**. Restoring former baylands to tidal marsh will positively benefit this target.
- **Current landowners want to maintain existing land uses (-)**. There are still thousands of acres of historic baylands that continue to be used for commercial salt-making or agriculture that could be restorable, as well as other undeveloped lands that are slated for urban development.

Mammalian Predators (High Threat at Don Edwards San Francisco Bay NWR, Low Threat at San Pablo Bay NWR)

Predatory species of mammals (as well as birds and reptiles) are known to take individuals and eggs of tidal marsh native species such as RIRA. The effect of mammalian predation on native small mammal species such as SMHM is unknown, but they are also assumed to be negatively impacted by larger mammalian predators. Some predators, such as the Norway rat (*Rattus norvegicus*), domestic cats, and the red fox are not native to California. Others, such as raccoons and striped skunks (*Mephitis mephitis*) may be native to the general area, but their abundance is increased by human modifications of the environment, such as levees providing dryland access, landfills providing an attractive nuisance, or infrastructure providing habitat.

Predation impacts are more severe at Don Edwards San Francisco Bay NWR (relative to San Pablo Bay NWR) because of the refuge's proximity to urban areas, both residential and commercial, as well as abundance of infrastructure (such as PG&E towers, PG&E boardwalks, railroads, roads, and an extensive levee system) within or surrounding tidal marsh. Vulnerability to predation is also exacerbated by reduction of tidal marsh to narrow and fragmented patches close to urban edge areas. Levees provide artificial access for terrestrial predators and displace optimal cover of high marsh vegetation. Urban sites also have increased artificial food resources (e.g., trash and pet food) that can lead to an increase in the density of predators, such as domestic and feral cats, rats, and others, as well as change their movement patterns and space use (Prange et al. 2004). Although mammalian predators like racoons, skunks, and coyotes are also present at San Pablo Bay NWR, their populations do not appear to be artificially inflated, and these species do not pose a serious threat to the tidal marsh ecosystem.

Factors that contribute positively (+) or negatively (-) to the mammalian predator threat include:

- **Urban growth (-)**. Urban growth increases synanthropic predators such as feral cats.
- **Infrastructure (levees, boardwalks, power towers, roads and railroads) (-)**. These facilities provide corridors to predators to access sensitive areas. Towers and other structures provide perches, hiding places, and denning or nesting sites for predators.

- **Landfills, composting facilities, and recycling plants (-)**. Increase food supplies for predators, such as common ravens, feral cats, skunks, raccoons, rats, and California gulls (*Larus californicus*), which are predators of tidal marsh species.
- **Poor public knowledge of the refuge can lead to disregard of protected federal lands (-)**. Poor public knowledge can lead people to let dogs off-leash in sensitive areas as well as release unwanted animals.

Avian Predators (Medium Threat at Don Edwards San Francisco Bay NWR, Low Threat: San Pablo Bay NWR)

Avian predation can have a significant impact on the reproductive success of marsh-associated bird species such as RIRA. It is estimated that avian predation can account for a third of lost RIRA eggs (USFWS 2013). Known avian predators of RIRA and their eggs include herons, egrets, raptors, owls, and ravens. Although many of these avian predatory species are native, their populations have increased above historical levels due to the increased availability of human food resources and human infrastructure that provides habitat. Common ravens, peregrine falcons, and red-tailed hawks nest in electrical towers and buildings and forage in nearby marshes. The peregrine falcon has increased locally in recent years in response to peregrine falcon recovery actions. Hunting intensity and efficiency by avian predators is increased by electric power transmission lines, towers, and boardwalks, many of which cross through tidal marshes and provide otherwise-limited hunting perches. These predation impacts are greatly intensified by a decrease in high marsh and high tide cover in marshes (Sibley 1955, Evens and Page 1986). Other species, such as the northern harrier (*Circus cyaneus*), can no longer forage in upland habitats due to urban development, and their foraging activities are now concentrated in wetland areas. Although little is known about predation impacts to SMHM, marsh flooding events may increase predation (Johnston 1957, Fisler 1965). During high winter tides, herons, egrets, and gulls, raptors, and owls can be seen taking small mammals from flooded marsh. Unnaturally high predation is also thought to exist in some marshes where SMHM is concentrated into narrow pickleweed zones due to surrounding habitat loss.

Avian predation pressure is low at San Pablo Bay NWR due to the minimal presence of nesting and perching structures in and adjacent to tidal marsh habitat. Avian predation occurs here, but predator populations or predation levels do not appear to be above normal.

Factors that contribute positively (+) or negatively (-) to the avian predator threat include:

- **Infrastructure (levees, boardwalks, power towers, roads and railroads) (-)**. Towers and other structures provide perches, hiding places, and denning or nesting sites for predators.
- **Landfills, composting facilities, and recycling plants (-)**. These facilities increase food supplies for common ravens, feral cats, skunks, raccoons, rats, and California gulls, which are predators of tidal marsh species.

Infrastructure: Roads, Railways, and Levees (High Threat)

Over the last century, tidal marsh of the Estuary was reduced in extent and became fragmented. Roads, railways, and levees have been the primary causes of this fragmentation, and this infrastructure also contributes to increased predation pressure (see "Mammalian Predators" earlier). Fragmentation complicates the impact of habitat loss by reducing tidal marsh populations—not to one contiguous population a tenth of its former size, for example, but instead to many small, isolated populations on habitat fragments of varying size, shape, and condition. In addition to the difficulty of supporting a viable population on a habitat fragment of limited area, marsh fragments may lack the full range of habitat features needed by a species throughout its life cycle. For example, a fragment might contain feeding and nesting habitat for SMHM but completely lack refuge from high tides or storm surges. As remaining marsh areas are reduced in size, edge effects become increasingly severe. Smaller populations and smaller (or narrower) habitats have less ability to absorb or buffer adverse impacts from outside influences such as predation, invasive species, human disturbance, extreme storm events, or pollution.

Factors that contribute positively (+) or negatively (-) to the infrastructure threat include:

- **Urban growth (-)**. Urban growth increases the need for infrastructure for transportation, communication, and development and increases pressure on open space for recreation, exercise, dog-walking, etc.

Oil Spills (High Threat at Don Edwards San Francisco Bay NWR, Low Threat at San Pablo Bay NWR)

Oil spills can stress estuarine ecosystems through direct oil contamination and subsequent clean-up activities. Oil spills around the globe have shown that oil contamination degrades water quality and alters the structure and composition of estuarine invertebrate, plant, and wildlife communities. Recovery of some elements of affected ecosystems may be rapid while other elements may take decades to recover (for example, Kingston 2002, Peterson 2003, Mendelssohn et al. 2012). Oil spills can have a catastrophic impact on tidal marsh–associated wildlife, including shorebirds and other waterbirds. For example, a spill within Humboldt Bay in 1997 killed thousands of shorebirds and hundreds of waterfowl and other waterbirds (California Department of Fish and Game and USFWS 2008).

In 2007, the cargo vessel *Cosco Busan* spilled approximately 58,000 gallons of medium-grade fuel oil into the Estuary. Most of the oil spread to central San Francisco Bay and the outer coast (north and south of the Golden Gate Bridge), including lands of the Refuge Complex. The spill resulted in direct mortality or indirect impacts on thousands of wildlife species. Indirect impacts included reduced reproductive success, lowered survival rates in remaining birds, reduced food availability, and food source toxicity. Although the likelihood of an oil spill in the South San Francisco Bay is low, it is a high priority threat given 1) historical occurrences, 2) prevailing tides and wind that could carry oil to South San Francisco Bay, and 3) the potential damage it could cause to the tidal marsh ecosystem and the larger Estuary.

Oil spills are a low priority for San Pablo Bay NWR because most oil spills in the Estuary occur in the Central Bay where tide and current movement generally keep spill boundaries around the Richmond-San Rafael Bridge (French-McCay and Rowe 2009). This puts Don Edwards San Francisco Bay NWR at a lower risk of pollution from oil spills than other refuges such as Marin Islands NWR or San Pablo Bay NWR.

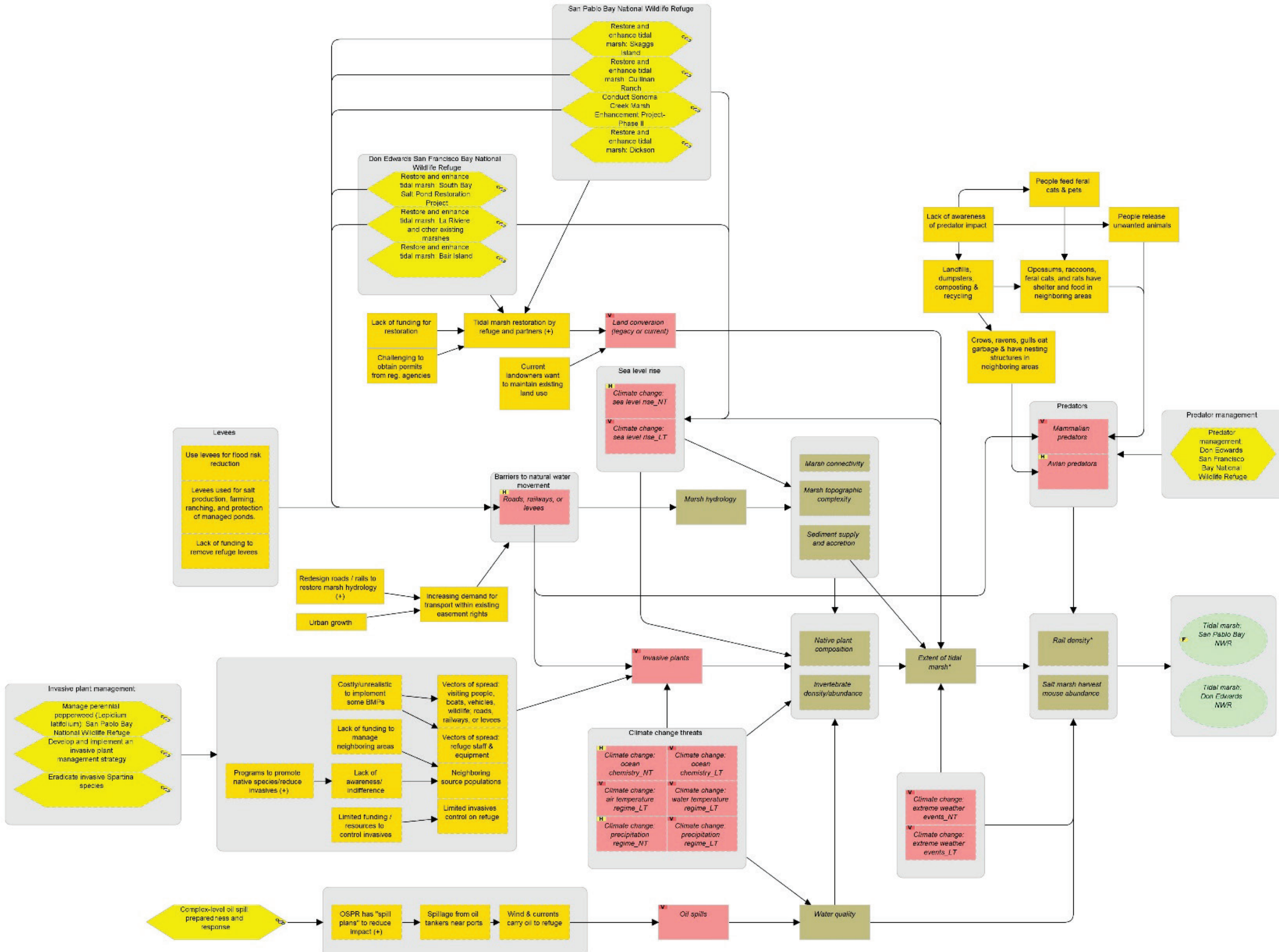


Figure 22. Conceptual model of the tidal marsh ecosystem at Don Edwards San Francisco Bay and San Pablo Bay National Wildlife Refuges.

Notes: Only Very High or High threats to the ecosystem are depicted here. Legend: green oval = natural resource conservation target; olive box = biophysical or human well-being attribute; pink box = direct threat; orange box = contributing factors; yellow hexagon = conservation strategy. The letters in the upper left portion of threats (pink boxes) represent the summary threat ranking across the seven refuges of the San Francisco National Wildlife Refuge Complex (L=low, M=moderate, H=high, VH=very high).

4.6.5 Conservation Strategies

Conservation strategies for the tidal marsh ecosystem are focused on reducing or mitigating the critical threats of climate change, legacy land conversion, invasive plants, predators, and transportation infrastructure (roads, railways, levees). Threats addressed by each strategy and expected outcomes (objectives) are summarized in table 26. Each strategy is briefly described in the following in order of priority to implement. Results chains visually depicting the assumptions behind these strategies (how they work) and expected outcomes are presented in a Miradi file associated with this NRMP (appendix B). Strategies outlined here support recovery actions identified in the *Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California* (USFWS 2013).

Restoration and Enhancement of Tidal Marsh

One of the most effective means to improve the long-term health of the tidal marsh ecosystem is through restoration or enhancement. *Restoration* here broadly refers to restoring tidal waters to areas where tidal influence was removed for some human purpose (such as agriculture, salt production, transportation, or housing) at some point in the past. *Enhancement* means improving some aspect of an existing tidal marsh, whether it's an abiotic (such as hydrology or soils) or biotic component (such as plants). Many tidal marsh enhancement and restoration (hereafter referred to collectively as *restoration*) projects have been completed in the Refuge Complex, and these systems are slowly becoming fully functioning tidal marsh. Other restoration projects are just beginning. Tidal marsh restoration efforts underway in the Refuge Complex include the South Bay Salt Pond Restoration Project in the southern portion of the Estuary and the Napa-Sonoma Baylands in the northern portion of the Estuary. As more of these newly breached sites mature and become vegetated, biologists expect to see improvements in tidal marsh biodiversity, including recovery of endangered species such RIRA and SMHM. Conversely, restoration of tidal marsh has the potential to adversely affect waterbirds where restoration involves conversion of former salt ponds. Such conversions can have adverse effects on waterbirds, such as removal of habitat for SNPL (see section 4.8 "Waterbirds"). Active or planned tidal marsh restoration or enhancement projects in the Refuge Complex, in order of high to low priority, are presented below. The list below does not include completed projects (although marsh may still be evolving) (= no active on-the-groundwork).

- **Cullinan Ranch,** San Pablo Bay NWR. This project involves raising the subsided marsh plain using approximately 3 million cubic yards of beneficial reuse of dredge material at Cullinan East Unit following reintroduction of tidal waters. The primary partner is Ducks Unlimited, who has generated the funds and will serve as project manager. The Refuge Complex's role is the development of, and facilitation in design of, climate change adaptation and endangered species habitat features. The Complex also facilitates permitting, construction, and general needs.
- **Dickson, San Pablo Bay NWR**. This project involves working with Sonoma Land Trust, Invasive Spartina Project, Point Blue STRAW Program, students, volunteers, and contractors to restore the tidal marsh transition zone plant community along the 2.5-mile north transition ramp (levee), internal side cast ridges, and islands at the Dickson Unit. This work will create high tide refugia for marsh-dwelling wildlife by creating low/mid-marsh and transition zone habitat within the larger Dickson Unit tidal marsh restoration project. The Complex's role is coordinating with STRAW to facilitate the planning and implementation of the biological portion of the native plant restoration program.
- **Skaggs Island, San Pablo Bay NWR**. This project involves restoring tidal marsh to previously diked historic marsh at the Skaggs Island Unit by reintroducing tidal water. This project is in the planning phase, with the Haire Ranch (Phase I) on-the-ground construction already underway. Partners on the Haire Ranch include the Natural Resource Conservation District and Ducks Unlimited. The Refuge Complex's role is to work with partners to facilitate

permitting, construction, and the eventual restoration of the island to tidal salt marsh habitat.

- **South Bay Salt Pond Restoration Project, Don Edwards San Francisco Bay NWR**. The South Bay Salt Pond Restoration Project is a multi-agency effort to restore tidal marsh habitat, reconfigure managed pond habitat, maintain or improve flood protection, and provide recreation opportunities and public access in 15,100 acres of former salt-evaporation ponds purchased from and donated by Cargill in 2003. The longer-term planning effort involves a 50-year programmatic-level plan for restoration, flood protection, and public access. This effort has already seen the implementation of Phase 1 projects, which were completed in 2009 and have already begun to provide habitat for tidal marsh wildlife including RIRA, SMHM, song sparrows, and a suite of native tidal marsh plants. The Complex role in this project is planning, permitting, and on-the-ground coordination of restoration activities.
- **Bair Island, Don Edwards San Francisco Bay NWR**. Outer, Middle, and Inner Bair Islands were restored to tidal action in 2008–2009, 2011–2013, and 2007–2015, respectively, and are transitioning to tidal marsh habitat with upland areas interspersed. In addition to passive restoration, actions at Inner Bair Island include the revegetation of the transition zone habitat. The refuge is currently coordinating transition zone and marsh mounds (high tide islands) seeding and planting and monitoring at Inner Bair with the San Francisco Bay Bird Observatory (SFBBO) and Save the Bay. Many of the native plants are grown at refuge nurseries managed by SFBBO. Regulatory monitoring conducted by refuge staff began in 2009 and includes monitoring marsh morphology, habitat development, vegetation assessment, bird use, invasive plants, and predator management; refuge staff will also help conduct RIRA and SMHM surveys.
- **LaRiviere Marsh and Other Existing Marshes, Don Edwards San Francisco Bay NWR**. This strategy involves enhancing existing marshes, such as LaRiviere Marsh (restored marsh), Dumbarton Marsh (historic marsh), and Warm Springs Mouse Pasture (diked marsh). While the refuge focuses funding on new large-scale tidal marsh restoration projects, it must also maintain existing marshes and, in many cases, improve and enhance these marshes. A number of diked or muted tidal marshes exist on Don Edwards San Francisco Bay NWR, and many of them would benefit from improved hydrology by reconnection to tidal waters or improved drainage. Many of these marshes would be enhanced by revegetating weedy transition zones with native plants that provide refugia for threatened and endangered species. Removing infrastructure within marshes would increase hydrological connections and allow better connectivity for plants and animals. In addition, the marshes would benefit from novel climate adaptation strategies, such as thin layer sediment deposition, gradual sloped marsh upland ecotones, and high tide islands. Activities include or will include 1) completing the Federal Lands Access Program (FLAP) project (LaRiviere marsh enhancement and bridge earthquake retrofit replacement project); 2) developing habitat management plan for Warm Springs Mouse Pasture; 3) working with railroads to begin to remove, realign, or elevate tracks within refuge boundaries; 4) maintaining a native plant nursery at EEC and Fremont; 5) annually propagating native plants from local sources and maintaining these plants for revegetation projects; and 6) restoring native plants in the marsh upland transition zone. Many of these activities will take years, or even decades to full implement.
- **Sonoma Creek Marsh Enhancement Project—Phase II, San Pablo Bay NWR**. This strategy involves working with the Richardson Bay Audubon Center & Sanctuary to complete the Sonoma Creek Marsh Enhancement Project (SCEP), which began in 2015. The SCEP design includes the enhancement of tidal marsh function through the alleviation of the impoundment of water within 100 acres of the “Central Basin” (located in the center of the SCEP project site). On-the-ground construction of phase II is expected to begin fall FY2019. The refuge has provided over $600,000 through grants for this project. Audubon will serve as the project manager refuge staff will provide consultation, coordination, and oversight. This

strategy will not expand the extent of tidal marsh (a KEA) but will improve the health of existing tidal marsh in poor health that provides little to no habitat for marsh-dwelling wildlife.

Predator Management: Don Edwards San Francisco Bay National Wildlife Refuge

The primary purpose of predator management at Don Edwards San Francisco Bay NWR is to increase the reproductive capacity of RIRA by reducing predation pressure on eggs, chicks, and adults. According to the *Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California* (USFWS 2013), predation pressures on RIRA must be reduced to down-list RIRA to threatened status. The recovery plan recommends that a predator management plan be developed and implemented at all sites with significant predation issues. Don Edwards San Francisco Bay NWR developed mammalian and avian predator management plans as part of the CCP process. Each year, the refuge staff develop an annual work plan that guides predator management activities in priority tidal marsh areas, which are chosen based on the number of rails in the marsh and identified predator threats. For example, tidal marsh areas with high numbers of rails and adjacent business parks and landfills that harbor predator populations are higher priorities for predator management relative to areas with similar numbers of rails but limited predator threats. Details about predator targets and management techniques are presented in the predator management plans.

Develop and Implement an Invasive Plant Management Strategy

This strategy focuses on refinement and implementation of the Don Edwards San Francisco Bay NWR invasive plant management plan (see CCP) and development and implementation of an invasive plant management strategy for San Pablo Bay NWR. Steps to inform refinement or development of a plan include 1) documenting the most harmful invasive plant species (current and potential future); 2) assessing the status of priority invasive plant threats (inventory); 3) refining and documenting invasive plant management strategies (integrated pest management plan) using information from the baseline inventory, invasive plant ecology, and current science; and 4) implementing strategies, monitoring effectiveness of strategies, and adapting strategies as needed. At both refuges, priorities and inventory have been conducted in the past but would be reviewed as part of the planning process. Evaluation and documentation of invasive plant management strategies will be conducted using a standardized Refuge Complex–level approach and is discussed in more detail in section 3.6, "Management Strategies." Regardless of whether a new standalone plan is developed for San Pablo Bay NWR or integrated into the Don Edwards San Francisco Bay NWR plan, invasive plant management will continue at both refuges, guided by existing inventory and monitoring data and an integrated pest management approach. Successful implementation of this strategy is expected to reduce the extent and abundance of invasive plants resulting in benefits to the tidal marsh ecosystem by maintaining or improving physical and biological conditions of tidal marsh, and ultimately providing high quality habitat for marsh-dependent plants and wildlife.

Manage Perennial Pepperweed (*Lepidium latifolium*): San Pablo Bay National Wildlife Refuge

One of the most critical threats to the tidal marsh ecosystem at San Pablo Bay NWR is perennial pepperweed. This species forms near monocultures in tidal marsh and alters habitat of tidal marsh–dependent species. It is especially aggressive in disturbed areas including the sides of slough channels and high marsh and transition zone habitats (Tobias et al. 2015). These habitats provide important refuge for tidal marsh wildlife, especially during extreme tides and storm events. Implementation of this strategy is expected to improve the functioning and structure of the tidal marsh ecosystem by maximizing the extent of tidal marsh dominated by native plants and improving habitat quality for marsh-dependent wildlife.

Management of this species is guided by the San Pablo Bay NWR pepperweed control plan (Hogle et al. 2007). The focus of this strategy over the next 5 years is to 1) continue to maintain or improve pepperweed control in established treatment areas (Sonoma Baylands, Strip Marsh West, Upper Tolay Creek, Lower Tolay Creek, Lower Tubbs Island, Tubbs Island Setback, and Sonoma Creek Marsh); and 2) expand control efforts into the marsh-upland transition zone, especially where other tidal marsh restoration projects are underway and other priority locations (Dickson, Strip Marsh East, Cullinan Ranch, Haire Ranch, Guadalcanal).

Eradicate Invasive Spartina Species

The San Francisco Estuary Invasive Spartina Project (ISP) is a coordinated regional effort to address the rapid spread of four introduced and highly invasive *Spartina* (cordgrass) species in the Estuary: *S. densiflora, S. anglica, S. alterniflora*, and *S. alterniflora* hybrids. These species cause a variety of impacts on the tidal marsh ecosystem including alteration of estuarine sediment dynamics, alteration of invertebrate communities, and ultimately loss or degradation of estuarine biodiversity. ISP was established by the Refuge Complex and the California State Coastal Conservancy in 2000 and is progressing toward its goal of eradicating non-native cordgrass, working in close cooperation with its many partners around the Estuary. The Service is the federal lead for ISP and has a very active role in eradication of non-native cordgrass species.

ISP has made tremendous progress toward eradication of non-native cordgrass species since 2000, reducing or eradicating populations throughout the Estuary and in the neighboring coastal areas of Point Reyes National Seashore and Bolinas Lagoon. As of 2017, there are only 27.5 net acres of invasive cordgrass remaining in the Estuary within 210 sub-areas—a 97% Estuary-wide reduction since a peak infestation of 805 net acres in 2005. The majority of the remaining infestation (21.5 net acres) occurs in 11 sub-areas where treatment has been restricted and invasive cordgrass has remained untreated since 2011 due to concerns that California RIRA populations would be adversely affected.

Table 26. Tidal marsh ecosystem management strategies and associated objectives, in order of priority to implement over the next 5 years.

Strategy Title	*Threat Addressed*	*Expected Outcome (Objectives)*
Restore and enhance tidal marsh: Cullinan Ranch, San Pablo Bay NWR	Land conversion, climate change, infrastructure	TME_O01. By 2022, mid-marsh elevation (6.5 feet NAVD) has been achieved at the Cullinan Ranch East Unit of San Pablo Bay NWR through active sediment placement.
Restore and enhance tidal marsh: Dickson, San Pablo Bay NWR	Land conversion, climate change	TME_O02. By 2028, the revegetation plan for the bayside transition habitat on the 2.5-mile-long North Dickson Unit levee (Elliot Trail) at San Pablo Bay NWR is implemented, and 50% of the bayside transition habitat is dominated with rhizomonous grasses (such as *Elymus triticoides* and *Distichlis spicata*), rhizomonous sedges (such as *Carex praegracilis*), rushes (such as *Juncus arcticus*) and large interspersed patches of competitive native broadleafs (such as *Euthamia occidentalis, Amborsia psilostachya*, and *Baccharis douglasii*).
Restore and enhance tidal marsh: Skaggs Island, San Pablo Bay NWR	Land conversion, climate change, infrastructure	TME_O03. By 2022, on-the-ground construction of the pre-breach, Haire Ranch (Phase I) restoration at San Pablo Bay NWR has been completed, including earth movement, channel creation, reservoir creation, and planting (interim seasonal habitat creation) on 1,100 acres. TME_O04. By 2025, the final design for Skaggs Island is complete, and Phase II of the tidal marsh restoration, including cell creation, is underway at San Pablo Bay NWR.

Strategy Title	*Threat Addressed*	*Expected Outcome (Objectives)*
Restore and enhance tidal marsh: South Bay Salt Pond Restoration Project, Don Edwards San Francisco Bay NWR	Land conversion, climate change, infrastructure	TME_O05. By 2023, approximately 1,000 acres (405 hectares) of tidal marsh are created at Don Edwards San Francisco Bay NWR (applies to Units R4, A1, and A2W). TME_O06. By 2023, approximately 90 acres (36 hectares) of transition zone habitat has been built at Don Edwards San Francisco Bay NWR (applies to Units R4, A1, A2W, and A8). TME_O07. By the completion of Phase 2 of the South Bay Salt Pond Restoration Project, western snowy plovers have been annually maintained at 250 breeding birds in the South Bay.
Restore and enhance tidal marsh: Bair Island, Don Edwards San Francisco Bay NWR	Land conversion, climate change	TME_O08. By 2028, upland transitional habitat at Inner Bair Island (approximately 40 acres) has at least 50% native plant cover. Upland transitional habitat includes marsh mounds and the marsh-upland ecotone.
Restore and enhance tidal marsh: LaRiviere Marsh and other existing marshes, Don Edwards San Francisco Bay NWR	Land conversion, climate change, infrastructure	TME_O09. By 2022, the FLAP project at Don Edwards San Francisco Bay NWR has been completed and met the success criteria outlined in the project: vegetative cover in the mitigation area and along the bridge construction area of 60% of the reference wetland adjacent to the mitigation site.
Sonoma Creek Marsh Enhancement Project—Phase II (San Pablo Bay NWR)	Land conversion, climate change, infrastructure	TME_O10. By 2025, an average of 5 inches of sediment accretes within the 100-acre central basin of the Sonoma Creek Marsh Enhancement Project site at San Pablo Bay NWR.
Predator management: Don Edwards San Francisco Bay NWR	Mammalian and avian predators	TME_O11. Over the next 6 years (2018–2023), there are no feral cat feeding stations directly adjacent to priority areas (as defined in predator management annual workplan) of Don Edwards San Francisco Bay NWR. TME_O12. By 2023, there is information available about the level of predation on waterbird and tidal marsh wildlife (rails or mice) and the effectiveness of current predator management activities at Don Edwards San Francisco Bay NWR. TME_O13. Over the next 15 years (2018–2032) there are no successful raven or raptor nests on PG&E towers in priority areas, as identified in the Don Edwards San Francisco Bay NWR Predator Management Plan and annual work plans. Objective applies to a select set of towers that are accessible.
Invasive plant management	Invasive plants	TME_O14. By 2022, a plan for preventing or reducing priority invasive plants at San Pablo Bay NWR is developed. Priority invasive plants were identified in 2013 and inventoried in from 2013 to 2016. The plan will incorporate and update information in 2007 *Lepidium latifolium* control plan. TME_O15. By 2022, the percent cover of Algerian sea lavender in tidal marsh at Don Edwards San Francisco Bay NWR is reduced by 50% of 2017 levels.

Strategy Title	*Threat Addressed*	*Expected Outcome (Objectives)*
Manage perennial pepperweed (*Lepidium latifolium*): San Pablo Bay NWR	Invasive plants	TME_O16. By the end of 2019, at least 80% of landowners (businesses and private landowners) adjacent to San Pablo Bay NWR are aware of *Lepidium latifolium* control success on the refuge. TME_O17. Over the next 15 years (2018–2032), percent cover of *Lepidium latifolium* is maintained at ≤5% of the 2007 baseline inventory (Hogle et al. 2007). This objective applies to the control/treatment area established in 2007, and includes the following management units: Tolay Creek, Lower Tubbs Island, Tubbs Island Setback, Sonoma Creek West, Sonoma Baylands, Strip Marsh West.
Eradicate invasive *Spartina* species	Invasive plants	TME_O18. By 2025, *Spartina densiflora* and *S. anglica* are eradicated (absence is documented over 3 consecutive years) at Don Edwards San Francisco Bay and San Pablo Bay NWRs. TME_O19. Over the next 8 years (2018–2025), there is a decrease (observed annually) in the percent cover of *Spartina alterniflora* (and hybrids) at Don Edwards San Francisco Bay and San Pablo Bay NWRs.

4.6.6 Natural Resource Surveys

Natural resource surveys needed to assess tidal marsh ecosystem health (goals) and effectiveness of refuge management strategies (objectives) are presented below (table 27). Surveys are listed in order of priority to conduct based on survey prioritization in 2017.

Table 27. Natural resource surveys to inform progress in achieving tidal marsh ecosystem goals and objectives at Don Edwards San Francisco Bay and San Pablo Bay National Wildlife Refuges.

Survey Name	*PRIMR ID*	*Status*	*Survey Frequency*	*Goal or Objective Informed by Survey*	*Survey Lead*
Don Edwards San Francisco Bay NWR					
Secretive marsh bird survey: Don Edwards San Francisco Bay and San Pablo Bay NWRs*	FF08RSFB00-052	Current	Annual	TME_G01, TME_G02	USFWS, San Francisco Bay NWR Complex
Western Snowy Plover Window Survey	FF08RSFB00-010	Current	Annual	TME_O07	Ben Pearl (SFBBO) and Cheryl Strong (USFWS)
Invasive *Spartina* survey*	FF08RSFB00-046	Current	Annual	TME_O18, TME_O19	California Coastal Conservancy, Invasive Spartina Project
Habitat Evolution Mapping Project (HEMP)*	FF08RSFB00-044	Current	Every 7 years	TME_G03, TME_O05, TME_O06	Brian Fulfrost and Associates
LaRiviere Monitoring Survey (FLAP project): vegetation survey*	FF08RSFB00-048	Current	Annual	TME_O09	USFWS, San Francisco Bay NWR Complex
Bair Island Restoration Project: ecotone vegetation composition survey	FF08RSFB00-065	Current	Annual	TME_O08	Save The Bay, San Francisco Bay Bird Observatory

Survey Name	*PRIMR ID*	*Status*	*Survey Frequency*	*Goal or Objective Informed by Survey*	*Survey Lead*
Weed inventory and monitoring	FF08RSFB00-017	Current	Annual	TME_O15	USFWS, San Francisco Bay NWR Complex
San Pablo Bay NWR					
Secretive marsh bird survey: Don Edwards San Francisco Bay and San Pablo Bay NWRs*	FF08RSNP00-049	Current	Annual	TME_G01, TME_G02	USFWS, San Francisco Bay NWR Complex
Salt marsh extent monitoring	FF08RSNP00-065	Expected	Every 5-10 years	TME_G03	USFWS, San Francisco Bay NWR Complex
Cullinan Ranch: sedimentation*	FF08RSNP00-031	Current	Every 5 years	TME_O01	Ducks Unlimited
Sonoma Creek: sediment accretion survey*	FF08RSNP00-055	Current	Every 2 years	TME_O10	USFWS, San Francisco Bay NWR Complex
Invasive *Spartina* survey*	FF08RSNP00-005	Current	Annual	TME_O18, TME_O19	California Coastal Conservancy, Invasive Spartina Project
Lepidium latifolium monitoring: San Pablo Bay NWR	FF08RSNP00-033	Expected	TBD	TME_O17	USFWS, San Francisco Bay NWR Complex
Tidal marsh transition zone native plant restoration monitoring	FF08RSNP00-016	Current	Annual	TME_O02	Students and Teachers Restoring a Watershed (Point Blue Conservation Science)

Notes: * = Survey also meets a regulatory permit requirement. TBD = to be determined in the future.

Survey status: current = survey is currently implemented on the refuge; expected = survey that will be conducted in future fiscal years. For some expected surveys, the survey frequency is an estimate and may change once a protocol is developed. Habitat evolution mapping (HEMP) used to measure extent of tidal marsh in the South San Francisco Bay—funding needed to expand this effort to San Pablo Bay or find other bay-wide methods that are more cost-effective.

4.7 Vernal Pool Grassland Ecosystem

Information sources used to describe the vernal pool grassland ecosystem are presented in the following. Any other sources are cited in-text.

- *Don Edwards San Francisco Bay National Wildlife Refuge Final Comprehensive Conservation Plan and Environmental Assessment* (USFWS 2012)
- *Recovery Plan for the Central California Distinct Population Segment of the California Tiger Salamander (Ambystoma californiense)* (USFWS 2017)
- *Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon* (USFWS 2005)
- *San Francisco Bay NWR Complex Climate Assessment* (CALCC et al. 2018)

4.7.1 Overview

Nested Targets of the Vernal Pool Grassland Ecosystem:

- Contra Costa goldfields
- Vernal pool native plants
- Vernal pool tadpole shrimp (VPTS)
- California tiger salamander (CTS)

The vernal pool grassland ecosystem is found on 719 acres Warm Springs Subunit of the Don Edwards San Francisco Bay NWR (figure 20). The initial 255 acres of the Warm Springs Subunit was acquired by the refuge in 1992. An additional 464 acres was later added, including the previously known Pacific Commons Preserve in 2012 by Catellus Development, along with a permanent endowment to ensure protection and restoration of its natural resources.

Vernal pools are precipitation-filled seasonal wetlands that experience periods of inundation, saturation, and also extreme desiccation for extended durations (Keeley and Zedler 1998). The vernal pool grasslands found at Warm Springs occur above the tideline atop clay soils along the margin of the Estuary. As the ecotone, or transition zone, between salt marsh and upland, the vernal pool grasslands represent a unique environment of the Estuary, providing habitat for a variety of rare and endemic vernal pool–adapted plants and animal species, including several which are federally listed as threatened or endangered. More than 250 vernal pools have been documented at Warm Springs (figure 23).

The vernal pool ecosystem at Warm Springs are classified as part of the "central coast vernal pool region" of California (Keeler-Wolf et al. 1998). Vernal pool regions of California and southern Oregon were identified largely on the basis of endemic species, with soils and geomorphology as secondary elements.

California's vernal pool ecosystems have been significantly fragmented and reduced in size by anthropogenic habitat alterations including urbanization, agricultural conversion, unsuitable grazing regimes, and non-native plant invasion. As a result, many of the endemic species that inhabit these vanishing wetlands are experiencing population declines, and some have become endangered.

4.7.2 Ecology

Acting as temporary wetlands, vernal pools retain rainwater and local runoff seasonally due to their largely impermeable underlying soil substrates. Fall and winter rains drive the "wet" period of the vernal pool hydrologic cycle. Initial rains stimulate plant germination and invertebrate hatching (Zedler 1987), and continued rains result in ponding. As precipitation declines in spring, vernal pools experience slow drying of surface water and substrate, with significant desiccation common by late summer (Zedler 2003). The result of this process is a gradient from the center of the pool to the surrounding upland edge, with flooding frequency, depth, duration, and timing varying considerably through the seasons. This gradient drives differences in vegetation and wildlife assemblages.

Vernal pool grassland at Don Edwards San Francisco Bay NWR. Credit: USFWS

The vernal pools and surrounding grasslands at Warm Springs provide habitat for Contra Costa goldfields (*Lasthenia conjugens*), which are federally listed as endangered, and numerous other vernal pool–obligate plant species. In addition, these areas provide habitat for the vernal pool tadpole shrimp (VPTS; *Lepidurus packardi*), which is federally listed as endangered, and CTS, which is federally listed as threatened and also a California Species of Special Concern.

Endemic to California and found mostly in the state's Central Valley and San Francisco Bay area, VPTS is usually found in sparsely-vegetated, grass-bottomed swales on old alluvial soils that are underlain by hardpan, or in mud-bottomed pools containing highly turbid water. At Warm Springs, VPTS is associated with mud-bottomed pools. During dry periods, VPTS occur as dormant cysts that can remain viable for up to 10 years. When rain falls, some of these cysts, or fertilized eggs protected with a hard shell to prevent dessication, will hatch. After 3–8 weeks, shrimp will reach sexual maturity and females will deposit eggs on vegetation and other objects on the bottom of pools. VPTS develop slowly and require a minimum hydroperiod of about 6–7 weeks to reach reproductive maturity. Inundation period, or the length of time the pool holds water, is an important factor in determining which vernal pools provide suitable breeding habitat for VPTS as well as CTS, with pools with observed VPTS or CTS larvae exhibiting greater maximum depths and inundation periods, on average, than pools where these species were not observed (WRA Environmental Consultants 2012).

CTS found at Warm Springs depends on the vernal pools and the surrounding grasslands to survive and reproduce. While CTS breeds in the vernal pools, it is otherwise terrestrial and spends most of its post-metamorphic life in widely dispersed underground retreats, such as the burrows of small mammals such as ground squirrels.

Prior to 1999, the vernal pool grassland ecosystem at Warm Springs was highly altered as a result of human uses including farming, a glider airport, and a racetrack. Much of the area was leveled but several vernal pools remained untouched. Restoration of this area began in 1999 by Catellus Development as mitigation for adjacent retail development. In 2012, management of the Pacific Commons area was turned over to Don Edwards San Francisco Bay NWR, along with a permanent endowment to provide for management in perpetuity.

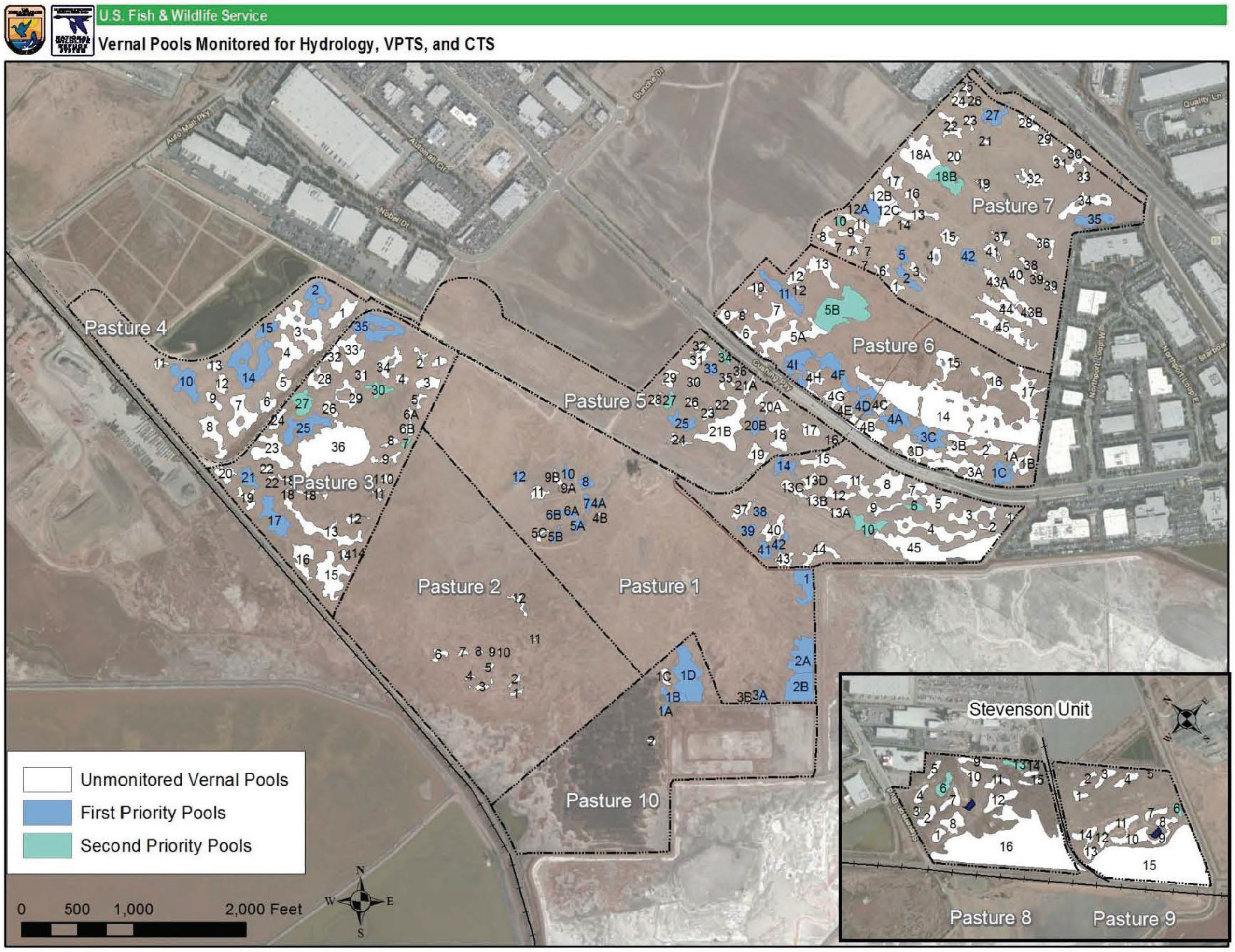


Figure 23. Vernal pools monitored for hydroperiod, California tiger salamander (CTS) and vernal pool tadpole shrimp (VPTS) in the Warm Springs Subunit (Mowry Unit) at Don Edwards San Francisco Bay National Wildlife Refuge.

Source: (Kakouros and Loredo 2016).

4.7.3 Target Status, Trends, and Goals

Three KEAs and associated indicators were selected to represent the ecological integrity and health of the vernal pool grassland ecosystem at Don Edwards San Francisco Bay NWR: 1) CTS breeding activity and vernal pool hydrology, 2) grassland vegetation structure and composition, 3) vernal pool vegetation composition, and 4) presence of VPTS. Based on current knowledge of the status and trends of the three KEAs and associated indicators, the health of the vernal pool grassland ecosystem at Don Edwards San Francisco Bay NWR is considered Fair. The relationship between indicator measures and the status of the vernal pool grassland ecosystem (Poor to Very Good) is detailed in the Refuge Complex conservation target viability database (appendix B). A summary of KEAs, associated indicators, indicator status and trends, and desired future conditions (SMART goals) is presented in table 28.

KEA 1, 4: California Tiger Salamander Breeding Activity, Presence of Vernal Pool Tadpole Shrimp

The vernal pool grassland ecosystem consists of two distinct features: pools and uplands. Vernal pool ecosystems depend on rainfall during the rainy season, and the duration of ponding in individual pools typically determines whether obligate vernal pool species can successfully complete their life cycles. Thus, hydrology monitoring at Warm Springs is crucial to understanding broad-scale patterns in habitat conditions, vegetation, and wildlife populations such as CTS and VPTS. In that CTS requires both the vernal pools and the surrounding grasslands to complete their life cycle, its habitat needs are similar to some aquatic species (such as VPTS) and upland species (such as burrowing owls) at Warm Springs. Because CTS is assumed to complete its entire life cycle at the site (a barrier fence prevents CTS movement out of the Warm Springs Uni), we infer CTS breeding activity reflects the health of the ecosystem at Warm Springs.

CTS breeding activity is indicated by the average number of pools (of 58 that are monitored) with CTS larvae present and adequate hydroperiods for metamorphosis (typically at least 100 days continuous inundation with water depth > 5 centimeters); this average is calculated as a mean of the highest 3 of the previous 5 years (table 1). Given the large number of pools in the Warm Springs Subunit, a representative subset of vernal pools is monitored annually (figure 27). Monitoring of hydrology, VPTS, and CTS occur in the same subset of pools. Pool duration is the principal factor determining CTS persistence and survival, with longer periods of inundation allowing for larger growth of metamorphs and increased chances of survival (Kakouros and Loredo 2016). Refuge surveys show reproductive success of CTS and other vernal pool plants and animals at Warm Springs is strongly influenced by rainfall and resulting pool inundation duration. In recent years, Warm Springs has experienced extreme precipitation conditions ranging from heavy rainfall and runoff to record drought conditions. For example, in 2012, a below-average rainfall year, there were only one CTS and two VPTS observations (table 28). Since 2000, there have been three other years (2001, 2007, and 2014) where CTS breeding was not documented (WRA Environmental Consultants 2012, Kakouros and Loredo 2016). Average inundation was 116 days in 2013 and 131 in 2015 (range = 50–177 days). Average inundation in 2012 and 2014 was 6 days and 20 days, respectively, explaining the much lower observance of CTS and VPTS (table 28).

From 2013 to 2017, the average annual number of adequate pools was 31.3, and the trend is increasing. This measure is considered Very Good (table 29). During this same period, the annual average number of pools (of 58 that are monitored in Warm Springs Subunit) with VPTS present and hydroperiod adequate to allow for completion of breeding cycle (typically 54 days) was 48 pools. This measure is considered Very Good (table 29).

Table 28. Number of pools containing California tiger salamander and vernal pool tadpole shrimp in relation to vernal pool hydroperiod (pool inundation) at the Warm Springs Subunit of Don Edwards San Francisco Bay National Wildlife Refuge, 2012–2015.

	2012	*2013*	*2014*	*2015*
Vernal pool inundation	6	116	20	131
California tiger salamander	1	31	0	31
Vernal pool tadpool shrimp	2	43	0	50

Note: Pool inundation = mean number of days vernal pools were inundated with water >5cm in the deepest part of the pool (N=58 pools).

Source: Kakouros and Loredo 2016.

KEA 2: Grassland Vegetation Structure and Composition

Grassland vegetation structure and composition is indicated by 1) percent absolute cover native plant species (for each pasture, N=4) and 2) native plant species richness measured over a 7-year period in the Warm Springs Subunit. Both vegetation structure and composition influence the ecological integrity of the ecosystem and reflect the state of key ecological processes. Nutrient cycling, food resource seasonal availability, availability of nesting habitat, and many other ecological attributes are dependent on vegetation composition either directly or indirectly. The term *composition* here refers to the abundance and richness of native plant species. The abundance of native plant species and specifically the metric of native plant cover has been used by many as an indicator of a healthy grassland ecosystem (Martin et al. 2005, Ruiz-Jaen and Aide 2005, Gannon et al. 2013).

KEA 3: Vernal Pool Vegetation Composition

Vernal pool vegetation composition is indicated by the percent relative cover of native vernal pool and wetland plant species (table 29). Relative cover of vernal pool–obligate species and wetland species indicates the state of ecosystem processes, such as the hydrological regime. Vernal pool species can be surveyed during a very narrow timeframe (usually April) and cannot be combined with later spring or summer surveys. Thus, while data from vernal pool vegetation and grassland vegetation do not overlap, they are complementary for describing the state of the vernal pool grassland ecosystem. In addition to developing a better understanding of native and non-native plant species in the Warm Springs Subunit, vernal pool grassland vegetation indicators will support the broader strategic goals of the *National Invasive Species Management Plan* as well as the USFWS's *Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon*.

Table 29. Current status and desired future state (goals) of the vernal pool grassland ecosystem at Don Edwards San Francisco Bay National Wildlife Refuge in terms of select indicators.

Key Ecological Attribute	*Indicator*	*Status (Trend)*	*Status Source*	*Goal*
California tiger salamander breeding activity and vernal pool hydrology	Average annual number of pools (of 58 that are monitored in Warm Springs Subunit) with CTS larvae present **and** adequate hydroperiods for metamorphosis (typically at least 100 days continuous inundation with water depths of more than 5 centimeters). Average calculated as the mean of the highest 3 values over the last 5 years.	31.3 pools (increasing)	Warm Springs dataset (2017)	VPG_G01. Over the next 5 years (2018–2022), the average annual number of pools occupied by California tiger salamanders is >27 (of the 58 pools monitored and with adequate hydroperiods for metamorphosis—typically at least 100 days with water depths more than 5 centimeters) at the Warm Springs Subunit of Don Edwards San Francisco Bay NWR. The average is calculated as the mean of the highest 3 of the last 5 years.
Grassland vegetation structure and composition	% absolute cover native plant species (for each pasture, N=4)	32% (>50% in two pastures, >20% in five pastures), < 20% in three pastures) (increasing)	Warm Springs dataset (2017	VPG_G02. By 2032, absolute native plant species cover is ≥20% in eight pastures and ≥50% in four pastures at the Warm Springs Subunit of Don Edwards San Francisco Bay NWR.
Grassland vegetation structure and composition	Native plant species richness measured over a 7-year period	To be determined for the period 2013–2019	Warm Springs dataset (2017)	VPG_G03. By 2027, maintain or increase native plant species richness (relative to 2013–2019) at the Warm Springs Subunit of Don Edwards San Francisco Bay NWR.
Vernal pool vegetation composition	% relative cover of native vernal pool and wetland plant species	438% (increasing)	Warm Springs dataset (2017)	VPG_G04. By 2032, relative cover of native vernal pool and wetland plant species is ≥35% at the Warm Springs Subunit of Don Edwards San Francisco Bay NWR. Measure based on an average of 19 pools monitored.
Vernal pool vegetation composition	Native vernal pool and wetland plant species richness	To be determined for the period 2013–2019	Warm Springs dataset (2017)	VPG_G05. By 2026, maintain or increase the number of native vernal pool and wetland plant species (relative to 2013–2019) in 19 vernal pools monitored for vegetation at the Warm Springs Subunit of Don Edwards San Francisco Bay NWR.
Presence of vernal pool tadpole shrimp	Average annual number of pools (of 58 that are monitored in Warm Springs Subunit) with VPTS present and hydroperiod adequate to allow for completion of breeding cycle (typically 54 days). Average calculated as the mean of the highest 3 values over the last 5 years.	48 pools (stable)	Warm Springs dataset (2107)	VPG_G06. Over the next 5 years (2018–2022), the average annual number of pools occupied by vernal pool tadpole shrimp is >40 (of the 58 pools monitored and with adequate hydroperiods to complete breeding cycle—typically 54 days) at the Warm Springs Subunit of Don Edwards San Francisco Bay NWR. The average is calculated as the mean of the highest 3 of the last 5 years.

Note: Status designations: red = Poor, yellow = Fair, light green = Good, dark green = Very Good. Refer to the San Francisco Bay National Wildlife Refuge Complex viability database for additional details (appendix B).

4.7.4 Critical Threats

The most critical threats (High or Very High) to the vernal pool grassland ecosystem are climate change, invasive plants, and lack of native grazers. Lower ranked threats (Low to Medium) are transportation corridors (roads, railways, levees), land conversion, invasive aquatic wildlife mosquito control pesticides, pollution, disease, native nuisance species (predators), illegal activities by humans, and mosquito management disturbance. A conceptual model depicting threats to the vernal pool ecosystem, their relationship to biophysical factors of the ecosystem, and strategies aimed at reducing the most critical threats is depicted in figure 24. The most critical threats (High to Very High) to the vernal pool ecosystem are summarized in the following.

Climate Change (High-Very high threat)

Climate change is expected to alter the amount and timing of precipitation events, and vernal pools are sensitive to such changes. Vernal pool species are typically adapted to seasonal drought (Zedler 2003), but severe drought periods can completely prevent vernal pool ponding, and many pools experience minimal ponding duration in years with below-average precipitation (Bauder 2005). Reduced precipitation results in a shorter hydroperiod and drier conditions. These changes would likely alter habitat suitability for a variety of vernal pool obligate species (as evidenced at Warm Springs in past years) and make vernal pools more vulnerable to exotic invasion (Marty 2005). Common invasive grasses are likely to benefit from drying, because they are intolerant of extended inundation and their abundance declines with increasing vernal pool water depth (Gerhardt and Collinge 2003). However, some invasive species also experience increased growth during high precipitation years (such as during El Niño) (Bauder 2005).

Even small hydroperiod reductions can affect community diversity and habitat suitability for plant and animal species, particularly those with longer aquatic life stages (such as CTS, Marty 2005). Vernal pool obligates with life histories that are tightly coupled to hydrological conditions, such as VPTS, will be most vulnerable to reduced hydroperiod.

In conjunction with total annual rainfall, shifts in seasonal precipitation patterns will influence ponding frequency and duration. For example, in several southern California study sites, high rainfall delivered in discrete periods yielded longer ponding time than the same rainfall volume distributed equally throughout the season in years with average precipitation. However, at the same study sites during years with low annual precipitation, consistent rain favored longer ponding times than discrete, intense rainfall events (Bauder 2005). Larger, deeper pools may show less of a response to precipitation shifts than shallow pools that currently provide marginal habitat (Pyke 2005).

Extreme Events: Flooding

Vernal pools are adapted to seasonal flooding. Prolonged flooding (usually a result of human modifications) can cause seed rot and trigger novel germination patterns, potentially facilitating vegetation shifts, including shifts to more permanent wetland-affiliated vegetation. Prolonged inundation can also increase habitat suitability for key crustacean predators, including fish and bullfrogs (USFWS 2005).

Water Temperature

Water temperature affects vernal pool crustacean hatching (Eriksen and Belk 1999) and development rates and influences immature and adult crustacean mortality (Helm 1998).

Invasive Plants (High threat)

Invasive plants can significantly deteriorate the ecological integrity of vernal pool grassland ecosystem in multiple ways. Invasive plants may displace native plant species, alter plant community structure (such as height), alter the soil chemistry through allelopathy, alter the nutrient cycle, alter the vernal pool hydrology, increase thatch accumulation, and destroy important microhabitats for native species (plant and animal) (Tilman 1997, Gerhardt and Collinge 2003, Marty 2005, Ford et al. 2013). For example, some invasive plants can increase vegetation height in areas where short vegetation height is crucial for many vernal pool grassland–associated wildlife species such as California ground squirrel (*Spermophilus beecheyi*), CTS, and burrowing owl (Ford et al. 2013). Other invasive plant species, such as non-native mustards and thistles, invade areas freshly excavated by ground squirrels and block burrow entrances, reducing the availability of habitat for burrowing species such as CTS. Perennial pepperweed invades pools and uplands forming monotypic stands. In the summer, stinkwort (*Dittrichia graveolens*) proliferates on disturbed areas or at edges of the pools. This is a genus that may inhibit germination of other species through allelopathy and has been recorded to even affect growth of other species (Levizou et al. 2013).

Factors that contribute positively (+) or negatively (-) to the invasive plant threat include:

- **Refuge management activities (+/-)**. Vehicles, staff, and volunteers are potential carriers of non-native species seed.
- **Adjacent source population (-)**. Warm Springs Subunit is surrounded by lands where invasive species thrive. The disturbed grounds include a landfill, a public trail, railroad tracks, and landscaped commercial lands. This means that even if total control of invasive species occurs in the Warm Springs Subunit, seeds from the surrounding lands may easily enter the unit and create new infestations.
- **Land conversion (legacy or current) (-)**. The history of land use on the site may affect soil quality, invasive species seed bank, and transient patterns in the formation of species communities. For example, parts of the Warm Springs Subunit, particularly the lands acquired through mitigation in 2012. These lands were formerly used for agricultural production, a racetrack, and an airport. The historic vernal pools had been levelled and were then restored as mitigation for an adjacent development. This history of land conversion has altered the natural topography and ecosystem processes, and those disturbed areas remain the most impacted by invasive weeds.
- **Mosquito abatement (-)**. Mosquito abatement personnel may transfer weed seeds from other areas they treat.
- **Grazing (+/-)**. Animals may carry non-native seeds from areas outside of Warm Springs or among pastures. In addition, the use of hay to attract and herd cattle may result in the introduction of non-native weeds.
- **Ground squirrel disturbance (-)**. The ground disturbance from ground squirrels favors the exposure of the old invasive plant seed bank and/or creates ideal conditions for the proliferation of common invasive plants.

Lack of Native Grazers (High Threat)

Large native ungulates (such as elk) historically occurred in the vernal pool grassland ecosystem at Warm Springs (Wagner 1989). These native grazers kept grassland vegetation short overall and did not allow for woody vegetation to take over (Barry et al. 2006). Native grazers created matrices of microhabitats and affected niche dynamics (Bush and Ptak 2006). They also influenced vernal pool hydrology, especially claypan pools: trampling increases the soil compaction, which in turn lengthens the inundation period. A longer inundation period is necessary for several vernal pool-obligate wildlife species to complete their breeding cycles and creates favorable conditions for vernal pool plants. Native grazers also consumed a large amount of biomass and through trampling increased the rate of organic matter decomposition. Increased decomposition reduced the accumulation of thatch, a favorable condition for native vernal pool plants that cannot germinate under a thick layer of thatch. Ungulate trampling also increased turbidity of the pools, lowering the predation pressure on CTS and VPTS (Ford et al. 2013). Finally, ground disturbance created by native ungulates benefited several native forb species which were very important to pollinators and other insects but also sustained a persistent seedbank of early successional species (pioneers). These pioneer species thrive only in disturbed grounds, and their presence increases the resilience of the ecosystem under environmental and biotic stresses (Mall et al. 2017).

4.7.5 Conservation Strategies

Strategies for the vernal pool grassland ecosystem are presented in the following. Threats addressed by each strategy and expected outcomes (objectives) are summarized in table 30. Each strategy is briefly described below in order of priority to implement. Results chains visually depicting the assumptions behind these strategies (how they work) and expected outcomes are presented in a Miradi file associated with this NRMP (appendix B).

Implement Grazing Program to Maintain Vernal Pool Shortgrass Habitat

The purpose of this strategy is to mimic the benefits provided by native ungulate grazers, a historic feature of the vernal pool grassland ecosystem (see previous section, "Lack of Native Grazers"). Cattle grazing at Warm Springs occurred over the last century and remains in practice on approximately 680 acres of Warm Springs. Non-native grasses accumulated in vernal pools when the refuge ceased grazing upon acquisition of Warm Springs in 1992. After non-natives were observed and a decline in native plant abundance became apparent, grazing was re-introduced to the Warm Springs area as part of a cooperative land management agreement (CLMA) with a local rancher. A CLMA was completed between the Refuge and a cooperative grazer (USFWS 2012). According to this CLMA, the cooperative grazer has to provide services-in-kind exchange for grazing. Services provided by the cooperative grazer include fence and road maintenance, herbicide spraying, weed mechanical control, trash pickup, and other tasks that require heavy equipment use. In 2012, grazing was approved as an appropriate use at Warm Springs for its utility in controlling non-native weeds and allowing native vernal pool and grassland vegetation to thrive and provide benefits to vernal pool-adapted species. Under the CLMA, a rotational cattle-grazing program is implemented on 10 pastures, each of them grazed according to the refuge grazing management plan (USFWS 2004). Detailed information regarding the rotational schedule, the framework of decision-making, and grazing monitoring can be found in the biological monitoring plan for the Warm Springs unit of Don Edwards San Francisco Bay NWR (WRA Environmental Consultants 2012).

Invasive Plant Management: Warm Springs Subunit

Invasive plants are one of the most critical threats to the vernal pool grassland ecosystem of the Refuge Complex. At Warm Springs, the focus of invasive plant management efforts is on species that are not already widespread, such as non-native annual grasses. Although it is well documented that exotic annual grasses negatively impact vernal pool grasslands, the likelihood of reducing or eradicating them is unlikely. Rather, the Refuge Complex uses grazing to control the grass height and imitate biomass cycling and vegetation structure of a more native ecosystem. Therefore, the focus of invasive plant management efforts at Warm Springs is mostly on non-native forb species that can further harm the integrity of the vernal pool grassland ecosystem. Targeted species are identified in the biological monitoring plan for the Warm Springs unit of Don Edwards San Francisco Bay NWR (WRA Environmental Consultants 2012) and in the *South San Francisco Bay Weed Management Plan* (Marriott et al. 2013). Invasive plant populations are controlled using chemical, physical, and cultural (grazing) techniques. These techniques are used in combination with native plant restoration (see strategy in the following).

Targeted invasive plant infestations are visually assessed and recorded on paper maps along with notes about effectiveness of control efforts. A more quantitative measure of target non-native species status is provided using data from the summer vegetation survey. This information is used to inform invasive plant control (treatment) decisions following general guidelines specified in the *South San Francisco Bay Weed Management Plan* (Marriott et al. 2013), site-specific conditions, and available resources.

Chemical control is conducted by trained staff and by the cooperative grazer as service hours in lieu of grazing fees. In this latter case, maps, herbicide prescriptions, and special directions are provided by Warm Springs staff. Mechanical control will be directed by the Warm Springs Manager and the Refuge Complex botanist and conducted by staff, partners, and volunteers. Specifically, volunteer weeding events are organized from March through October to tackle small and dispersed infestations of annual weeds. Our volunteers include the general public, environmental organizations, college groups, corporate groups, and high schools.

Lastly, control of non-native target species is provided through the Refuge Complex's partnership with Santa Clara Valley Habitat Agency and SFBBO for the enhancement of burrowing owl habitat project. This project focuses on maintaining short vegetation around burrows (including historic and current burrowing owl nests) and suppressing target non-native plants that proliferate on burrow mounds. SFBBO staff leads and conducts these weeding activities following refuge protocols. This project is funded through burrowing owl mitigation funds managed by the Santa Clara Valley Habitat Agency.

Restore Vernal Pool and Upland Native Plant Communities

Restoring ecological processes in a vernal pool grassland ecosystem, such as through reintroducing grazing or modifying the pool depth, may move the system towards a recovery trajectory, but often times more active restoration techniques are needed to expedite recovery (Wright 2009, Collinge and Ray 2009). In grassland and vernal pool restoration, research has shown that lack of adequate seedbank of native species is among the top limiting factors in vernal pool and grassland restoration, and seeding or planting repeatedly over the years can lead to a more sustainable and resilient plant community (Martin and Wisley 2006). Strong presence of native species is associated with higher resistance to exotic species invasion (Collinge et al. 2011). Choice of methods, materials, and intensity of intervention requires careful examination of many biotic and abiotic factors as well as the disturbance history of each pool or upland site for ecosystem restoration (Dessaint et al. 1997, Gerhardt and Collinge 2003, Collinge et al. 2013, University of California 2017). The strategy at the Warm Springs Subunit is to identify and adaptively use appropriate methods to restore or enhance native plant communities in vernal pool and uplands in priority areas. Because of the different processes that drive vegetation recruitment in pools versus upland sites, we identified the need of different restoration approaches in these two habitats.

Specifically, for the pools, selection of priority areas will be based on the findings of the vernal pool research (see strategy in the following). We propose to actively enhance these areas by re-vegetating sites with priority native plant species through seeding. Securing adequate quantities of seed may involve seed amplification offsite. The products of our research strategy, which aims to identify vernal pool plant species habitat requirements, germination cues, and interactions with pollinators, will inform the selection of restoration sites, protocols, applied methods, seeding palettes, etc.

For the uplands, selection will be based on summer vegetation survey data, observations during routine site visits, and wildlife habitat management needs. We will use both seeding and planting. For seeding we will use seeds collected from onsite when available in sufficient quantities or from local sources and/or similar ecotypes. For plant stock, where the amount of seeds needed is generally low, only seeds collected onsite will be used in order to preserve genetic integrity.

Research: Vernal Pool Plant Habitat Needs for Germination and Pollinators

Increased understanding about vernal pool plant species requirement as well as plant community dynamics to inform how best to restore the vernal pool plant community. The Refuge Complex will develop partnerships with universities to study vernal pool plant habitats, germination, and pollinator needs with an emphasis on the dynamics at Warm Springs Subunit. This strategy also involves analysis of the Warm Springs historical survey and restoration data against microhabitat and environmental conditions (e.g., soil, climate, geology, hydrology). This knowledge will also help inform a vernal pool plant restoration strategy. We expect that some of the knowledge gaps we have identified can be answered by the scientific literature and a literature review is part of this strategy. However, we expect we will still need site-specific information to select the best pools for restoration.

The work product of this strategy will support our vernal pool restoration strategy but also will inform the implementation of the grazing program and invasive plant management.

Table 30. Vernal pool grassland ecosystem conservation strategies and associated objectives.

Strategy Title	*Threat Addressed*	*Expected Outcome (Objectives)*
Implement grazing program to maintain vernal pool shortgrass habitat	Lack of native grazers	VPG_O01. Over the next 15 years (2018–2032), annually maintain residual dry matter to 1,000-1,500 pounds/acre at the end of the growth cycle (end of September) in upland grassland areas of the Warm Springs Subunit of Don Edwards San Francisco Bay NWR.
Manage target non-native plants (Don Edwards San Francisco Bay NWR: Warm Springs Subunit)	Invasive plants	VPG_O02. Over the next 15 years (2018–2032), targeted non-native plant species (excluding grasses) comprise <30% cover at the Warm Springs Subunit of Don Edwards San Francisco Bay NWR. Targeted non-native plant species are identified in the *Warm Springs Monitoring Plan* and in the *South San Francisco Bay Weed Management Plan*. VPG_O03. Through 2023, vegetation height is maintained at <6 inches around select ground squirrel burrows in order to provide summering habitat for California tiger salamanders at the Warm Springs Subunit of Don Edwards San Francisco Bay NWR.
Restore vernal pool and upland native plant communities	Invasive plants, lack of native grazers	VPG_O04. Relative cover of native plant species increases by ≥5% within 4 years of vernal pool plant restoration (seeding/planting native plants) at the Warm Springs Subunit of Don Edwards San Francisco Bay NWR. VPG_O05. Absolute cover of native plant species increases by ≥10% within 5 years of vernal pool plant restoration (seeding/planting native plants) at the Warm Springs Subunit of Don Edwards San Francisco Bay NWR.

Note: Strategies are listed in order of priority to implement.

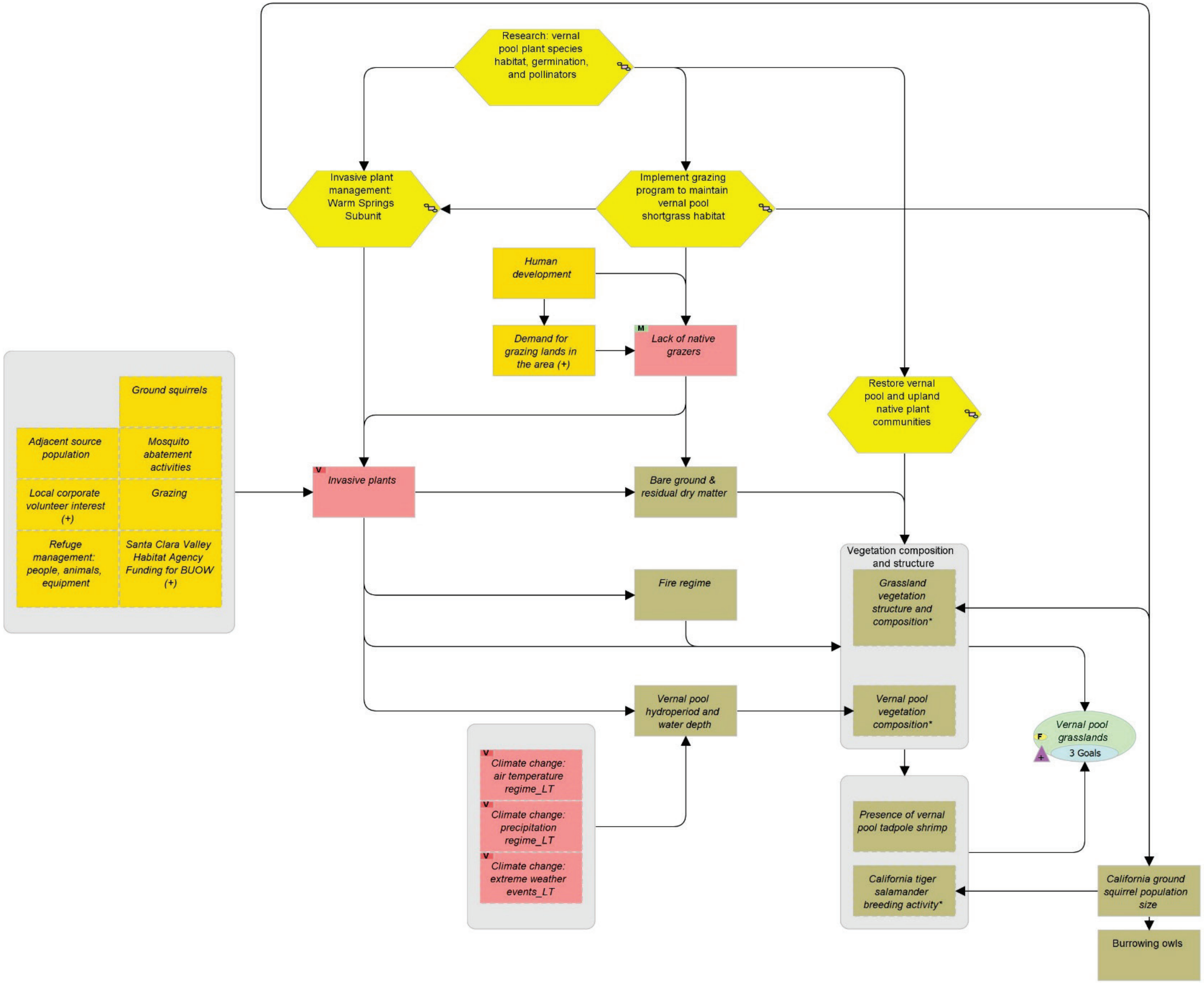


Figure 24. Conceptual model of the vernal pool grassland ecosystem at Don Edwards San Francisco Bay National Wildlife Refuge depicting natural resource threats and strategies aimed at addressing the most critical threats (ranked High or Very High).

Notes: Legend: green oval = natural resource conservation target; olive box = biophysical attribute; pink box = direct threat; orange box = contributing factors; yellow hexagon = conservation strategy. The letters in the upper left portion of threats (pink boxes) represent the summary threat ranking across the seven refuges of the San Francisco National Wildlife Refuge Complex (L=low, M=moderate, H=high, VH=very high).

4.7.6 Natural Resource Surveys

Natural resource surveys to evaluate vernal pool grassland ecosystem health (goals) and effectiveness of conservation strategies (objectives) are presented below (table 31). Surveys are listed in order of priority to conduct based on survey prioritization in 2017.

Table 31. Vernal pool grassland ecosystem natural resource surveys to inform management effectiveness and progress on goals and objectives.

Survey Name	*PRIMR ID*	*Status*	*Survey Frequency*	*Goal or Objective Informed by Survey*	*Survey Lead*
Vernal pool vegetation survey	FF08RSFB00-024	Current	1	VPG_G04, VPG_G05	USFWS, San Francisco Bay NWR Complex
Native plant restoration success survey	FF08RSFB00-026	Expected	3	VPG_O04, VPG_O05	USFWS, San Francisco Bay NWR Complex
Vernal pool hydroperiod survey	FF08RSFB00-027	Current	1	VPG_G01, VPG_G06	USFWS, San Francisco Bay NWR Complex
Residual dry matter survey	FF08RSFB00-015	Current	1	VPG_O01	USFWS, San Francisco Bay NWR Complex
California tiger salamander and vernal pool tadpole shrimp survey	FF08RSFB00-028	Current	1	VPG_G01, VPG_G06	USFWS, San Francisco Bay NWR Complex
Summer vegetation survey	FF08RSFB00-029	Current	1	VPG_O02	USFWS, San Francisco Bay NWR Complex

Notes: Survey status, current = survey is currently implemented on the refuge; expected = survey will likely be implemented. For expected surveys, the survey frequency is an estimate and may change once a protocol is developed.

4.8 Waterbirds

Primary information sources used for this chapter are presented below. Any other sources of information are directly cited in-text.

- *Citizen Science-Based Colonial Waterbird Monitoring: 2016 Nesting Summary* (Tarjan 2016)
- *Don Edwards San Francisco Bay NWR Comprehensive Conservation Plan* (USFWS 2012)
- *Marin Islands NWR Comprehensive Conservation Plan* (USFWS 2007)
- *San Francisco Bay NWR Complex Climate Assessment* (CALCC et al. 2018)
- *San Pablo Bay NWR Comprehensive Conservation Plan* (USFWS 2011)
- *Western snowy plover monitoring in the San Francisco Bay* (San Francisco Bay Bird Observatory 2016)

4.8.1 Overview

> **Waterbird Nested Targets:**
>
> - Breeding waterbirds at Don Edwards San Francisco Bay NWR
> - Breeding waterbirds at Marin Islands NWR and State Ecological Reserve
> - Wintering waterbirds at Don Edwards San Francisco Bay NWR and San Pablo Bay NWR

The waterbird target encompasses bird species that depend on wetlands of the Estuary, particularly wetlands of San Pablo Bay NWR and Marin Islands NWR and State Ecological Reserve (Marin Islands) in the northern portion of the Estuary, and Don Edwards San Francisco Bay NWR in the southern portion of the Estuary (figure 2). These refuges were established in part to protect migratory birds. Wetland environments found at these refuges, and the larger Estuary, are critically important to waterbirds along the Pacific Flyway. For example, from 1981–2012, the Estuary supported a large proportion of the lower Pacific Flyway[5] mid-winter waterfowl count for diving ducks: 60% for greater and lesser scaup (*Aythya marila, A. affinis*), 54% for scoter (*Melanitta* spp.), 51% for canvasback (*Aythya valisineria*), 36% for ruddy duck (*Oxyura jamaicensis*), and 32% for bufflehead (*Bucephala albeola*) (Richmond et al. 2014). Shorebird surveys also show the Estuary is critical to shorebirds. Surveys conducted from 1988 to 1993 annually supported more than 325,000 shorebirds in autumn and early winter, 225,000 in late winter, and as many as 932,000 during spring migration (Stenzel et al. 2002). Because of the Estuary's importance to waterbird conservation, it has been formally recognized by the global conservation community. For example, the Estuary is designated as a site of hemispheric importance to shorebirds by the Western Hemisphere Shorebird Reserve Network. Portions of the Estuary that encompass San Pablo Bay and Don Edwards San Francisco Bay NWRs are also recognized by Audubon as Important Bird Areas in California. Lastly, South San Francisco Bay is designated as a Globally Important Bird Area by the America Bird Conservancy due to the high diversity of waterbird habitats and abundance of bird species it supports. Wetland losses throughout California and in other places along the Pacific Flyway over the last century have made the Estuary's protected wetland areas, including those of the Complex, increasingly important in conserving Pacific Flyway migratory waterbird populations.

4.8.2 Ecology

Don Edwards San Francisco Bay, San Pablo Bay NWR, and the Marin Islands together provide a wide diversity of environments used by waterbirds, including open bay, intertidal mudflats, salt and freshwater marshes, terrestrial islands, and managed ponds (former salt ponds and active salt evaporation ponds). Waterbirds are present throughout the year although the highest densities are found during migration and winter. Each of the refuges plays an important role in providing breeding, wintering, or migratory habitat for waterbirds in the Estuary. For example, the Don Edwards San Francisco Bay NWR former salt ponds provide critical breeding habitat for shorebirds and terns. San Pablo Bay NWR provides extensive open water and tidal mudflat environments used by wintering and migratory shorebirds and waterfowl. Lastly, Marin Islands NWR has provided protected breeding habitat for one of the largest heron and egret breeding colonies in the Estuary.

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[5] South of the Canadian border, including parts of Arizona, California, Colorado, Idaho, Montana, New Mexico, Oregon, Utah, Washington, and Wyoming.

Breeding Waterbirds at Don Edwards San Francisco Bay NWR

At Don Edwards San Francisco Bay NWR, breeding waterbirds utilize mudflats, managed ponds, and tidal marsh areas. Waterbirds of particular conservation concern include Forster's tern (*Sterna forsteri Nuttall*), American Avocet *(Recurvirostra americana Gmelin*), and the federally endangered SNPL. Breeding habitat for these species is predominantly found in managed ponds of the refuge.

Snowy plover (*Charadrius nivosus nivosus*) chick and eggs.
Credit: M. Kern, San Francisco Bay Bird Observatory

Forster's terns and American avocets

The managed ponds at Don Edwards San Francisco Bay NWR provide habitat to one of the largest breeding populations of American avocets and Forster's terns along the Pacific Coast (Ackerman and Herzog 2012). Approximately 30 percent of the breeding population of Forster's terns on the Pacific Coast nests in the southern part of the Estuary (South Bay, San Francisco Bay) (McNicholl et al. 2001, Strong et al. 2004), and the islands within managed ponds here currently provide nesting habitat for 80 percent of those terns (Strong et al. 2004). Thus, the South Bay accounts for about one-quarter of the nesting habitat on the Pacific Coast. Similarly, the Estuary is the largest breeding area for avocets along the Pacific Coast (Stenzel et al. 2002, Rintoul et al. 2003), and 75 percent of breeding avocets in the South Bay nest on islands within managed ponds (Ackerman et al. 2013).

Snowy plovers

SNPL breeds and forages at several sites within the Don Edwards San Francisco Bay NWR. Coastal breeding SNPL have declined throughout their geographic range as a result of poor reproductive success that is attributed to habitat loss, habitat alteration, human disturbance, and increasing predation pressure (Page et al. 1991, USFWS 2007). As a result, the species was listed as federally threatened in 1993. Lands of the Don Edwards San Francisco Bay NWR are part of the SNPL recovery unit 3, which includes San Francisco Bay; Napa, Alameda, and Santa Clara Counties; and the eastern portion of San Mateo County (USFWS 2007). SNPL breeding habitat on the refuge is predominantly found in former salt evaporation ponds (dry salt pannes, pond islands, levees, and berms). The refuge does not play a significant role in conservation of SNPLs in the San Francisco Estuary relative to other conservation lands (such as the California Department of Fish and Wildlife Eden Landing) but it still plays an important role in the recovery of this species. Of primary concern is ensuring tidal marsh restoration activities do not harm SNPL populations (see section 4.6.5 "Conservation Strategies" and table 26 [TME_O07]).

Breeding Waterbirds at Marin Islands NWR

According to the environmental assessment establishing the Marin Islands NWR, the refuge protects an important existing egret and heron rookery. West Marin Island once supported one of the largest egret and heron colonies in the Estuary. More recently, the rookery has crashed, likely as a result of mammalian predation (Kelly et al. 2015, 2016). Waterbirds also use the refuge during winter but little documentation exists about wintering waterbird status and trends here.

Marin Islands, Marin County, CA. Credit: USFWS

Wintering Waterbirds at Don Edwards San Francisco Bay NWR and San Pablo Bay NWR

Wintering marbled godwits (*Limosa fedoa*) and willets (*Tringa semipalmata*). Credit: Judy Irving © Pelican Media

Wintering waterbirds encompasses waterfowl and shorebirds that use environments of Don Edwards San Francisco Bay and San Pablo Bay NWRs during winter or migration. Wintering waterfowl include many species including northern shoveler, canvasbacks, scaup, and scoters. Historically, the Estuary was the primary wintering area for the Pacific Flyway canvasback population, and the San Pablo Bay NWR was established, in part, for its importance as wintering habitat for migratory waterfowl, particularly canvasbacks. Shorebirds also use refuge lands of the Estuary to overwinter or as a stopover during migration. San Francisco Bay holds higher proportions of the Southern Pacific region's total wintering and migrating shorebirds than any other coastal wetland within the Pacific coast wetland system, including species such as least sandpiper, willet, and long-billed curlew (Page et al. 1999). At San Pablo Bay NWR, the extensive open bay and tidal mudflat environments provide important foraging habitat for both shorebirds and waterfowl, especially during winter and migration. At Don Edwards San Francisco Bay NWR, managed ponds provide the primary habitat for both wintering and migratory shorebirds and waterfowl.

4.8.3 Target Status, Trends, and Goals

Three KEAs and 5 associated indicators were selected to represent the health of waterbird populations and associated habitat on Complex lands of the Estuary (table 32) during breeding, migration, and winter.

KEA 1: Colonial Waterbird Breeding Activity at Don Edwards San Francisco Bay NWR

Colonial waterbird breeding activity at Don Edwards San Francisco Bay NWR is indicated by 1) the annual peak number of active nests of Forster's tern and American avocet and 2) number of adult snowy plovers observed during breeding window surveys. Both indicators help assess the status and trend of breeding waterbird populations on the refuge and contribute to Estuary-wide assessments of breeding waterbird population status and trends. Increasing trends in breeding activity (number of breeding adults or number of nests) can indicate improvements in the quantity or quality of colonial nesting waterbird habitat, likewise, decreasing trends can trigger reflection on what factors are contributing to a decline, locally or at a larger landscape scale. Terns and avocets, in particular, are good indicators of waterbird habitat quantity and quality in managed ponds because they depend largely on managed ponds during the breeding season. The species selected are also representative of the diversity of waterbird forage needs, from invertebrates to fish, and thus can be good indicators of overall food web quality.

Annual peak number of active nests of Forster's tern and American avocet. Since 1982, the San Francisco Bay Bird Observatory has monitored colonial nesting waterbird species within the counties of Santa Clara, San Mateo, Alameda, Contra Costa and San Joaquin, including lands of the Don Edwards San Francisco Bay NWR. Data collection is conducted primarily by well-trained citizen scientists. Examination of measures taken in 2016 compared to 2011 suggest breeding activity of Forster's terns and American avocets has decreased within the survey scope. In 2016, survey results show the majority of active nests of American avocet across the South Bay survey scope were on refuge lands. In 2016, the most active refuge nesting sites were New Chicago Marsh for Forster's terns (N = 192 nests) and Alviso A16 for American avocets (N = 38).

Annual western snowy plover count

The Don Edwards San Francisco Bay National Wildlife Refuge began monitoring SNPL populations in 1992. From 2003-present, the refuge monitored SNPL in collaboration with the San Francisco Bay Bird Observatory (SFBBO; Pearl 2016). This collaborative monitoring also encompasses other parts of the southern portion of the Estuary (South Bay), including lands owned and managed by California Department of Fish and Wildlife, Hayward Area Recreation and Park District, and East Bay Regional Park District. The monitoring is focused on 1) identifying breeding areas (search areas with potential breeding habitat); 2) estimating breeding population size (summer window surveys); 3) documenting nest fates, next densities, and chick fledging rates (by nest monitoring and chick banding); and 4) assessing SNPL predation and identification of other potential disturbances of breeding SNPL. The refuge uses the estimated breeding population size of SNPL obtained from summer window surveys as an indicator of colonial waterbird breeding activity. The summer window survey is conducted annually during 1-week of the breeding season to estimate recovery unit 3 SNPL breeding population size. Since 2005, SNPL observed during the breeding season in recovery unit 3 has increased from 124 (2004) to 208 (2016), with the majority found at California Department of Fish and Wildlife's Eden Landing preserve. Refuge lands held 37% (N = 77 individuals counted) of the total South Bay count in 2016.

KEA 2: Number of Heron and Egret Breeding Pairs (Marin Islands NWR)

Colonial waterbird breeding activity at Marin Islands NWR is indicated by the annual total number of colonial waterbird breeding pairs across 4 species: great blue heron (*Ardea herodias*), black-crowned night heron (*Nycticorax nycticorax*), great egret (*Ardea alba*), and snowy egret (*Egretta thula*). This indicator helps assess the status and trend of colonial nesting heron and egret breeding populations on the refuge and contributes to Estuary-wide assessments of heron and egret rookeries. The refuge was established primarily to protect the rookery, which at the time of establishment in 1992, supported one of the largest heron and egret rookeries in the Estuary. Increasing trends in breeding activity can indicate improvements in the quantity or quality of colonial nesting waterbird habitat. Likewise, decreasing trends suggest can trigger reflection on what factors are contributing to a decline, locally or at a larger landscape scale.

Herons and egrets are high-level consumers and therefore can indicate the health of the overall food web adjacent to the Marin Islands rookery. Increasing or decreasing trends in rookery productivity are likely to depend on local conditions (feeding, nesting) and larger scale processes that affect regional populations (such as the larger San Francisco Estuary population) (Parnell et al. 1988). Such processes may involve predation, disturbance, weather, quantity and quality of nesting and feeding habitat, or pollution (Kelly et al. 2006). Many of these same factors and processes affect other waterbird species. Thus, understanding trends in the rookery can inform the health of the systems in which they occur.

Annually during the spring and summer season, the heron and egret colony on West Marin Island is monitored by Audubon Canyon Ranch to assess status and trends in the colony size, reproductive success, and stressors. Monitoring of the colony began in 1979 and continues today.

KEA 3: Wintering Waterbird Species Richness and Abundance (San Pablo Bay NWR and Don Edwards San Francisco Bay NWR)

This KEA is indicated by species richness and abundance of wintering waterbirds, specifically waterfowl and shorebirds at San Pablo Bay and Don Edwards San Francisco Bay NWRs. Species richness and abundance tracks population levels and biodiversity and indicates the health of ecosystems in the larger landscape in response to environmental changes such as climate change or management actions such as tidal marsh restoration. At Don Edwards San Francisco Bay NWR, numbers and species of waterbirds can also indicate pond management effectiveness in maintaining adequate and appropriate water levels and salinity. In San Pablo Bay NWR, numbers and species of shorebirds indicate health of intertidal/mudflat habitat and shift in response to other landscape changes such as tidal marsh restoration and enhancement projects.

A 2016 study of wintering shorebirds in the South Bay (De La Cruz et al. 2016) reported bird abundance trends between 2002 and 2015 from 5,055 pond surveys during 13 field seasons. The team observed 98 species of waterbirds. Waterfowl (dabbling and diving ducks, 17% each), shorebird (small shorebirds, 39%; medium shorebirds, 10%), and gull (11%) guilds represented the most abundant bird taxa in ponds studied across all years. Peak waterbird abundances occurred during winter (December through February). Total winter waterbird abundance increased nonlinearly over the study period, more than doubling from 98,151 ± 38,826 (mean ± 95% confidence interval) in 2002 to 235,936 ± 16,564 in 2014 (De La Cruz et al. 2018).

The Complex also participates in the annual Pacific Flyway Waterfowl Survey. These surveys monitor populations and allow annual comparisons of wintering waterfowl populations within and across sites along the Pacific Flyway, which includes the San Francisco Bay area. Richmond et al. (2014) reported waterfowl trends from 1981 to 2012. In 2012, the SF Estuary had a large proportion of the Lower Pacific Flyway count for diving ducks: 60% for greater and lesser scaup, 54% for scoter spp., 51% for canvasback, 36% for ruddy duck, and 32% for bufflehead. The Estuary is currently a relatively minor wintering area for dabbling ducks and American coots in the Lower Pacific Flyway. A total of 381,301 waterfowl were counted in the SF Estuary during the MWS in 2012, comprising 18 species and 4 species groupings. Of these, 104,137 were dabbling ducks and 228,581 were diving ducks. Two of the areas with the highest counts of waterfowl coots in the SF Estuary included major portions of the Don Edwards San Francisco Bay NWR managed ponds and the open bay of San Pablo Bay NWR. Managed ponds of San Pablo Bay and South San Francisco Bay accounted for 55% of the waterfowl and coots counted in the SF Estuary in 2012, while the open waters of San Pablo Bay accounted for 28%. Aside from the open bay areas, Don Edwards San Francisco Bay National Wildlife Refuge (NWR) had the highest count of waterfowl/coots observed in the Estuary, followed by Napa-Sonoma Marshes Wildlife Management Area and San Pablo Bay National Wildlife Refuge.

Table 32. Current status and desired future state (goals) of waterbirds at Don Edwards San Francisco Bay National Wildlife Refuge, Marin Islands National Wildlife Refuge, and San Pablo Bay National Wildlife Refuge in terms of select indicators.

Key Ecological Attribute	*Indicator*	*Status (Trend)*	*Status Source*	*Goal*
Colonial waterbird breeding activity at Don Edwards San Francisco Bay NWR	Annual peak number of active nests of Forster's tern and American avocet	2016: Forster's tern = 213, American avocet = 54 (decline)	Citizen Science-Based Colonial Waterbird Monitoring 2016 (Tarjan 2016)	WTB_G01. By 2021, the annual peak number of waterbird nests in managed ponds at Don Edwards San Francisco Bay NWR is >250 for Forster's tern and >175 for American avocet.
Colonial waterbird breeding activity at Marin Islands NWR	Annual total number of colonial breeding waterbird pairs: great blue heron, black-crowned night heron, great egret, snowy egret	2016: 7 [great blue heron, east island only] (decreasing)	Heron and egret monitoring results at Marin Islands NWR: 2016 Nesting Season (Kelly and Fischer 2017)	WTB_G02. By 2032, the annual number of colonial waterbird breeding pairs at Marin Islands NWR increases to ≥300. Breeding colonial waterbird species evaluated are great blue heron, great egret, snowy egret, and black-crowned night heron.
Wintering waterbird species richness and abundance	Annual number of eared grebes at Don Edwards SF Bay NWR; annual number of waterfowl (waterfowl + grebes) at Don Edwards SF Bay NWR and San Pablo Bay NWR	2012: Don Edwards SF Bay NWR = 5,343 eared grebes; 80,793 waterfowl; 14 spp. San Pablo Bay NWR = 31,984 ducks, 10 spp. (waterfowl only)	U.S. Geological Survey and San Francisco Bay Bird Observatory pond count data for spring; San Francisco Bay midwinter waterfowl survey data	WTB_G03. Over the next 5 years (2018-2022), annual wintering waterfowl species richness and abundance is stable or increasing at Don Edwards San Francisco Bay and San Pablo Bay NWRs relative to 2012 measures (Richmond et. al 2014). Measures in 2012 are as follows: Don Edwards San Francisco Bay NWR: 14 species waterfowl, eared grebes = 5,343, waterfowl = 80,793; San Pablo Bay NWR: 10 waterfowl species, waterfowl count = 31,984. The 2012 reference year was chosen because it represents the most comprehensive and recent data.
Wintering waterbird species richness and abundance	Annual number of shorebirds and number of species of shorebirds (Don Edwards San Francisco Bay, San Pablo Bay NWRs)	Don Edwards San Francisco Bay NWR: 56,147 shorebirds, 22 shorebird species San Pablo Bay NWR: 14 shorebird species (stable)	Don Edwards San Francisco Bay NWR: San Francisco Bay Bird Observatory pond spring count data; San Pablo Bay NWR: Point Blue Conservation Science November count (partial survey)	WTB_G04. Over the next 5 years (2018-2022), wintering shorebird species richness and abundance does not decrease at San Pablo Bay NWR (SNP) and increases at Don Edwards SF Bay NWR (SFB) relative to 2015 baseline (SFB: 56,147, 22 spp; SNP: 14 spp). Expected values: SFB = 22 shorebird species, 70-90,000 individuals, SNP = 14 spp). Abundance baseline needed for SNP.

Note: Status designations: red = Poor, yellow = Fair, light green = Good, dark green = Very Good. Refer to the San Francisco Bay National Wildlife Refuge Complex viability database for additional details (appendix B).

4.8.4 Critical Threats

Because the scope and severity of threats to waterbirds vary across the Complex, threats were assessed for each of the three nested targets (table 33). The most critical threats to waterbirds (classified as High or Very High for at least one nested target) are land conversion, predators (avian or mammalian), pollution, and illegal activities by humans. Medium ranked threats included oil spills and other pollution, human disturbance, invasive plants, and climate change. A conceptual model depicting threats to waterbirds, their relationship to biophysical factors associated with waterbirds, and strategies aimed at reducing the most critical threats is depicted in figure 25. Threats to waterbirds are summarized in the following (table 33).

Table 33. Threats to nested waterbird targets at San Pablo Bay NWR, Don Edwards San Francisco Bay NWR, and Marin Islands NWR.

Nested Waterbird Target	*Very High or High Threats*	*Medium Ranked Threats*	*Low Ranked Threats*
Breeding waterbirds at Don Edwards San Francisco Bay NWR	Land conversion, avian predators, mammalian predators, pollution, climate change (long-term air and water temperature regimes, near and long-term extreme weather events and sea level rise)	Oil spills, invasive plants, climate change (near-term water and air temperature regimes)	Disease, refuge management activities, illegal human activities, human disturbance from recreation
Breeding waterbirds at Marin Islands NWR	Mammalian predators, illegal human activities, climate change (long-term air and water temperature regimes, near and long-term extreme weather events and sea level rise)	Oil spills, human disturbance from recreation, climate change (near-term water and air temperature regimes)	Avian predators, pollution (other than oil spills), disease, invasive plants, refuge management activities
Wintering waterbirds at Don Edwards San Francisco Bay NWR and San Pablo Bay NWR	Land conversion, climate change (long-term water and air temperature regimes)	Oil spills, other pollutants, invasive plants, climate change (near-term water and air temperature regimes)	Avian and mammalian predators, climate change (sea level rise), marine debris, disease, hunting or poaching, boat disturbance

Land Conversion (Legacy or Current) (Very High Threat: Wintering Waterbirds, Breeding Waterbirds [Don Edwards San Francisco Bay NWR]

Land conversion here refers to lands used by waterbirds, primarily wetlands, that were altered by humans.

Breeding and wintering waterbirds at Don Edwards San Francisco Bay NWR. In the southern part of the Estuary, tidal marshes were extensively diked for salt production. Diking began in the mid-1800s and by the 1930s, almost half of the South Bay's historical tidal marshes were converted into salt ponds. In 1952, the Leslie Salt Company (later purchased by the Cargill Salt Division) expanded salt production into the North Bay with the purchase and conversion of nearly 11,000 acres of diked agricultural tidelands to salt ponds. At their peak, salt ponds covered about 36,000 acres in and adjacent to the baylands throughout the Estuary (Goals Project 1999). As in the North Bay, the decline in tidal marsh caused populations of marsh-dependent fish and wildlife to decline. However, salt ponds have been in the South Bay for many decades and are now important roosting and foraging sites for many waterbird species. Some formal salt ponds are now managed to support wildlife, primarily waterbirds, and are heavily used by the majority of the waterbirds in the San Francisco Bay (Warnock et al. 2002, De La Cruz et al. 2018). Throughout the Estuary, salt ponds are being converted back to tidal marsh, more recently as part of the larger *South Bay Salt Pond Restoration* project that includes Don Edwards San Francisco Bay NWR. Because conversion of ponds back to tidal marsh would reduce the extent of pond habitats preferred by some waterbirds, some ponds have been preserved are now actively managed to maximize waterbird habitat (Athearn et al. 2012). The challenge in managing these ponds is to provide optimal waterbird habitat which requires maintaining pond infrastructure (levees, trails, and water control structures). Maintaining pond infrastructure carries a high cost.

Wintering waterbirds at San Pablo Bay NWR. Nearly all of the lands adjacent to San Pablo Bay NWR were once tidal salt marsh, tidal brackish marsh, or intertidal/mudflats (converted to tidal marsh by human-induced sediment loading). Hereafter, these environment types are collectively referred to as "tidelands" or "baylands." Although the historic extent of baylands within this area are relatively free of human-occupied structures (such as homes and airports) compared to other parts of the Estuary, they have been altered primarily for agricultural uses (plant crops, salt production, and cattle). Initial diking of tidal marsh within the current boundaries of the refuge was undertaken to develop grazing lands for livestock. Some of the early reclamation efforts, including lands now encompassed by San Pablo Bay NWR, converted large tracts of tidal marsh to what was termed "diked baylands." By the 1930s, diking for agricultural purposes was essentially complete. In some cases, landowners let their lands "pond up" in the fall to provide opportunities for hunting waterfowl. Today, agricultural practices continue both on and adjacent to the refuge. The result of land conversions, particularly for the purposes of agriculture, was a reduction in the extent of habitats used by wetland-dependent wildlife such as waterbirds. Since refuge establishment, there has been a significant amount of investment in converting diked baylands back to wetland-associated environments (open bay, mudflats, and tidal marsh) (such as Cullinan Ranch, Tolay Creek, Lower Tubbs Island, Sonoma Baylands, and Sears Point restoration projects).

Factors that contribute positively (+) or negatively (-) to the threat of land conversion include:

- **Historic conversion of bayland environments for agriculture (San Pablo Bay) (-)**. Much of the historic tidal marshes within the Refuge boundary were diked and drained for agriculture in the mid-1800s to early 1900s.
- **Restoration of tidal marsh habitat (-/+)**. At Don Edwards San Francisco Bay NWR, the restoration of tidal marsh habitat can result in both gains and losses of waterbird habitat. Habitat loss is most pronounced where former salt ponds heavily used by waterbirds are converted to tidal marsh.
- **South Bay Salt Pond Restoration Project (+)**. At Don Edwards San Francisco Bay NWR, the South Bay Salt Pond Restoration Project has implemented an adaptive management plan to balance out the needs of tidal marsh and pond-associated species, the latter of which includes nesting waterbirds such as American avocet and Forster's tern, as well as wintering shorebirds and waterfowl.

Pollutants (High Threat: Breeding Waterbirds [Don Edwards San Francisco Bay NWR])

Two of the most significant anthropogenic changes in the San Francisco Bay over the past 150 years are the loss of over 85% of tidal wetlands (Goals Project 1999) and the contamination of the estuarine food web with mercury and other pollutants. These impacts are particularly evident in the South Bay, which was historically fringed with extensive tidal marshes and which receives drainage from New Almaden, the largest historic mercury mine in North America. Extensive wetland restoration in the South Bay aims to return tidal marshes and restore the important ecosystem function these wetlands provided; however, such restoration activities could release mercury trapped in diked salt production ponds. Once former salt ponds are opened to tidal waters, the mercury is released and converted by microscopic organisms into methylmercury. Methylmercury can then accumulate in the food chain, or *bioaccumulate*. High rates of bioaccumulated methylmercury are associated with wetlands in other areas, so the potential exists for restoration activities in the South Bay to increase mercury bioavailability, particularly in the short term. Mercury concentrations in tissues and eggs of birds in the South Bay currently exceed toxicological thresholds (Ackerman and Eagles-Smith 2008), and evidence suggests that mercury may be impairing egg and chick survival and body condition of birds (Ackerman and Eagles-Smith 2008; Ackerman et al. 2008, 2012). Accordingly, any increase in methylmercury production and subsequent bioaccumulation in waterbirds may have a substantial impact on bird reproduction. There is no known, cost-effective remediation to remove mercury from the tidal marsh environment. The South Bay Salt Pond Restoration Project has been monitoring mercury in birds and fish as well as water and sediment to track trends and determine if restoration is having a long-term negative effect on mercury in the environment.

Factors that contribute positively (+) or negatively (-) to the threat of pollution include:

- **Legacy mercury (-)**. At Don Edwards San Francisco Bay NWR, legacy mercury is present in all waterways, particularly in the far South Bay. Mercury is present in tern and avocet eggs at levels known to cause developmental impairment. However, there is no known, cost-effective remediation to remove mercury from the tidal marsh environment.
- **South Bay Salt Pond Restoration Project (+)**. At Don Edwards San Francisco Bay NWR, the South Bay Salt Pond Restoration Project has been studying the impacts of restoration on mercury availability and bioaccumulation in the South Bay.

Mammalian Predators (Very High Threat: Breeding Waterbirds [Marin Islands and Don Edwards San Francisco Bay NWRs])

Predation is a natural part of a healthy, functioning ecosystem and there are many native predators that prey on migratory waterbirds of the Estuary. However, mammalian predators are a direct threat to breeding waterbirds, especially in cases where new predators are introduced, or predator populations are inflated as a result of human activities (such as landfills and feral cat feeding stations). For example, urban areas often have increased artificial food resources (e.g., trash) that can lead to an increase in the density of predators as well as change their movement patterns and space use (Fischer et al. 2012). Overall, the addition of human-provided food resources changes the interplay of predator-prey interactions and can redefine food web relationships (Newsome et al. 2015).

Marin Islands NWR. Mammalian predation pressure on nests may be the single largest cause of the recent heron and egret rookery crash at (Brad Kelly, CNPS—pers. comm. 2017). Raccoons were first detected on East Marin Island by game cameras in May 2014. Although the refuge lacks evidence of nest predation by raccoons, there is a correlation between first raccoon detection and the heron/egret rookery decline in 2014 and 2015 and complete crash in 2016 and 2017. Raccoons are known predators of heron and egret nests, and raccoons are specifically called out as a predator of concern for heron and egret rookeries (McCrimmon et al 2011, Hothem et al 2010). Raccoons can easily swim short distances and are likely capable of swimming 0.5 miles, the distance between the mainland and West Marin Island. It is highly probably that raccoons are responsible for the subsequent crash of the rookery that declined significantly in 2015 and has not since recovered. Heron and egret nests were substantially lower in 2015 (31 nests) than they had been since the rookery survey started in 1979 (next lowest nest number was 122 in 2013; all-time-high of 767 nests in 1982). Nest numbers increased only slightly in 2014 to 156. Rats were also detected in 2014, although rats are known to have occurred on both East and West Marin Islands at least since 1960 (Anderson 1960). However, rats are known nest predators and could be contributing to the overall predation pressure. For herons and egrets, colony site selection can be predator-driven, whereby birds select nest sites that are difficult to reach by predators (e.g., islands, trees, high branches, etc.(Hothem et al. 2010).

Raccoons are specifically called out as a predator of concern for heron and egret rookeries (McCrimmon et al. 2011, Hothem et al. 2010).

Don Edwards San Francisco Bay NWR. Non-native red fox in particular has made a devastating impact to plover hatching success along the coast (Neuman et al. 2004). Red foxes are known to have destroyed a major Caspian tern colony of >600 adults in the South Bay in 1990 (SFBBO unpub. data). Refuge biologists observed cached eggs and fox tracks in—and leading to and from—the colony. The terns attempted to re-nest over the next month, but red foxes repeatedly took eggs. Subsequently, the colony was abandoned and has not returned as of 2017 (USFWS unpub. data). In addition, data from nest cameras in 2010 documented grey fox depredating an SNPL nest in the South Bay (Robinson-Nilsen and Demers 2010). In addition, visuals or evidence of red foxes, opossums, raccoons, and domestic cats is common in and around ponds used by nesting birds. In 2017, a single large rat depredated and cached up to 30 Forster's tern chicks at one small colony (J. Fasan, USGS—pers. comm. 2018). One raccoon can deplete a Forster's tern colony in a single night (Cheryl Strong, USFWS biologist—pers. comm. 2018).

Factors that contribute positively (+) or negatively (-) to the threat of mammalian predators include:

- **Roads, railways, and levees (-)**. At Don Edwards San Francisco Bay NWR, mammalian predators can access nesting areas more easily due to the presence of roads, railways, and levees; these features act as corridors into ponds and other areas where birds nest and roost.
- **Boaters (-)**. At Marin Islands NWR, rats and other predators can be transported to the Marin Islands (intentionally or unintentionally) by humans.
- **Dumpsters and landfills (-)**. Open dumpsters and landfills can provide food and therefore supplement populations of nuisance mammals.
- **Feral cat feeding stations (-)**. People maintaining feral cat feeding stations, as well as people feeding their pets outdoors, can increase the number of cats adjacent to waterbird nesting and roosting sites.
- **Released animals (-)**. People releasing unwanted nuisance animals (those trapped by animal services or by individuals) onto Don Edwards San Francisco Bay NWR is also a known problem.
- **Lack of awareness (-)**. The overall lack of awareness of the impact mammalian predators can have on waterbird resources is an indirect threat, and negative attitudes toward predator management present an educational opportunity.

Avian Predators (Very High Threat: Breeding Waterbirds, Least Tern; High Threat: Don Edwards San Francisco Bay NWR)

Avian predators are a direct threat to breeding waterbirds including the Forster's terns, American avocets, and SNPL. Avian predators such as peregrine falcon, common raven, and California gull predate upon all waterbird life stages (adult, chick, and egg) negatively affecting reproductive success (such as Pearl et al. 2016, Ackerman et al. 2014). Impacts can be even more severe when introduced or human-subsidized avian predator population numbers are inflated, such as the case for California gulls, common ravens, and American crows. For example, gull numbers have increased dramatically in the South Bay (Strong et al. 2004), and abundant food resources in the form of landfills and other waste may be subsidizing their population numbers (Osterback et al. 2015).

A variety of avian predators have been documented on camera depredating SNPL nests. SNPL is the species for which we have the most information, and we can infer that these predation events are also occurring at Forster's tern, American avocet, and other nesting waterbird sites. Peregrine falcons, red-tailed hawks, northern harrier, California gulls, and common ravens have all been seen depredating plovers at the nest, chick, and or adult stage either through camera footage or through direct observation (San Francisco Bay Bird Observatory reports such as Pearl et al. 2016). Each year varies in number of events caught on camera, as well as species caught on camera and thus requires a quick response to on-the-ground conditions and a flexible management program. For example, in 2016 and 2017, the only avian predators on camera were common ravens. However, in 2015, peregrine falcons and common ravens were the main predators caught on camera depredating SNPL nests.

From 2009 to 2011, California gulls were the most consistent predator of SNPL nests, and the only predator documented in all three seasons (Donehower et al. 2013). The total number of California gulls nesting in the South Bay was 47,806 breeding birds in 2015 (Washburn and Butler 2015, Tokatlian et al. 2014). Since 2011, SFBBO and refuge biologists have coordinated a non-lethal gull hazing program and successfully prevented gulls from nesting in areas identified as sensitive plover habitat (Cheryl Strong, USFWS biologist—pers. comm. 2018). California gull nests are removed from boardwalks and levees located adjacent to sensitive habitat. Continued California gull hazing and tracking is essential to prevent gulls from expanding into other nesting areas in future years. Ackerman et al. (2014) examined gull predation and survival of Forster's tern chicks before (2010) and after (2011) the managed relocation of the largest California gull colony (24,000 adults) in the South Bay. Gulls were the predominant predator of tern chicks, potentially causing 54% of chick deaths. Prior to the gull colony relocation, 56% of radio-marked and 20% of banded tern chicks from the nearest tern colony were recovered dead in the gull colony, compared to only 15% of radio-marked and 4% of banded chicks recovered dead from all other tern colonies. The managed relocation of the gull colony substantially increased tern chick survival (by 900%) in the nearby (<1 kilometer) colony but not at the more distant (>3.8 kilometer) reference tern colony. Among 19 tern nesting islands, fledging success was higher when gull abundance was lower at nearby colonies and when gull colonies were farther from the tern colony.

Peregrine falcon populations continue to recover throughout North America, coinciding with declining environmental levels of pesticides. Urban populations have recovered even more significantly (Kaufmann et al. 2004), including in the South Bay. On two separate occasions in 2015, peregrine falcons were observed depredating SNPL, including newly hatched chicks in the nest, a chick depredated while running on the pond with the associated male, and an adult male SNPL depredated by an adult peregrine and subsequently given to a juvenile peregrine to eat.

Red-tailed hawks are commonly perched in the transmission towers within ponds and over marsh. The refuge coordinates with the power company to remove hawk and raven nests in towers over sensitive habitat.

In 2015, northern harriers represent another predator of concern. As well as documenting the predation of SNPL nests and chicks with nest cameras in 2009 and 2011, refuge staff frequently observe northern harriers hunting in ponds with SNPL nests. The restoration of marsh habitat in the future will increase potential northern harrier nesting habitat in the South Bay and may result in higher predation pressure on pond nesting waterbirds.

Factors that contribute positively (+) or negatively (-) to the threat of avian predators include:

- **Towers (-).** At Don Edwards San Francisco Bay NWR, towers are nesting and roosting sites for avian predators including ravens and hawks.
- **California protections (-).** Some species is listed as "fully protected" by the state of California can limit management actions such as nest removal. It also limits our abilities on federal lands given public sentiment.
- **Human-food sources (-).** At all sites, crows, ravens, and gulls all forage on human food sources in adjacent neighborhoods, and this can supplement the populations of these species.

Illegal activities by humans (High Threat: Breeding Waterbirds [Marin Islands NWR])

Illegal activities by humans at Marin Islands NWR that disturb waterbirds are primarily humans in watercraft approaching the Marin Islands too closely and disturbing adult birds within the rookery. This type of disturbance has been observed repeatedly (Meg Marriott, refuge biologist—pers. comm. 2018). This type of disturbance can result in waterbird nest abandonment, especially when individuals are in the pre-laying or courtship phase (February–April) (Kelly et al. 2006). Various scientific investigators have recommended buffers between 100 meters and 300 meters around nesting colonies (Kelly et al. 2006) to keep humans from disturbing/flushing adults and potentially causing nest abandonment. In 2015, in an attempt to decrease disturbance to the rookery, Marin Islands NWR staff erected six 8-by-5-foot signs alerting humans not to trespass within 100 meters of Marin Island shorelines. However, these signs are not 100% effective (Meg Marriott, USFWS biologist—pers. comm. 2018).

Factors that contribute negatively (-) to the threat of illegal activities by humans include:

- **Lack of patrol (-)**. At Marin Islands NWR, lack of resources limits the ability to effectively patrol the area to enforce the no trespassing policy. The presence of the old housing structures on the islands creates an attractive nuisance and draws people in to explore the islands.

Climate Change (High-Very High Threat [breeding and wintering waterbirds])

Key climate-change-related stressors for waterbirds are loss of habitat, nesting sites, and food sources due to sea level rise and changing ocean conditions. Bay water quality may also be affected by changing climate and hydrologic conditions, causing other potential as-yet unknown impacts. Over the long-term, sea level rise is projected to cause inundation and significant loss of tidal marsh and mudflats-key habitat used by shorebirds and waterfowl. Ocean acidification is likely to cause changes in mudflat biotic community structure and productivity, impacting food sources for birds (Largier et al. 2010). Bay conditions may change as a result of more extremes in precipitation and drought already suspected to be happening due to climate change, affecting aquatic and marsh habitats and the species that rely on them. There have recently been observations of impacts to water quality within the Bay associated with the freshwater runoff from the extremely wet winter of 2016–17. Low salinity and increased pollution resulting from this runoff is suspected of causing an outbreak of a protozoan pathogen thought to be the cause of a mass die-off of sharks and rays (Simons 2017). These effects could compound other stressors in ways not yet well understood.

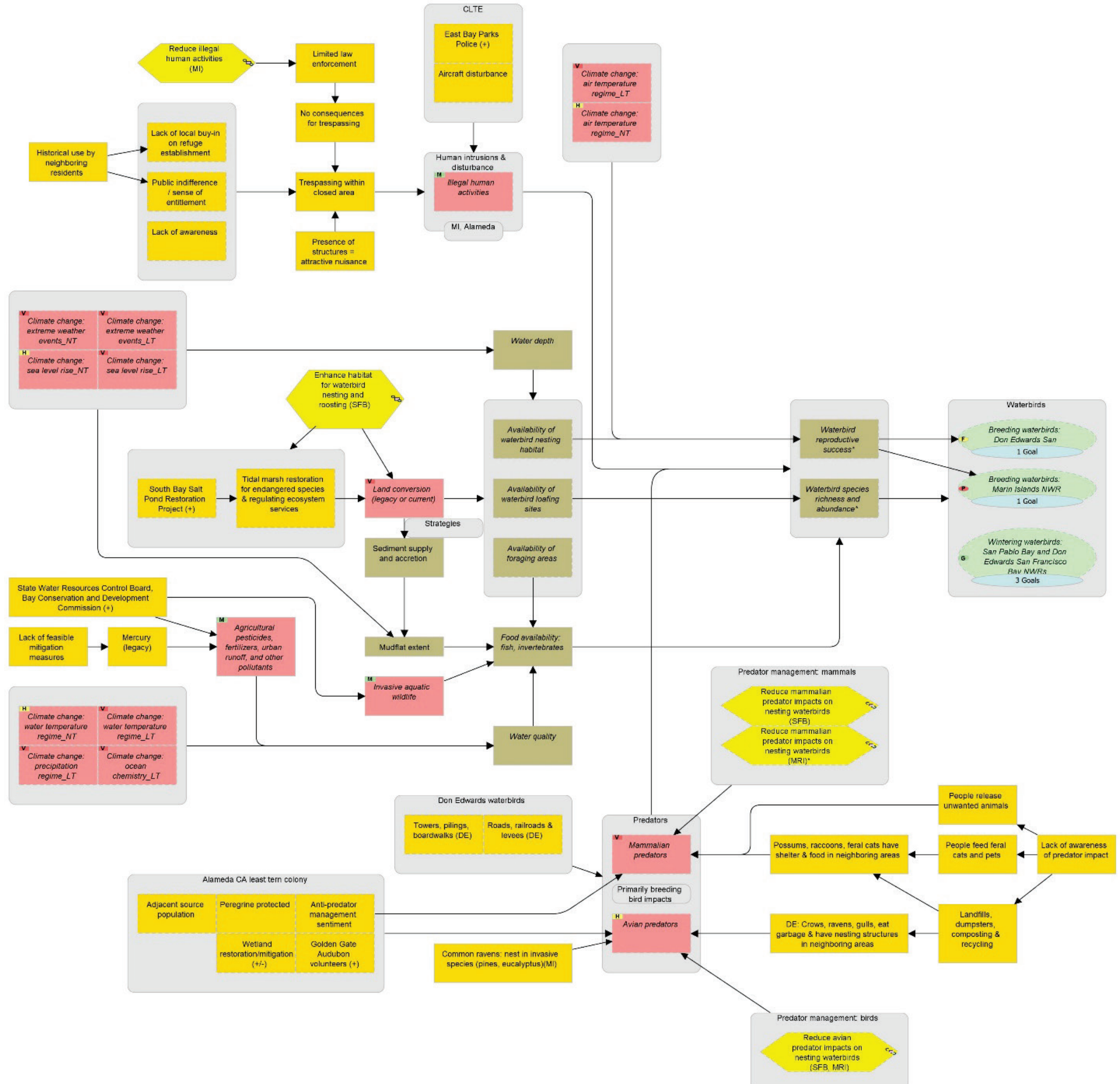


Figure 25. Conceptual model of waterbirds for Don Edwards San Francisco Bay (SFB), San Pablo Bay (SNP), and Marin Islands (MRI) National Wildlife Refuges depicting natural resource threats and strategies aimed at addressing the most critical threats (ranked High or Very High). The letters in the upper left portion of threats (pink boxes) represent the summary threat ranking across the seven refuges of the San Francisco National Wildlife Refuge Complex (L=low, M=moderate, H=high, VH=very high).

Notes: Legend: green oval = natural resource conservation target; olive box = biophysical attribute; pink box = direct threat; orange box = contributing factors; yellow hexagon = conservation strategy. The letters in the upper left portion of threats (pink boxes) represent the summary threat ranking across the seven refuges of the San Francisco National Wildlife Refuge Complex (L=low, M=moderate, H=high, VH=very high).

4.8.5 Conservation Strategies

Conservation strategies for waterbirds at Don Edwards San Francisco Bay, San Pablo Bay, and Marin Islands NWRs are focused on reducing or mitigating the most critical threats: land conversion, predators, illegal human activity, and climate change. Threats addressed by each strategy and expected outcomes (objectives) are summarized in table 33. Each strategy is briefly described below in order of priority to implement. Results chains visually depicting the assumptions behind these strategies (how they work) and expected outcomes are presented in a Miradi file associated with this NRMP (appendix B). Strategies outlined here support conservation strategies identified in the *Recovery Plan for the Pacific Coast Population of the Western Snowy Plover* (USFWS 2007), the *Baylands and Climate Change: What We Can Do. Baylands Ecosystem Habitat Goals Science Update 2015* (Goals Project 2015), and the San Francisco Bay Joint Venture Implementation Plan (Steere and Schaefer 2001).

Enhance Waterbird Habitat (Don Edwards San Francisco Bay NWR)

The intent of this strategy is to create or enhance foraging, loafing, and nesting waterbird habitat in managed ponds at Don Edwards San Francisco Bay NWR. This is critically important given the conversion of some ponds to tidal marsh as a result of the South Bay Salt Pond Restoration Project. In order to continue supporting waterbirds in fewer ponds, the refuge needs to create or enhance ponds so that they provide optimal waterbird habitat. Features that can increase waterbird habitat suitability of ponds include adding islands and berms to change pond topography, manipulating water salinity and depth, weed management in waterbird nesting areas, and other related tasks. This strategy also supports the Don Edwards SF Bay NWR Pond Operations Plans (USFWS 2017). The plan specifies pond characteristics such as:

- Most ponds maintained to circulate bay waters while maintaining discharge salinities (permit requirement) to the Bay at less than 40 ppt.
- Maintain a mix of shallow (0-0.4 meter) and deep (0.4-1.5 meter) water levels in ponds to support dabbling ducks, diving ducks, eared grebes, terns, and shorebirds that allow for a variety of foraging depths across ponds while still maintaining the integrity of the levees to prevent erosion and over- topping.
- Maintain pond A15 at higher salinity level to promote brine shrimp and brine fly production for foraging waterbirds such as eared grebes.
- Regulate water levels in some ponds (including A22, SF2 Unit 3, R3) as seasonal ponds to reduce vegetation by flooding and drying to provide for nesting habitat on the pond bottom, exposed islands, and interior levees.
- Clearing islands at SF2 and A16 of tall vegetation and keeping low-growing vegetation on 80% of islands to <50% of island area. Terns and shorebirds prefer more open ground for nesting, but some low-growing cover gives a place for chicks to hide from predators.
- Deploying decoys and sound system on select islands in A16 in order to attract Forster's terns. This social attraction has been successful in the past to attract new colonies of nesting birds.

This strategy is informed by previous studies of the factors that influence use of ponds by wintering waterbirds. For example, a study by Ackerman et al (2014) suggests the presence of 3–5 islands within ponds increased the overall abundance of most waterbird species within ponds. Therefore, more islands within ponds will likely have an overall positive benefit to waterbird abundance. The study also showed the abundance of foraging American avocets, gulls, diving ducks, and medium shorebirds was greatest in areas closer to islands, though diving ducks were most abundant farther from islands. A more recent analysis of 13 years of waterbird data from South Bay salt ponds and managed ponds showed pond water depth, salinity, pond size, topographic relief, presence of islands, and hunting influenced many waterbird guilds and species (De La Cruz et al. 2016). These findings suggest that pond characteristics can be targeted to increase waterbird use and diversity. Waterbirds are able to quickly adapt to landscape changes as they are highly mobile and can move between habitats.

Reduce Mammalian Predator Impacts on Nesting Waterbirds (Marin Islands NWR, Don Edwards San Francisco Bay NWR)

This strategy is focused on reducing mammalian predation (where necessary) on waterbird populations. Specifically, the heron and egret rookery at Marin Islands NWR or other waterbirds at Don Edwards San Francisco Bay NWR.

Marin Islands NWR

Activities involve initial trapping and removal of predatory mammals (such as raccoons and rats) as well as development of a long-term plan to prevent re-infestation, early detection monitoring, and rapid response to future predation events at Marin Islands NWR. Only three individual raccoons have been detected on camera in any given year since 2014. Activities include removal of raccoons, developing a predator plan, maintaining eradication and preventing humans from feeding raccoons near the Loch Lomond Marina. Together, these activities require more predator management resources from the Complex than expended in the past at Marin Islands. With a reduction in raccoons and rats, herons and egrets may re-colonize the west island and the overall size of the colony is expected to increase.

Don Edwards San Francisco Bay NWR

At Don Edwards San Francisco Bay NWR, this strategy proposes to increase the success of nesting waterbirds by conducting selective mammalian predator management at areas of highest value to endangered species and colonial nesting birds (see also tidal marsh predator management strategy). Predation is the number one cause of nest failure, and many of the local predators have inflated numbers due to human landscape changes and food resources. Controlling predation should help increase nesting success. Predator species of concern include rats (*Rattus spp.*), red fox (*Vulpes vulpes*), gray fox (*Urocyon cinereoargenteus*), raccoon, striped skunk (*Mephitis mephitis*), opossum, and feral cats (*Felis* spp). In 2016, observed mammalian predators during SNPL surveys included red fox, skunk, and domestic cat (SFBBO 2016).

The current predator management program at the refuge utilizes a combination of lethal and non-lethal predator techniques. Available non-lethal methods are used as a first defense and lethal controls are used only when necessary, and as humanely and selectively as possible. The refuge *Mammalian Predator Management Plan* (appendix to CCP) details the various non-lethal and lethal methods employed.

Reduce Avian Predator Impacts on Nesting Waterbirds (Don Edwards San Francisco Bay NWR)

At Don Edwards San Francisco Bay NWR, this strategy proposes to increase the success of nesting waterbirds by conducting selective avian predator management at areas of highest value to endangered species and colonial nesting birds. Here, avian predators are any species that could potentially prey on waterbirds. Predation is the number one cause of nest failure and many of the local predators have inflated numbers due to human landscape changes and food resources. Controlling predation should help increase nesting success. Target predators include California gulls

(*Larus californicus*), common ravens (*Corvus corax*), and American crows (*Corvus brachyrhynchos*). Other potential, but less likely target species include a variety of raptor and owl species. The refuge Avian Predator Management Plan (see appendix to CCP) is intended to result in a small-scale reduction in the local population of some predatory species in localized areas. The management approach is similar to mammalian predator management—non-lethal methods (such as perch and nest removal, trap and relocate) are used first followed by lethal methods when necessary. The tiered approach to avian predator management is described in the refuge Avian Predator Management Plan.

Reduce Illegal activities by humans (Marin Islands NWR)

This strategy proposes to reduce the number of people who are illegally trespassing within the 100-meters of the shoreline of East or West Marin Island, or on the Islands themselves—especially during heron and egret nesting season (February through August) when nest abandonment due to disturbance is most likely. This strategy will be implemented by 1) increasing law enforcement patrols and enforcement of refuge no-trespassing policy, 2) coordination between Complex law enforcement and local law enforcement agencies and organizations to increase patrols and enforce refuge no-trespassing policy, 3) educating trespassers as to the importance of Marin Islands and the importance of respecting the 100m boundary regulation, and 4) developing and delivering educational materials about the refuge to local proprietors/residents/stakeholders (i.e. the Marina boat owners, the Marina management, Andy's Market, condominium HOA, local shopkeepers) through meetings, fliers and/or brochures, interpretive panels at the Marina.

Table 33. Waterbird management strategies and associated objectives, in order of priority to implement over the next 5 years.

Strategy Title	*Threat Addressed*	*Expected Outcome (Objectives)*
Enhance waterbird habitat (Don Edwards San Francisco Bay NWR)	Land conversion (legacy or current), climate change	WTB_O01. Over the next 10 years (FY 2018-2027), managed ponds at Don Edwards SF Bay NWR achieve the target water levels and salinity levels prescribed in the Pond Operations Plan (Pond Operations Plan 2017). Examples of pond operations for waterbird habitat management are: a) Maintain a mix of shallow (0-0.4 meter) and deep (0.4-1.5 meter) water levels in ponds to support dabbling ducks, diving ducks, eared grebes, terns, and shorebirds while still maintaining the integrity of the levees to prevent erosion and over- topping. b) Maintain higher salinity ponds including A15 to support foraging waterbirds such as eared grebes to boost brine shrimp and brine fly production. c) Regulate water levels in some ponds including A22, SF2 Unit 3, R3 to reduce vegetation by flooding and drying to provide for nesting habitat on the pond bottom, exposed islands, and interior levees. WTB_O02. Over the next 10 years (2018–2027), at least 80% of the existing pond islands used by nesting waterbirds at Don Edwards San Francisco Bay NWR have <50% low vegetation cover (<1 foot) and no high vegetation cover (>1 foot).

Strategy Title	*Threat Addressed*	*Expected Outcome (Objectives)*
Reduce mammalian predator impacts on nesting waterbirds (Marin Islands NWR, Don Edwards San Francisco Bay NWR)	Mammalian predators, climate change	WTB_O03. By 2020, raccoon presence is not detected (such as by video, photo, footprints, or scat) on Marin Islands NWR. WTB_O04. By 2023, feral cat feeding stations do not occur immediately adjacent to Don Edwards San Francisco Bay NWR. WTB_O05. By 2023, red fox sightings are reduced to zero on Don Edwards San Francisco Bay NWR.
Reduce avian predator impacts on nesting waterbirds (Don Edwards San Francisco Bay NWR)	Avian predators, climate change	WTB_O06. Over the next 15 years, (2018-2032), successful gull colonies are not established in priority areas of Don Edwards San Francisco Bay NWR (SFB), as identified in the *Don Edwards SF Bay Predator Management Plan* (USFWS 2017). WTB_O07. Over the next 15 years, (2018-2032), successful raven and raptor nests do not occur on PG&E towers in accessible priority areas of Don Edwards San Francisco Bay NWR (SFB), as identified in the *Don Edwards SF Bay Predator Management Plan* (USFWS 2017).
Reduce illegal activities by humans (Marin Islands NWR)	Illegal activities by humans, climate change	WTB_O08. By 2025, 100 informational brochures/rack cards are distributed each year to at least 3 major stakeholders of the Marin Islands NWR (such as Loch Lomond Marina, Condominium Homeowners Association, and Andy's Market). WTB_O09. By 2022, illegal human trespassing is reduced by at least 50% (baseline = 2018) within 100-m of island shorelines (including the islands) at Marin Islands NWR.

4.8.6 Natural Resource Surveys

Natural resource surveys needed to assess waterbird health (goals) and effectiveness of refuge management strategies (objectives) are presented below (table 34). Surveys are listed in order of priority to conduct based on survey prioritization in 2017.

Table 34. Estuarine island ecosystem natural resource surveys to inform management effectiveness and progress on goals and objectives.

Survey Name	*PRIMR ID*	*Status*	*Survey Frequency*	*Goal or Objective Informed by Survey (ID)*	*Survey Lead*
Don Edwards San Francisco Bay NWR					
Managed and Salt Pond Waterbird Survey	FF08RSFB00-008	Current	Annual	WTB_G01	Cheryl Strong (USFWS), Max Targan (SFBBO)
Western Snowy Plover Window Survey	FF08RSFB00-010	Current	Annual	WTB_G01	Tanya Graham (USGS)
Mid-Winter Waterfowl Survey	FF08RSFB00-006	Current	Annual	WTB_G03	Tanya Graham (USGS)
Managed Ponds: Water Monitoring	FF08RSFB00-061	Current	Annual	WTB_O01	Jared Underwood (USFWS)
Avian Predator Nest Survey	FF08RSFB00-057	Current	Annual	WTB_O07	Cheryl Strong (USFWS)
Avian Predator Survey	FF08RSFB00-058	Current	Annual	WTB_O06	Ben Pearl (SFBBO)
Pacific Flyway Migratory Shorebird Project	FF08RSFB00-009	Current	Annual	WTB_G04	Matthew Reiter (PBCS)
Managed Ponds: Vegetation Monitoring	FF08RSFB00-064	Current	Annual	WTB_O02	Cheryl Strong (USFWS)
Colonial Waterbird Breeding Season Surveys	FF08RSFB00-007	Current	Annual	WTB_G01	Max Tarjan (SFBBO)
Marin Islands NWR					
Predator Management Effectiveness Survey: Marin Islands NWR	FF08RMRI00-008	Expected	Annual	WTB_O03	Don Brubaker (USFWS)
Marin Islands: Colonial Nesting Waterbird Survey	FF08RMRI00-002	Current	Annual	WTB_G02	John Kelly (ACR)
San Pablo Bay NWR					
San Francisco Bay Mid-Winter Waterfowl Survey	FF08RSNP00-011	Current	Annual	WTB_G03	Cheryl Strong USFWS
Pacific Flyway Migratory Shorebird Project	FF08RSNP00-006	Current	Annual	WTB_G04	Matthew Reiter (PBCS)

Note: Status as of based on 2017. Survey leads: SFBBO = San Francisco Bird Observatory, ACR = Audubon Canyon Ranch, PBCS = Point Blue Conservation Science

Chapter 5—Human Well-Being Target Summaries

5.1 Overview

Conservation targets are the ecosystems and species that the Service has chosen to prioritize its work and are representative of the array of biodiversity in the Refuge Complex. We wish to acknowledge that healthy conservation targets can also provide human well-being benefits through ecosystem services, described in the following and in figure 26. Additionally, because the Don Edwards San Francisco Bay and San Pablo Bay NWRs are considered urban refuges,[6] we have identified human well-being strategies that build public support and stewardship for our priority conservation targets as well as advance the Service's mission to connect people with nature. Furthermore, the Don Edwards San Francisco Bay NWR has a public use component in its establishing purposes.

These strategies also further our contributions toward the Service's Urban Wildlife Conservation Program to engage and inspire people who live in urban areas to become part of a conservation constituency, so that together we can leave a legacy of abundant and healthy wildlife and wildlands for future generations of Americans to enjoy (USFWS 2015). Many of our refuges are surrounded by dense urban development, and Americans are spending less and less time outdoors. The success of our conservation efforts lies ultimately in our ability to reach urban audiences, become relevant in their daily lives, and inspire them to become stewards of the environment.

The *Millennium Ecosystem Assessment* (Reid et al. 2005) was a report called for by the United Nations Secretary General Kofi Annan in 2000. The objective of the assessment was to assess the consequences of ecosystem change for human well-being and the scientific basis for action needed to enhance the conservation and sustainable use of those systems and their contribution to human well-being. The assessment provides a state-of-the-art scientific appraisal of the condition and trends in the world's ecosystems and the services they provide. The assessment recognizes four general categories of ecosystem services: regulating, supporting, provisioning, and cultural, as defined as follows.

- *Regulating services* are the benefits obtained from the regulation of ecosystem processes (e.g., air quality regulation, climate regulation, water purification).
- *Supporting services* are those that are necessary for the production of all other ecosystem services. They differ from provisioning, regulating, and cultural services in that their impacts on people are often indirect and occur over a very long time (e.g., soil formation), whereas others' services are relatively direct and have short-term impacts to people.
- *Provisioning services* relate to the products obtained from an ecosystem (e.g., food, fuel).
- *Cultural services* are nonmaterial benefits people get from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences.

A variety of specific ecosystem services and related human well-being benefits provided by our conservation targets were identified through the work plan process, with definitions excerpted from

[6] Urban refuges are defined by the USFWS' Urban Wildlife Conservation Program as refuges within a 25-mile radius of a population greater than 250,000 people and to be open to the public.

Reid et al. 2005. Summarized in the following and in table 35 are those specific ecosystem services in the context of our conservation targets:

- **Food**. Ecosystems are sources of food products. The conservation targets serve as nurseries, food sources, or resting areas with vegetation and wildlife. Three of the refuges provide opportunities for harvesting fish and waterfowl for human consumption.
- **Water regulation**. Ecosystems can regulate the timing and magnitude of runoff, flooding, and aquifer recharge depending on their types of land cover. Many of the conservation targets are in urban areas, acting as buffers to flood events or providing recharge for groundwater.
- **Air quality regulation**. Ecosystems both contribute chemicals to and extract chemicals from the atmosphere, influencing many aspects of air quality.
- **Climate regulation**. Ecosystems influence climate both locally and globally. At a local scale, for example, changes in land cover can affect both temperature and precipitation. At the global scale, ecosystems play an important role in climate by either sequestering or emitting greenhouse gases.
- **Erosion regulation**. Vegetative cover plays an important role in soil retention and the prevention of landslides.
- **Water purification**. Ecosystems can be a source of impurities (for instance, in fresh water) but also can help filter out and decompose organic wastes introduced into inland waters and coastal and marine ecosystems and can assimilate and detoxify compounds through soil and subsoil processes.
- **Disease regulation**. Changes in ecosystems can directly change the abundance of human pathogens, such as cholera, and can alter the abundance of disease vectors, such as mosquitoes. Ecosystem changes can also affect the prevalence of crop and livestock pests and diseases.
- **Pollination**. Ecosystem changes affect the distribution, abundance, and effectiveness of pollinators.
- **Natural hazard regulation**. Different types of ecosystems can reduce the damage caused by natural hazards, such as flooding from strong winter storms or large waves.
- **Soil formation**. Because many provisioning services depend on soil fertility, the rate of soil formation influences human well-being in many ways.
- **Nutrient dispersal, cycling**. Approximately 20 nutrients essential for life, including nitrogen and phosphorus, cycle through ecosystems and are maintained at different concentrations in different parts of ecosystems. Ecosystems can also serve to disperse seeds and act as a seed bank.
- **Photosynthesis**. Ecosystems provide the place for photosynthesis to occur. Photosynthesis produces oxygen necessary for most living organisms.
- **Primary production**. Primary production involves the assimilation or accumulation of energy and nutrients by organisms.
- **Cultural diversity**. The diversity of ecosystems is one factor influencing the diversity of cultures.
- **Spiritual or religious values**. Many people attach spiritual and religious values to ecosystems or their components.
- **Knowledge systems (traditional and formal)**. Ecosystems influence the types of knowledge systems developed by different cultures. Knowledge systems can include environmental education based on ecosystem/landscape (i.e., outside the formal context of a school) or knowledge in terms of traditional knowledge and specialist expertise arising from living in a particular environment (Kandziora et al. 2013). The conservation targets provide places to conduct research that can further expand and diversify knowledge systems.

- **Educational values**. Ecosystems and their components and processes provide the basis for both formal and informal education in many societies. Ecosystems can also be places to conduct research and provide interpretive and educational opportunities.
- **Inspiration**. Ecosystems provide a rich source of inspiration for art, folklore, national symbols, architecture, and advertising.
- **Aesthetic values**. Many people find beauty or aesthetic value in various aspects of ecosystems, as reflected in the support for parks, scenic drives, and the selection of housing locations. The conservation targets serve as open space for visitation or simply the idea that open space exists.
- **Social relations**. Ecosystems influence the types of social relations that are established in particular cultures. Fishing societies, for example, differ in many respects in their social relations from nomadic herding or agricultural societies. Ecosystems can be places to gather for a common purpose and social engagement, such as opportunities to volunteer and engage in social activities.
- **Sense of place**. Many people value the "sense of place" that is associated with recognized features of their environment, including aspects of the ecosystem.
- **Cultural heritage values**. Many societies place high value on the maintenance of either historically important landscapes ("cultural landscapes") or culturally significant species. Examples of these landscapes include places used by Native peoples. The conservation targets provide a place to experience or learn about cultural heritage of a place or activity.
- **Recreation and ecotourism**. People often choose where to spend their leisure time based in part on the characteristics of the natural or cultivated landscapes in a particular area. A variety of ecosystems can provide opportunities to connect with nature through activities such as wildlife observation, hunting, and fishing. Ecosystems can also provide opportunities to improve physical well-being such as jogging or cycling, which also nurture mental well-being.

Table 35. Ecosystem services provided by conservation targets.

	Coastal Sand Dune	*Estuarine Island*	*Marine Island*	*Pajaro Valley Watershed*	*Riverine Sand dune*	*Tidal Marsh*	*Vernal Pool Grassland*	*Waterbirds*
Food	X					X		X
Water regulation	X			X	X	X	X	
Air quality regulation	X	X	X	X	X	X	X	
Climate regulation	X	X	X	X	X	X	X	
Erosion regulation	X			X	X	X	X	
Water purification	X	X	X	X	X	X	X	
Disease regulation	X		X	X	X	X	X	
Pollination	X	X	X	X	X	X	X	
Natural hazard regulation	X			X	X	X	X	
Soil formation	X	X	X	X	X	X	X	

	Coastal Sand Dune	*Estuarine Island*	*Marine Island*	*Pajaro Valley Watershed*	*Riverine Sand dune*	*Tidal Marsh*	*Vernal Pool Grassland*	*Waterbirds*
Nutrient dispersal, cycling	X	X	X	X	X	X	X	
Photosynthesis	X	X	X	X	X	X	X	
Primary production	X	X	X	X	X	X	X	
Cultural diversity	X	X	X	X	X	X	X	X
Spiritual, religious values	X	X	X	X	X	X	X	
Knowledge systems	X	X	X	X	X	X	X	X
Educational values	X	X	X	X	X	X	X	X
Inspiration	X	X	X	X	X	X	X	X
Aesthetic values	X	X	X	X	X	X	X	X
Social relations	X				X	X	X	
Sense of place	X	X	X	X	X	X	X	X
Cultural heritage	X	X	X	X	X	X	X	X
Recreation, ecotourism	X		X		X	X		X

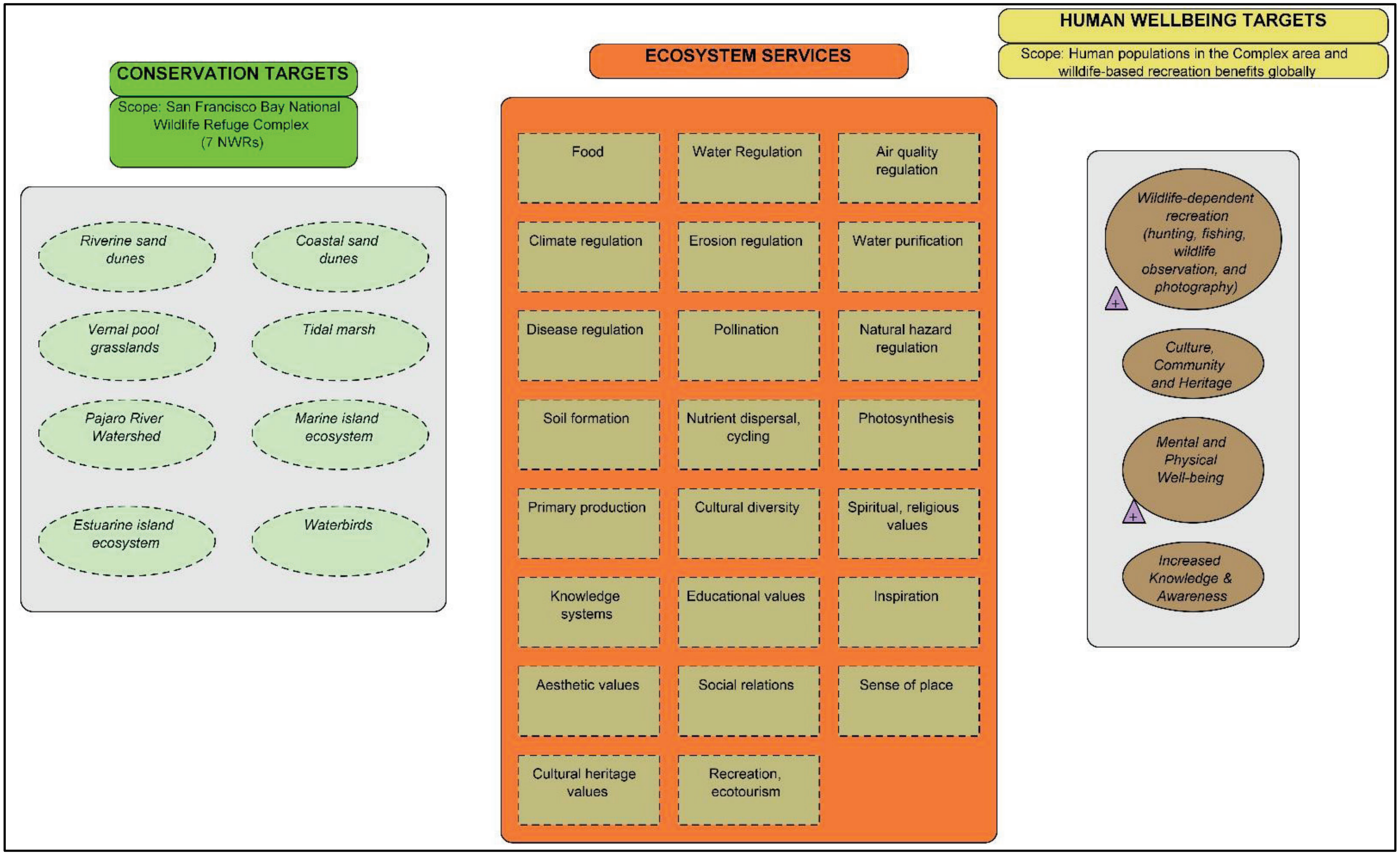


Figure 26. Conceptual model of human well-being benefits connected to conservation targets of the San Francisco Bay National Wildlife Refuge Complex.

5.2 Human Well-Being Targets

Based on the ecosystem services provided by the Refuge Complex conservation targets, four human well-being targets were identified: wildlife-dependent recreation (hunting, fishing, wildlife observation, and photography); culture, community, and heritage; mental and physical well-being; and increased knowledge and awareness.

5.2.1 Wildlife-Dependent Recreation

Where deemed appropriate and compatible by the Service, hunting, fishing, wildlife observation, and photography are priority public uses permitted on certain refuges within the Refuge Complex. These types of recreation help connect people with nature and hunting and fishing can also provide food for human consumption.

5.2.2 Culture, Community, and Heritage

The lands across the Refuge Complex have rich cultural histories that predate refuge establishment and help convey the area's heritage and sense of place. Additionally, the refuges can serve as places where local communities and community interest groups (like birdwatchers or hunters) can gather, share experiences, and learn.

5.2.3 Mental and Physical Well-Being

Refuges can promote mental and physical well-being by providing a physical place for relaxation and revitalization, recreation, and exercise.

5.2.4 Increased Knowledge and Awareness

Developing educational and interpretation opportunities can increase public awareness, knowledge, and understanding of fish and wildlife resources and ecological processes. Refuges also provide opportunities for scientific and human well-being research.

5.3 Viability of the Human Well-Being Targets

Nine KEAs—with respect to human well-being targets, KEA stands for key *engagement* attributes rather than key *ecological* attributes—and associated indicators were identified for each human well-being target to represent the quality of our targets in benefiting the local community and the larger interested public. The status and trend of each KEA, its associated indicators, and the health of the human well-being targets are described below and summarized in table 36. Information used to characterize indicator status (Poor to Very Good) can be found in the Refuge Complex conservation target viability database (appendix B).

5.3.1 Wildlife-Dependent Recreation

KEA 1: Participation

Participation in wildlife-dependent recreational opportunities at the refuges conveys visitor satisfaction and interest in these activities. The indicator for participation is the number of persons participating in hunting and fishing at Salinas River, Don Edwards San Francisco Bay, and San Pablo Bay NWRs and the number of persons participating in wildlife observation and photography at Salinas River, Don Edwards San Francisco Bay, San Pablo Bay, Marin Islands, and Farallon Islands NWRs.

The current status of this KEA is judged to be Good based on the following: 1) staff best professional knowledge, 2) refuge trail counter data, and 3) tallies of the number of participants at events from each of the refuges. These data inform annual estimates of participation that are reported in the Refuge System's refuge annual performance plans. This is consistent with national trends, as the Refuge System has reported an increase in the number of visitors each year, although participation in fishing declined 5% over the past 6 years (USFWS 2016). Furthermore, from 2011 to 2016, total participants in refuge fishing, hunting, and other wildlife-associated recreation increased 16%, primarily among those who participated in wildlife observation (USFWS and USCB 2016).

Formal baseline surveys of participation in hunting, fishing, wildlife observation, and photography have not been conducted at our refuges. A survey method must be developed to better estimate and track trends in these activities by refuge.

KEA 2: Bird Species Abundance and Diversity

Providing an abundant, diverse range of bird species is essential for providing satisfactory opportunities for hunting, wildlife observation, and photography. The indicator for this KEA is the total number of birds and the number of species counted at a refuge. Waterfowl and shorebird surveys that inform the waterbird conservation target KEAs would also inform this KEA. Based on current survey data, this KEA is believed to be Good for waterfowl and Fair for shorebirds.

KEA 3: Access to Ecosystem Types

Providing access to places for the public to view, photograph, hunt, or fish is another necessary component of providing wildlife-dependent recreation. Seven types of ecosystems are provided through our conservation targets, and this KEA is indicated by the number of ecosystems accessible to the public. Note that accessible does not necessarily mean direct physical access, but it can also mean indirect access via a web camera or presentation. The current status of this KEA is considered Good.

5.3.2 Culture, Community, and Heritage

KEA 1: Communicating Culture/Heritage of the Refuges

Communicating culture and heritage is indicated by the number of refuges in the Refuge Complex that annually conduct programs involving Native American cultural history and other human history of refuge lands. We believe that these types of programs provide a range of benefits including giving individuals a sense of place and improving mental well-being.

No formal assessment has been conducted to measure the number of programs across the Refuge Complex. Refuge staff believe the current status of this KEA is Poor across the Refuge Complex; with the exception of Don Edwards San Francisco Bay NWR, the refuges do not conduct regular programs concerning the culture and/or historical heritage of their areas to the local communities. Methods to track when programs or outreach are conducted are needed.

KEA 2: Connecting with Communities

Opportunities to connect with communities are indicated by the diversity and number of partnerships across the Refuge Complex. By establishing relationships with partners, we can share refuge area culture, heritage, and appreciated natural resources with the community more efficiently than by engaging individuals; working with diverse partners also broadens our community connections.

Refuge staff believe the current status for this KEA is Very Good, although we do not formally track the number or effectiveness of our partnerships at this time. Many partnerships exist across refuges and programs. Methods to track partnerships and type of relationship and associated community connections must be created.

KEA 3: Community Support

Community support is indicated by the number of long-term stewards/advocates or volunteers. Refuge advocates and volunteers from the community suggests a strong relationship with the community and an interest by the community in the purpose and goals of a refuge. Like the KEA "Opportunities to Connect with Community," this KEA can further establish relationships with community individuals that benefit both the refuge needs and the individual's connection to his or her community while also improving their knowledge, awareness, and mental well-being.

Refuge staff believe the current status for this KEA is Fair, where data on number of long-term advocates (in the form of refuge Friends and advocacy groups) and regular (repeat) volunteers across the Refuge Complex is roughly flat.

5.3.3 Mental and Physical Well-Being

KEA 1: Participant Satisfaction

Participant satisfaction is indicated by the degree to which visitors are satisfied with refuge facilities, safety, and the variety of recreational opportunities. If they are satisfied with their visit, we believe that their mental and physical well-being will improve.

Current trends across the Refuge Complex are unknown because visitors are not formally nor regularly surveyed. Two visitor surveys have been conducted at Don Edwards San Francisco Bay NWR (Dietsch et al. 2012, Sloan 2017), but methods differed so results are not comparable for identifying trends over time nor applicable to other refuges in the Complex. Baseline surveys on participant satisfaction are needed, particularly of regular visitors. The Service is developing a standardized visitor survey that should be implemented on the Refuge Complex and repeated over time to detect trends in participant satisfaction.

5.3.4 Increased Knowledge and Awareness

KEA 1: Participation by Target Audience

Participation by target audience is indicated by the percent of target cities per refuge reached through our programs and outreach. Our refuge lands are located across 13 different counties in urban areas that are highly diverse across both ethnic and economic demographics, and our visitors have different backgrounds and interests. Accordingly, our target audiences should reflect this diversity.

Refuge staff believe the current status of this KEA is Very Good in that program participants generally represent the local diversity of the area. Participant demographics are not currently tracked but could be documented as part of the Service's soon-to-be approved standardized visitor surveys mentioned previously.

KEA 2: Increased Knowledge and Awareness

Refuge lands can be places for people to learn about ecosystems and interact with resources. We provide opportunities for scientific and human dimension research opportunities. Increased knowledge and awareness are indicated by the number of published papers from research occurring on our refuges.

Table 36. Current status and desired future state (goals) of the human well-being targets for the San Francisco Bay National Wildlife Refuge Complex in terms of select indicators.

Key Engagement Attribute	*Indicator*	*Status*	*Status Source*	*Goal*
Participation	# of hunting and fishing participants at Salinas River, Don Edwards San Francisco Bay, and San Pablo Bay NWRs; # of wildlife observation and photography participants at Salinas River, Don Edwards San Francisco Bay, San Pablo Bay, Marin Islands, and Farallon Islands NWRs	Good	Best educated guess	HWB_G01. Through 2023, maintain participation in wildlife observation and photography at Antioch Dunes NWR (from 2020 baseline numbers) and Marin Islands NWR (from 2019 baseline numbers). Through 2023, increase participation in wildlife observation and photography at Ellicott Slough and Farallon Islands NWRs from 2019 baseline numbers. Through 2023, increase participation in wildlife observation, photography, and fishing at Salinas River NWR; maintain participation in hunting at Salinas River NWR from 2019 baseline numbers. Through 2023, increase participation in hunting, fishing, wildlife observation, and photography at San Pablo Bay and Don Edwards San Francisco Bay NWRs from 2019 baseline numbers.
Bird Species Abundance and Diversity	Bird species diversity and abundance on a refuge	Good	SFBBO data, USGS data, Point Blue Conservation Science data	WTB_G01. By 2021, the annual peak number of waterbird nests in managed ponds at Don Edwards San Francisco Bay NWR is >250 for Forster's tern and >175 for American avocet. WTB_G02. By 2032, the annual number of colonial waterbird breeding pairs at Marin Islands NWR increases to ≥300. Breeding colonial waterbird species evaluated are great blue heron, great egret, snowy egret, and black-crowned night heron. WTB_G03. Over the next 5 years (2018-2022), annual wintering waterfowl species richness and abundance is stable or increasing at Don Edwards San Francisco Bay and San Pablo Bay NWRs relative to 2012 measures (Richmond et. al 2014). Measures in 2012 are as follows: Don Edwards San Francisco Bay NWR: 14 species waterfowl, eared grebes = 5,343, waterfowl = 80,793; San Pablo Bay NWR: 10 waterfowl species, waterfowl count = 31,984. The 2012 reference year

Key Engagement Attribute	*Indicator*	*Status*	*Status Source*	*Goal*
				was chosen because it represents the most comprehensive and recent data. WTB_G04. Over the next 5 years (2018-2022), wintering shorebird species richness and abundance does not decrease at San Pablo Bay NWR (SNP) and increases at Don Edwards SF Bay NWR (SFB) relative to 2015 baseline (SFB: 56,147, 22 spp; SNP: 14 spp). Expected values: SFB = 22 shorebird species, 70-90,000 individuals, SNP = 14 spp). Abundance baseline needed for SNP. CDE_G04. Over the next 15 years (2018–2032), western snowy plover fledging success ([# banded chicks fledged/# banded chicks]*100) is >40% at Salinas River NWR. Goal evaluated based on a 3-year moving average. MIE_G02. Over the next 5 years, indices of population size for Cassin's auklet, rhinoceros auklet, common murre, Brandt's cormorant, and pelagic cormorant population trends at Farallon Islands NWR are stable or increasing (based on 5-year running trend).
Access to Ecosystems	Number of ecosystems (N=7) in the Refuge Complex that are accessible to the public	Good	Best professional opinion	HWB_G02. Through 2023, all of the conservation target ecosystems of the Refuge Complex can be accessed by the public to understand and enjoy, either directly or indirectly.
Communicating culture/heritage of the Refuges	# of refuges in the Refuge Complex that have annually conducted an opportunity sharing human history of refuge lands	Poor	Best professional opinion	HWB_G03. By 2023, at least one opportunity to share the culture/heritage of each refuge in the Refuge Complex is conducted annually to a target city.
Connecting with Communities	Diversity and abundance of partnerships	Very Good	Best professional opinion	HWB_G04. The Refuge Complex will maintain more than 11 types of partnerships through 2023.
Community Support	# of long-term stewards/advocates (e.g., friends groups, advocacy groups, long-term volunteers, individual advocates, regular volunteers/ volunteer groups organizations)	Fair	Refuge volunteer and Friends data	HWB_G05. By 2023, we will increase our long-term stewards that advocate and/or volunteer for each Refuge across the Refuge Complex (based on 2019 baseline numbers).
Participant Satisfaction	Degree to which visitors are satisfied	Fair	Best professional opinion	HWB_G06. By 2023, average satisfaction of visitors is rated at 3 or above (out of 5), based on visitor surveys.

Key Engagement Attribute	*Indicator*	*Status*	*Status Source*	*Goal*
Participation by Target Audience	% of program participants from target city/minority	Fair	Best professional opinion	HWB_G07. By 2023, majority of participants attending environmental education or interpretive programs conducted for each refuge in the Refuge Complex have representation from the ethnic and cultural diversity of the target cities.
Increased Knowledge and Awareness	% of participants indicating an increase in knowledge and awareness	Good	Data from environmental education program surveys	HWB_G08. Through 2023, greater than 50% of participants surveyed indicate an increase in knowledge and awareness of refuges and their purposes from environmental education, habitat restoration learning, and interpretive programs across the Refuge Complex.
Increased Knowledge and Awareness	Number of published papers involving refuge resources	Good	Best professional opinion	HWB_G09. Through 2023, annually there are at least two published articles from scientific and human well-being research conducted on the Refuge Complex.

Note: Status designations: red = Poor, yellow = Fair, light green = Good, dark green = Very Good. Refer to the San Francisco Bay National Wildlife Refuge Complex viability database for additional details (appendix B).

5.4 Threats to the Human Well-Being Targets

Staff brainstormed the various internal and external direct threats that affect their ability to support human well-being targets. They then ranked those threats and selected threats to address for the human well-being targets (table 37). Brief descriptions of these threats are included below.

Table 37. Selected threats per human well-being target

Threats/Targets	*Mental and Physical Well-Being*	*Culture, Community, and Heritage*	*Increased Knowledge and Awareness*	*Wildlife-Dependent Recreation (Hunting, Fishing, Wildlife Observation, Photography)*
Insufficient amenities		X		X
Lack of interest			X	
Lack of knowledge, awareness			X	X
Language barrier		X		
Trash, vandalism	X			
Lack of ADA/ABA accessible infrastructure	X			
Lack of staff knowledge			X	
Competition (+/-)				X
Personal income		X		
Wayfinding challenges	X	X		X
Staff perceptions			X	
Fear of nature			X	

5.4.1 Insufficient Amenities

Amenities can include bathrooms, blinds, parking, accessible and well-maintained trails, and shade shelters. Insufficient amenities can deter people from visiting refuges and enjoying wildlife-dependent recreational opportunities promoted by a refuge. *Insufficient* not only means inadequate amenities in number, location, and type (e.g., picnic tables), but it can also mean that the amenities do not meet needs of the local community or are poorly maintained. The local community may have particular needs for enjoying the refuge that are not provided (e.g., large gathering areas, fishing and hunting locations). The insufficient amenities threat affects the culture, community, and heritage and the wildlife-dependent recreation targets.

Factors that contribute positively (+) or negatively to the insufficient amenities threat include the following:

- **Funding (-).** Limited or lack of funding can hinder the upkeep, replacement, or addition of amenities.
- **Insufficient staffing to maintain amenities (-).** Similar to the funding factor, limited or lack of staffing can hinder the upkeep, replacement, or addition of amenities.
- **Service policy on compatibility of uses with natural resources (-).** Service policy can limit the location, quantity and type of amenities that can be installed on refuges if they negatively impact natural or cultural resources.

5.4.2 Lack of Interest

Lack of interest in outdoor activities affects staff ability to increase general knowledge and awareness about the refuge and related conservation issues. Many external competing factors further reduce interest in the outdoors such as the use of electronics or other activities (e.g., organized sports, art classes, music lessons). This threat affects the increased knowledge and awareness target. Factors that contribute positively (+) or negatively (-) to the lack of interest threat include the following:

- **Lack of repeated exposure (-).** There may be a lack of interest due to limited exposure to refuge activities and conservation issues in general.
- **Lack of ways people can connect with the refuge (conventional and unconventional) (-).** Limited variety of refuge programs may also contribute to the lack of interest. The type of programs offered may not attract the local community.
- **Lack of opportunities to be in nature (young children) (-).** Many of our refuges are located in urban areas, or the nearest local community is in city centers where opportunities to connect with nature are limited or non-existent.
- **Continuity in education opportunities (throughout school years) (-).** With declining school budgets and rising costs, environmental education in the school curriculum may not be consistent and continuous across grade levels, which would exacerbate the lack of interest in nature.
- **Socio-economic barriers (generational/cultural) (-).** Most of our refuges are located in areas of high cost of living which may limit the ability of even local residents to travel to our refuges because most of the refuges have limited public transportation options. The refuges in the Complex are also located in diverse communities where there may be lack of exposure to nature, or an emphasis in other, non-nature-oriented activities.

5.4.3 Lack of Knowledge and Awareness

Similar to the lack of interest threat, lack of knowledge and awareness can affect refuge visitation and interest. Especially for refuges in urban areas, there may be many competing activities that leave people little time to explore local refuges or other open space areas. The threat affects the increased knowledge and awareness and wildlife-dependent recreation targets. Factors that contribute positively (+) or negatively (-) to the lack of knowledge and awareness threat include the following:

- **Insufficient staffing (-).** Limited or lack of staffing to make contact with visitors or conduct community outreach can exacerbate lack of knowledge and awareness about refuges.
- **Marketing/outreach (lack of funding/policy) (-)**. Lack of funding or methods to conduct marketing and outreach can inhibit lack of knowledge and awareness about refuges in the community.
- **Knowledge of local open space (-).** Lack of knowledge about local open space areas contributes to the lack of knowledge and awareness of refuges.
- **Cultural barriers (-).** Cultural barriers, including language barriers, can inhibit the local community from learning about or exploring the opportunities on refuges.
- **Lack of environmental education in public schools (-).** Lack or limited environmental education in public schools can be a barrier to exploring refuges.
- **Technology-focused area (-).** Urban refuges such as Don Edwards San Francisco Bay NWR are located in the Silicon Valley where technology is the emphasis, and opportunities in open space areas may not well known.

- **Lack of interest (-).** There is a declining interest in open space areas like refuges as people gravitate towards urban activities such as social sports, music, sporting events, arts, and social media.
- **Lack of cultural competence/experience/exposure (-).** Different cultures may not feel comfortable or confidant exploring natural areas like refuges.
- **Other outdoor recreation trends increasing/more demand (+).** With people increasingly gravitating towards urban areas, demand for outdoor recreation opportunities are a popular outlet for mental and physical well-being.
- **Declining trends in hunting and fishing (-).** Declining interest and knowledge of hunting and fishing practices may exacerbate the lack of knowledge and awareness about refuges.

5.4.4 Language Barrier

Language barrier was identified because many of the refuges are located in diverse urban areas where multiple languages are spoken. With the variety of languages spoken, it may be difficult for refuges to communicate and relate to all of the people of the surrounding communities. Signage and information only in English may detract potential visitors and supporters. This threat affects the culture, community, and heritage target. Factors that contribute positively (+) or negatively to the language barrier threat include the following.

- **Lack of funding for translations, publishing (-).** Insufficient funding to translate outreach materials may exacerbate our ability to connect to diverse cultures.
- **Many different languages spoken (difficulty translating for every language) (-).** Many of the refuges are located in areas of diverse cultures making it a challenge to provide outreach.
- **(Limited) diversity of staff/volunteers (-).** The lack of diversity of refuge staff and volunteers may also create a barrier to outreach as visitors and the local community.
- **Multilingual staff/volunteers (+).** Some refuge staff and volunteers may know languages other than English which may put visitors of those languages at ease.

5.4.5 Trash and Vandalism

Trash and vandalism on refuge properties can also deter visitors from enjoying the refuge amenities to improve their mental and physical well-being. Evidence of illegal dumping and illegal activities by humans can suggest to visitors that the area is not safe. This threat affects the mental and physical well-being target. Factors that contribute positively (+) or negatively to the trash and vandalism threat include the following.

- **Funding (-).** Limited or lack of funding could exacerbate upkeep and prevention of trash and vandalism.
- **Homelessness (-).** Increased homelessness in urban areas can make nearby open space areas a target for trash and vandalism.
- **Insufficient staffing to maintain and protect amenities (i.e., law enforcement, maintenance) (-).** Like funding, insufficient law enforcement and maintenance staff can hinder a refuge's ability to keep up with trash and vandalism.
- **Illegal activities by humans (e.g., gang activity, drug use) (-).** Proximity of refuges to urban areas makes them a target for gang or illegal drug activity which can result in increased trash and vandalism.
- **Lack of education (-).** Visitor lack of understanding of the purpose of refuges can also exacerbate trash and vandalism.
- **Development pressure (-).** Some refuges are adjacent to roads, housing development, or commercial properties that can be sources of trash and runoff.

5.4.6 Lack of ADA/ABA Accessible Infrastructure

Lack of Americans with Disabilities Act (ADA) / Architectural Barriers Act (ABA) accessible infrastructure may deter individuals and groups with special needs from enjoying the refuge amenities to improve their mental and physical well-being. This threat affects the mental and physical well-being target. Factors that contribute positively (+) or negatively to the lack of ADA/ABA accessible infrastructure threat include the following.

- **Funding (-).** Limited or lack of funding exacerbates the ability to provide sufficient universally accessible amenities.
- **Lack of staff training/knowledge (-).** Refuge staff may not have the training or knowledge to plan, design, and implement universally accessible amenities.
- **Lack of tools/equipment (-).** A refuge may not have the specialized tools or equipment to construct universally-= accessible infrastructure.

5.4.7 Lack of Staff Knowledge

Staff may not have the knowledge or training to share information that can increase the knowledge and awareness of visitors. This threat affects the increased knowledge and awareness target. Factors that contribute positively (+) or negatively to the lack of staff knowledge threat include the following.

- **Lack of time in daily routine (to interact with visitors) (-).** Refuge staff may not have the time permitted or regular experience to interact with visitors to improve public knowledge and awareness about refuges.
- **Lack of communication (-).** Refuge staff may not have training or confidence in how or what to communicate to visitors and the local community.
- **Competing priorities (-).** Other refuge staff priorities may also limit staff time or ability to communicate with visitors.
- **Lack of internal training (-).** Internal training may not be available or available at inopportune times for refuge staff to improve how they might interact with the visitors or the local community.

5.4.8 Competition

Many of our refuges are in urban areas where parks, open space areas, and other places attract visitors and thereby create competition for the Refuge Complex. Additionally, refuge visitors may compete for space or priority—e.g., bicyclists and walkers may not easily share the same trails. Visitors may also hold conflicting ideologies—e.g., hunters versus anti-hunters. This threat affects the wildlife-dependent recreation target. Factors that contribute positively (+) or negatively to the competition threat include the following:

- **Lots of other opportunities (e.g., parks to visit and recreate) (-).** Some of the refuges are located in areas where other similar open space exists which can result in visitation numbers spread across different sites. These other areas may also provide more accessible opportunities (e.g., barbecuing, recreation fields) than are compatible with refuges.
- **Lack of clear identity and distinction of refuges (-).** Directions to refuges are often not well marked due to challenges and sometimes restrictions on placing signage off refuge.
- **Free access to refuges (compared to most parks that charge entrance fees) (+).** The refuges in the Complex may be receive more visitation than other nearby opens space because they do not require a fee.
- **Refuge offers hunting in urban area (parks do not) (+).** Many open space areas do not permit hunting like our refuges.

- **Multiple uses on a trail (-).** Different types of uses may not easily share public areas such as hunters and bird watchers, resulting in reduced enjoyment in wildlife-dependent recreation opportunities.

5.4.9 Personal Income

Disposable income can limit one's ability to spend time on refuge activities. The amount of time spent working also limits one's ability to spend time on refuge. This threat affects the culture, community, and heritage target. Factors that contribute positively (+) or negatively to the personal income threat include the following:

- **Rising cost of living in San Francisco Bay and Monterey Bay areas (-).** The refuges in the Complex are located in areas of high living cost which may make it difficult to allot time to enjoy community assets like refuges.
- **Competing opportunities (-).** Particularly in urban areas where refuges are located, there are many other activities such as social sports, music, sporting events, arts, and social media.
- **No "free" time (people hold multiple jobs so lack of free time to play) (-).** Related to the high cost of living where our refuges are located, it is not uncommon for people to hold multiple jobs to meet living expenses.
- **Refuges have free entry (+).** The refuges in the Complex may be more accessible to those in the community with limited disposable income because they do not require a fee.
- **Affordable housing, transportation linkages, community focus (+).** Because many of the refuges are located in urban areas, there may be more opportunities for the community to access affordable housing, public transit, and community services allowing for time and disposable income to access local open space areas.

5.4.10 Wayfinding Challenges

Wayfinding challenges concern navigating to the refuge and around the refuge. Refuges may be difficult to find with so many access points and a lack of wayfinding signage. This threat affects the mental and physical well-being; wildlife-dependent recreation; and culture, community, and heritage targets. Factors that contribute positively (+) or negatively (-) to the wayfinding challenges threat include the following:

- **Lack of accurate location info (e.g., GPS, Google Maps) (-).** Mainstream wayfinding technology such as Google Maps or Waze may not accurately show how to navigate directly to a refuge trail or parking area, which may deter visitors from a refuge.
- **Reliance on technology (compared to written directions) (-).** Due to lack of accurate information on mainstream wayfinding technology as mentioned earlier, the local community may not be comfortable using traditional written directions found on refuge websites to access refuges.
- **Transportation agency barriers (-).** Many of the refuges in the Complex have limited or no public transit options. For instance, the closest bus stop to the headquarters of the Don Edwards San Francisco Bay NWR is not deemed by the Refuge System standards to be accessible enough based on distance and safety.
- **Language barrier (-).** The refuges are located in diverse communities where many languages are spoken. The signage and website information are primarily in English with some limited Spanish.
- **Comfort levels (-).** The public may have different comfort levels in following existing signage and online directions.
- **Lack of effective/readable signs/communication (-).** Some of the existing wayfinding signage and online instructions are old and may not be in appropriate locations or in poor condition.

- **Communication (websites, apps, etc.) (-).** Wayfinding information to the refuges may not be updated or located in online websites and applications where the public may commonly use.
- **Unmaintained trails (-).** Some refuge trails and their associated amenities (e.g., wayfinding signage, benches) have not been maintained which may deter the local community from enjoying the refuge's public opportunities.
- **Insufficient staffing – law enforcement and maintenance (-).** Insufficient presence of staff may also exacerbate visitors experience in navigating around a refuge.
- **Funding (-).** Limited or lack of funding may also challenge a refuge's ability to communicate how to access a trail or site.
- **Lack of facilities (-).** Insufficient facilities to enjoy outdoor areas due to funding may also exacerbate the ability to explore all parts of a refuge.
- **Complicated to access refuge (e.g., drive through other property first) (-).** Some access points to the refuges require access through other properties that may deter visitors.

5.4.11 Staff Perception

Staff perception concerns the idea that staff beliefs and training (or lack thereof) can affect visitor interactions. The interactions could also be affected by staff availability or interest in interacting with visitors. With regard to research, staff are focused on permitting research that relates to management priorities, so some research may be denied even though it can increase general knowledge. This threat affects the increased knowledge and awareness target. Factors that contribute positively (+) or negatively (-) to the staff perception threat include the following:

- **Policy barriers (local, regional, national) (-).** Institutional or conservation policies may present barriers to staff in welcoming more of the public to the refuge.
- **Career ladder is geared towards biological sciences (-).** The career ladder for visitor services careers in the Service is not as comprehensive compared to the biological program. This can hinder staff development and initiative to work with the public.
- **Perception that closed refuges do not need outreach or education opportunities (-).** There has been limited development of outreach and education opportunities for refuges closed to the public, suggesting that there is no need for it.
- **Lack of internal education (-).** Lack of training about how to communicate with visitors and the local community can affect staff interactions with the local community.

5.4.12 Fear of Nature

The local community may have a perceived fear of nature based on other non-nature-based experiences, limited exposure to nature, or incorrect beliefs about nature in popular culture. This threat affects the increased knowledge and awareness target. Factors that contribute positively (+) or negatively (-) to the fear of nature threat include the following:

- **Fear of unknown (lack of information, misconceptions) (-).** Fear of the unknown or misconceptions about nature can inhibit the transfer of any knowledge or awareness about a refuge.
- **Fear of crime (-).** The local community may have a perception that quiet nature areas may attract crime and deter them from visiting.
- **Lack of amenities (-).** Insufficient facilities to enjoy outdoor areas due to funding may also prevent the local community from exploring a refuge.
- **Perceptions of trails (-).** The public may have perceptions of trails being dangerous as they often have few people or that wildlife seen on trails can be dangerous.

- **Law enforcement (-).** Refuge law enforcement may be compared or seen as equivalent to immigration law enforcement, which may deter visitation.
- **Socio-economic (lack of exposure to outdoor activities) (-).** Lower income individuals and families may not have had past opportunities to the outdoors due to financial ability and therefore may not feel comfortable in nature.
- **Cultural barriers (urban area, way of life, ethnicity) (-).** Different cultures may not have exposure to nature and outdoor recreational opportunities and thus have a fear of nature.

5.5 Strategies to Support Human Well-Being

Ten strategies were identified to reduce the selected threats to human well-being targets described above. Threats addressed by each strategy and expected outcomes (objectives) are summarized in table 38. Each strategy is briefly described in the following, in order of priority to implement. Results chains visually depicting the assumptions behind these strategies (how they work) and expected outcomes were developed as part of the process.

5.5.1 Conduct Environmental Education in Schools

Conduct environmental education programs for grades K–6 about the conservation targets of the Refuge Complex; these should include hands-on, small group activities focusing on the selected conservation targets of the Refuge Complex per the 5-year work plan. Programs include field trips, school visits, science nights, and summer camp. This strategy intends to improve knowledge, interest, and awareness of the refuge and conservation issues as well as reduce the fear of nature.

5.5.2 Conduct Environmental Education and Interpretation with Community Groups

This strategy involves conducting environmental education and interpretation to the public and specific groups to increase knowledge, awareness, and interest in refuges across the Refuge Complex and nature in general. Programs would focus on selected conservation targets of the Refuge Complex per the 5-year work plan and on target audience of refuges within the Refuge Complex (this would not include school field trips, as this falls under a separate strategy). Groups include Girl Scouts and Boy Scouts, senior groups, youth groups, universities, special interest clubs, afterschool programs, homeschool programs, and other local organizations. Programs would be both onsite and offsite, and we would leverage partner involvement. This strategy is intended to improve knowledge, interest, and awareness of the refuge and conservation issues as well as reduce fear of nature.

5.5.3 Conduct Habitat Restoration-Learning Programs

This strategy aims to improve knowledge and awareness through service activities to support conservation targets identified in the Refuge Complex's 5-year work plan. Programs would include education and habitat restoration through science explorations, citizen science (scientific research conducted by the non-professionals), and service-learning focused on the selected conservation targets. This strategy is intended to improve knowledge and awareness of the refuge and conservation issues as well as reduce fear of nature. This strategy will also help reduce invasive species.

5.5.4 Enhance and Manage a Volunteer Program

This strategy realigns and integrates a coordinated volunteer program to provide meaningful community engagement and learning opportunities that directly support the needs of the priority conservation strategies identified in Refuge Complex's 5-year work plan. This includes a docent program to conduct outreach and volunteer events to improve presence on refuges (Antioch Dunes and Salinas River NWRs) and controlling invasive vegetation (Don Edwards San Francisco Bay, San Pablo Bay, Marin Islands, and Antioch Dunes NWRs). This strategy will improve mental and physical well-being as well as improve knowledge and awareness while also reducing invasive species.

5.5.5 Conduct Strategic Communications to Affect Behavior Change

Conduct strategic communications to change behavior of individuals and groups that are identified as contributing to high threats to conservation targets per the Refuge Complex's 5-year work plan. Threats identified include reducing human disturbance (Salinas River and Marin Islands NWRs), controlling invasive vegetation (Don Edwards San Francisco Bay NWR), and managing predators (Don Edwards San Francisco Bay NWR). This strategy is also intended to improve knowledge and awareness and support the conservation targets by reducing avian and mammalian predators.

5.5.6 Conduct Community Outreach Offsite with (New) Target Audiences

This strategy raises awareness of refuges (and ultimately boosts participation in refuge activities or stewardship/support for refuge resources) and targets specific, non-traditional groups within the target audience of each refuge using appropriate methods of communication based on the target group. Communication and marketing methods may differ depending on the group; partners would be utilized to capitalize on their resources and relationships. Local communities with lower incomes near our refuges would be a priority target audience.

5.5.7 Conduct Patrols and Increase Staff or Volunteer Presence in Public Areas

This strategy increases the presence of refuge staff, refuge law enforcement, and/or volunteers in public areas of the Refuge Complex to enhance visitor safety and knowledge. It would involve trail patrols by uniformed individuals who would make contact with visitors; it would also involve tracking safety/vandalism/trash that detracts from the visitor experience in order to rectify. This strategy is intended to reduce trash and vandalism; it is also intended to reduce fear of nature with staff and volunteers making connections with visitors.

5.5.8 Improve Communication on How to Get around the Refuge (once here)

This strategy focuses on communicating with visitors across the Refuge Complex to improve wayfinding and, as a consequence, enhancing visitor safety and knowledge. It involves identifying language needs per site/refuge, inventorying signage and conditions, updating materials (pre-visit and during visit), and creating or managing websites, including virtual and "live" tools. It also involves training staff and volunteers to address visitor wayfinding questions. This strategy includes evaluating, designating, and communicating zones/trails for priority uses in order to reduce competition/conflict between user groups. This strategy is intended to reduce wayfinding challenges and competition at refuges.

5.5.9 Improve and Maintain Visitor Amenities

This strategy concerns communicating with visitors across the Refuge Complex to improve visitor ability to experience refuge priority public uses (hunting, fishing, wildlife observation, interpretation, and photography) while on a refuge. It will include inventorying amenities and identifying gaps; consulting groups for types of special needs; and developing a maintenance plan for infrastructure, care/prevention of high trash/vandalized areas, and removal of unnecessary/unused/inappropriate infrastructure. This strategy is intended to improve wayfinding challenges and address insufficient amenities.

This strategy also includes improving refuge visitor amenities in order to comply with the Americans with Disability Act (ADA) and the Architectural Barriers Act (ABA). It involves assessing current conditions, identifying gaps, identifying requirements, understanding Service funding mechanisms, and seeking alternative funding opportunities. This strategy is intended to improve visitor amenities, particularly ADA/ABA amenities.

A conceptual model depicting threats to human well-being targets and strategies aimed at reducing the most critical threats is depicted in figure 29.

Table 38. Threats addressed by each strategy and expected outcomes (objectives)

Strategy Title	*Threat Addressed*	*Expected Outcome (Objectives)*
Conduct environmental education in schools	Lack of knowledge, awareness; lack of interest; fear of nature	HWB_O01. By end of 2020, Refuge Complex has a strategic plan for its environmental education program (schools), environmental education/interpretation program (community groups), habitat restoration-learning program, and community outreach program. HWB_O02. By 2023, we will have environmental education programs (with a documented curriculum) established with a partner school at Don Edwards San Francisco Bay, San Pablo Bay, Marin Islands, and Salinas River NWRs.
Conduct environmental education and interpretation with community groups	Lack of knowledge, awareness; lack of interest; fear of nature	HWB_O01. By end of 2020, Refuge Complex has strategic plan for its environmental education program (schools), environmental education/interpretation program (community groups), habitat restoration-learning program, and community outreach program. HWB_O03. By end of 2020, the Refuge Complex has identified up to two priority audiences for each refuge. HWB_O04. By 2022, annually conduct environmental education and interpretation with priority audiences for each refuge in the San Francisco Bay NWR Complex. HWB_O05. By 2023, the number of groups and residents from a target city at a complex program increases by 20% of 2020 baseline numbers.
Conduct habitat restoration-learning programs	Lack of knowledge, awareness; lack of interest; fear of nature; invasive species	HWB_O06. By 2019, the San Francisco Bay National Wildlife Refuge Complex has identified priority restoration sites that benefit conservation targets and priority audience groups for Ellicott Slough, Salinas River, and Antioch Dunes NWRs. HWB_O01. By end of 2020, Refuge Complex has strategic plan for their environmental education (schools), environmental education/interpretation (community groups), habitat restoration-learning, and community outreach programs. HWB_O07. By 2023, habitat restoration-learning projects (with a documented curriculum) are occurring at Ellicott

Strategy Title	*Threat Addressed*	*Expected Outcome (Objectives)*
		Slough, Salinas River, and Antioch Dunes NWRs in sites that benefit conservation targets.
Develop a volunteer program	Invasive species	HWB_O08. By 2020, Refuge Complex has a comprehensive list of volunteer job descriptions for refuges across the Complex. List is updated annually. HWB_O09. By 2023, at least 50 percent of volunteer positions are filled annually. HWB_O10. By 2025, we have increased our regular volunteers (those that participate in more than one event annually) by 20 percent of 2019 baseline regular volunteers. HWB_O11. By 2025, 20% of volunteers for a refuge are from the target cities identified by the refuge staff.
Conduct strategic communications to affect behavior change	Avian and mammalian predators	WB_O12. On Marin Islands NWR, mammalian predators are not present during the nesting season. HWB_O13. Through 2023, annually there are no feral cat feeding stations directly adjacent to priority areas (as defined in predator management annual workplan) of Don Edwards San Francisco Bay NWR. HWB_O14. By 2023, USFWS has a better understanding of why gull populations are increasing and what actions could be taken to address this. HWB_O15. On an annual basis in Don Edwards NWR, there are no successful raven and raptor nests on PG&E towers in accessible priority areas, as identified in the Don Edwards San Francisco Bay NWR predator management plan and annual work plans. HWB_O16. Over the next 5 years, within season frequency of eggs, chicks, and fledgling predation events decrease as a result of predator management at Salinas River NWR. HWB_O17. By 2023, develop communication plan which addresses the human behavior threats to conservation targets. HWB_O18. By 2030, as a result of receiving messaging, 50% of known/specific target audience commits/agrees to adopt/support best management practices.
Conduct community outreach off-site with target (new) audience	Lack of knowledge, awareness; fear of nature; lack of interest	HWB_O03. By end of 2020, the Refuge Complex has identified up to 2 priority audiences for each refuge to conduct community outreach. HWB_O01. By end of 2022, Refuge Complex has strategic plan for their environmental education (schools), environmental education/interpretation (community groups), habitat restoration-learning, and community outreach programs. HWB_O19. By 2022, conduct community outreach programs for Farallon Islands and Ellicott Slough NWRs. HWB_O20. By 2023, the number of local community groups and residents that participate at a complex program increases by 30% of 2020 baseline numbers.
Conduct patrols/increase staff/volunteer presence in public areas	Trash, vandalism; fear of nature	HWB_O21. By 2022, develop and implement plan for non-law enforcement staff and volunteers to increase time on Refuges by 20% of 2019 baseline.

Strategy Title	*Threat Addressed*	*Expected Outcome (Objectives)*
		HWB_O22. By 2025, vandalism, trash dumping, and violations are reduced by 25% of baseline rates. (Ex. ~450 reports in 2018)
Improve communication on how to get around the refuge (once here)	Wayfinding challenges	HWB_O23. By 2023, we will have translated all important wayfinding material (web, brochure, etc.) into languages that target our target audiences. HWB_O24. By 2025, of the visitors surveyed, 10% above 2020 baseline are satisfied with our wayfinding tools (maps, signs, brochure, apps).
Improve and maintain visitor amenities	Insufficient amenities; wayfinding challenges; ADA/ABA Accessibility	HWB_O25. By end of FY2020, team will conduct site visits to perform an inventory and rapid assessment of trails, fishing infrastructure, hunt blinds, photography blinds, wildlife observation platforms, interpretive panels and signs on Salinas River NWR. HWB_O26. By end of 2023, teams will have completed accessibility plans for both Don Edwards San Francisco Bay and San Pablo Bay NWRs. HWB_O27. By 2025, refuge staff will have completed accessibility plans for all refuges with public access in the San Francisco Bay National Wildlife Refuge Complex. HWB_O28. By 2030, we will have completed 50% of identified tasks in the accessibility plans for Don Edwards San Francisco Bay and San Pablo Bay NWRs.

5.6 Urban Wildlife Conservation Program—Standards of Excellence

The human well-being strategies also further our contribution to meeting the Service's *Standards of Excellence for Urban National Wildlife Refuges* (USFWS 2014). The Don Edwards San Francisco Bay NWR is specifically recognized by the Service as one of 14 priority urban refuges in the Refuge System, but all the refuges in the Refuge Complex provide outstanding opportunities to engage our urban neighbors in the San Francisco and Monterey Bay areas. The following eight standards serve as a framework for collaboration among the Service and urban communities, whether such collaboration is on or off Service lands:

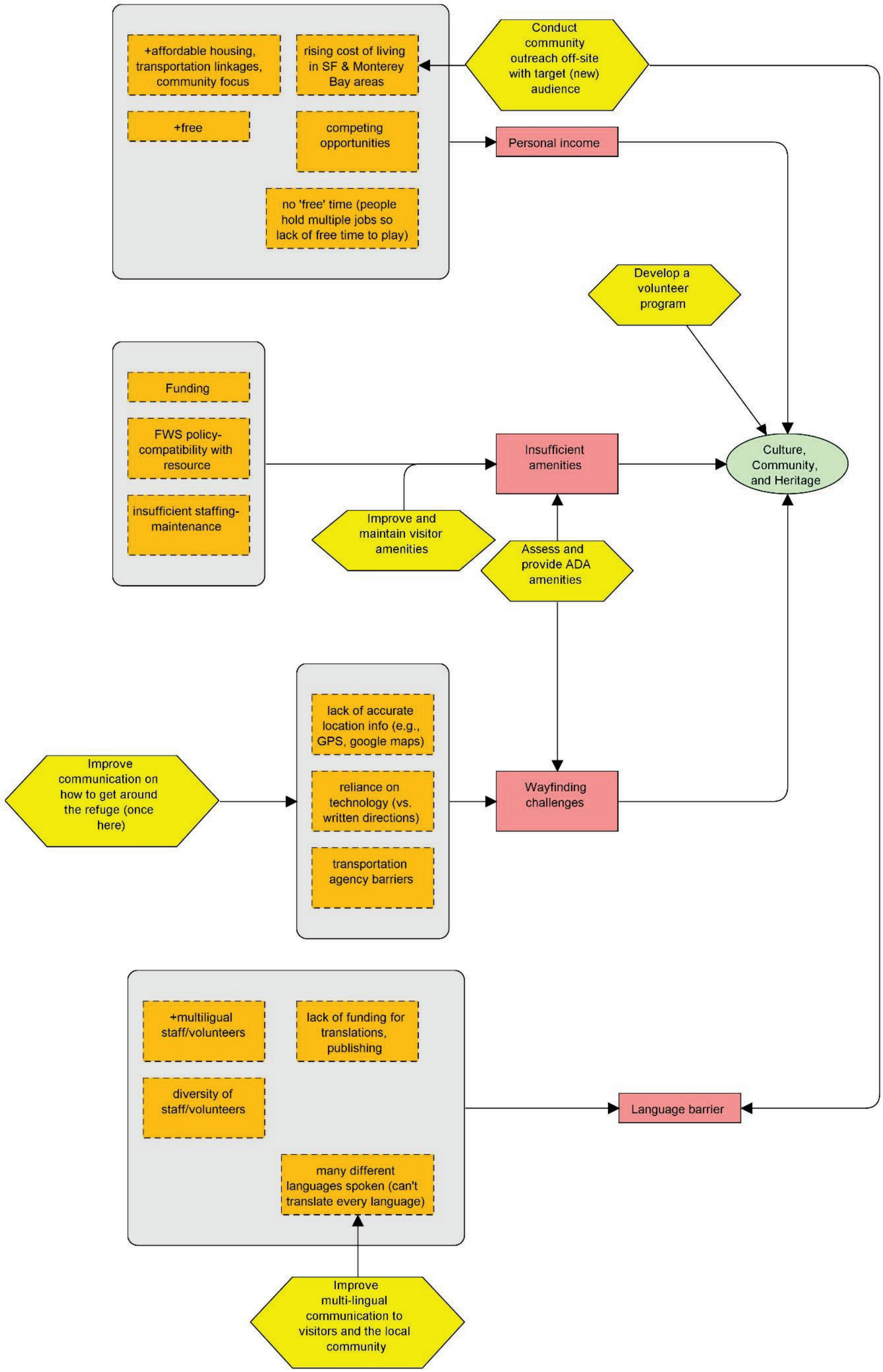
1. Know and relate to the community
2. Connect urban people with nature via stepping stones of engagement
3. Build partnerships
4. Be a community asset
5. Ensure adequate long-term resources
6. Provide equitable access
7. Ensure visitors feel safe and welcome
8. Model sustainability

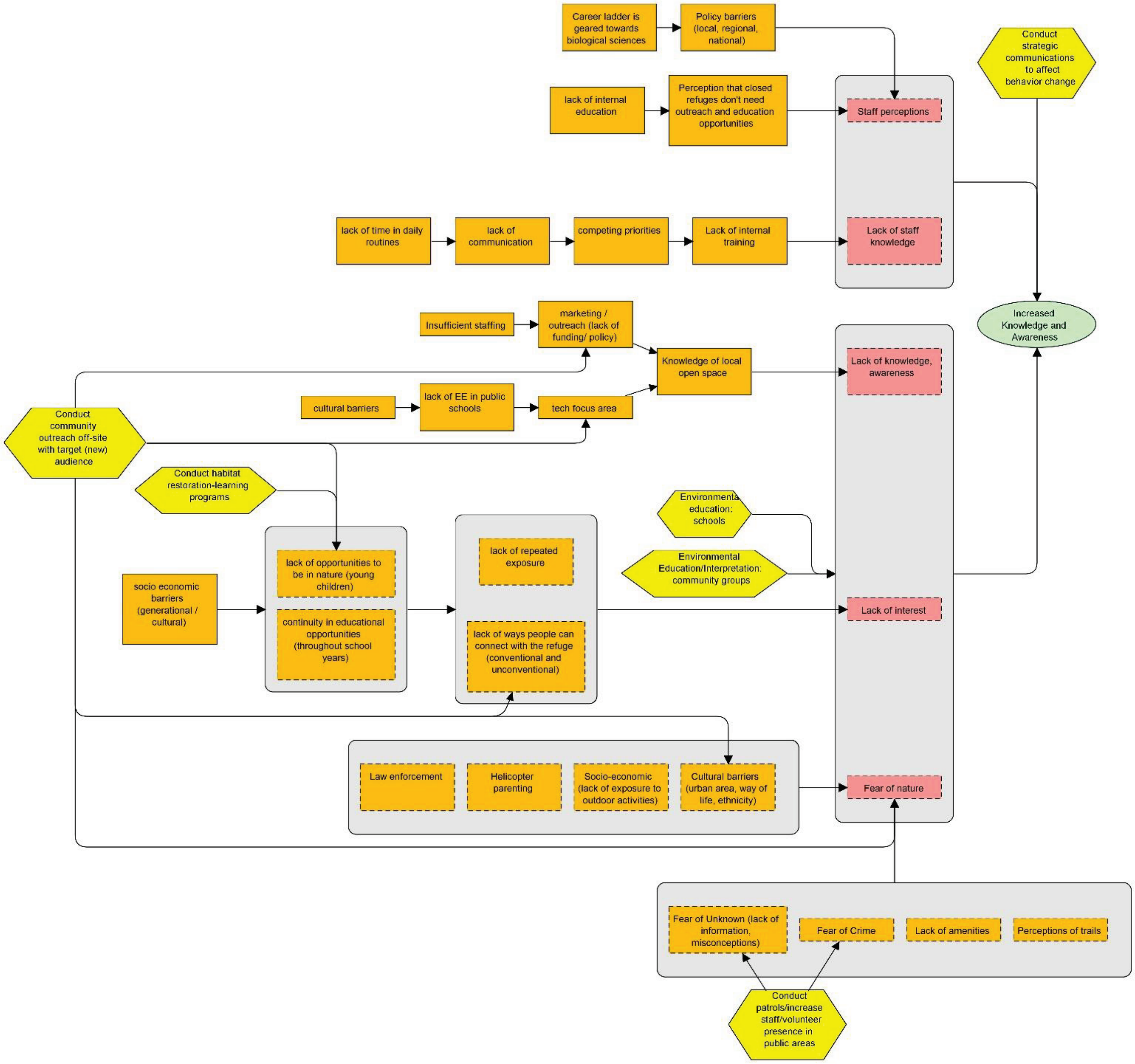
Table 39 provides a quick view of where our human well-being strategies contribute to these eight standards.

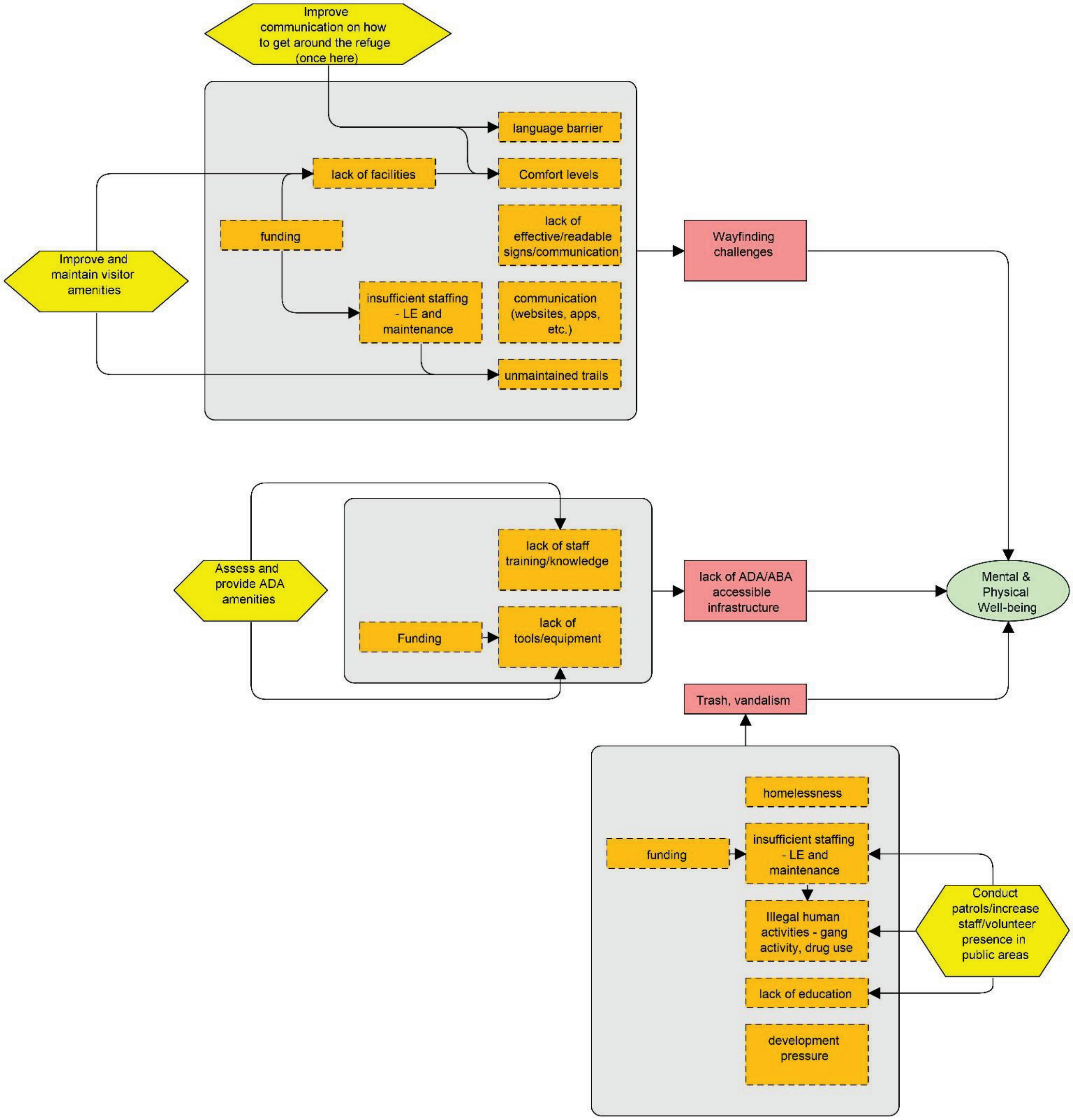
Table 39. Human well-being strategies and contributions to Standards of Excellence.

Human Well-Being Strategies	*Standards of Excellence for Urban National Wildlife Refuges*							
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Conduct environmental education in schools	X	X	X	X		X	X	X
Conduct environmental education/interpretation with community groups	X	X	X	X			X	X
Conduct habitat restoration-learning programs		X	X	X			X	X
Enhance the volunteer program	X	X	X	X	X	X	X	X
Conduct strategic communications that affect behavior change							X	X
Conduct community outreach off-site with target (new) audience	X	X	X	X			X	X
Improve and maintain visitor amenities	X			X	X	X	X	
Conduct patrols/increase staff/volunteer presence in public areas	X			X			X	
Improve communication on how to get around the refuges (once here)	X	X		X		X	X	

Note: For standards, see the list in text that precedes this table; additional information can be found in *Standards of Excellence for Urban National Wildlife Refuges* (USFWS 2014)


+affordable housing, transportation linkages, community focus
rising cost of living in SF & Monterey Bay areas
Conduct community outreach off-site with target (new) audience
+free
competing opportunities
Personal income
no 'free' time (people hold multiple jobs so lack of free time to play)
Develop a volunteer program
Funding
FWS policy-compatibility with resource
insufficient staffing-maintenance
Insufficient amenities
Culture, Community, and Heritage
Improve and maintain visitor amenities
Assess and provide ADA amenities
lack of accurate location info (e.g., GPS, google maps)
Improve communication on how to get around the refuge (once here)
reliance on technology (vs. written directions)
Wayfinding challenges
transportation agency barriers
+multiligual staff/volunteers
lack of funding for translations, publishing
diversity of staff/volunteers
Language barrier
many different languages spoken (can't translate every language)
Improve multi-lingual communication to visitors and the local community


Career ladder is geared towards biological sciences
Policy barriers (local, regional, national)
Conduct strategic communications to affect behavior change
lack of internal education
Perception that closed refuges don't need outreach and education opportunities
Staff perceptions
lack of time in daily routines
lack of communication
competing priorities
Lack of internal training
Lack of staff knowledge
Increased Knowledge and Awareness
Insufficient staffing
marketing / outreach (lack of funding/ policy)
Knowledge of local open space
Lack of knowledge, awareness
cultural barriers
lack of EE in public schools
tech focus area
Conduct community outreach off-site with target (new) audience
Conduct habitat restoration-learning programs
Environmental education: schools
Environmental Education/Interpretation: community groups
socio economic barriers (generational / cultural)
lack of opportunities to be in nature (young children)
continuity in educational opportunities (throughout school years)
lack of repeated exposure
lack of ways people can connect with the refuge (conventional and unconventional)
Lack of interest
Law enforcement
Helicopter parenting
Socio-economic (lack of exposure to outdoor activities)
Cultural barriers (urban area, way of life, ethnicity)
Fear of nature
Fear of Unknown (lack of information, misconceptions)
Fear of Crime
Lack of amenities
Perceptions of trails
Conduct patrols/increase staff/volunteer presence in public areas



Improve communication on how to get around the refuge (once here)
language barrier
lack of facilities
Comfort levels
funding
lack of effective/readable signs/communication
Improve and maintain visitor amenities
insufficient staffing - LE and maintenance
communication (websites, apps, etc.)
unmaintained trails
Wayfinding challenges
lack of staff training/knowledge
Assess and provide ADA amenities
lack of ADA/ABA accessible infrastructure
Mental & Physical Well-being
Funding
lack of tools/equipment
Trash, vandalism
homelessness
funding
insufficient staffing - LE and maintenance
Illegal human activities - gang activity, drug use
Conduct patrols/increase staff/volunteer presence in public areas
lack of education
development pressure

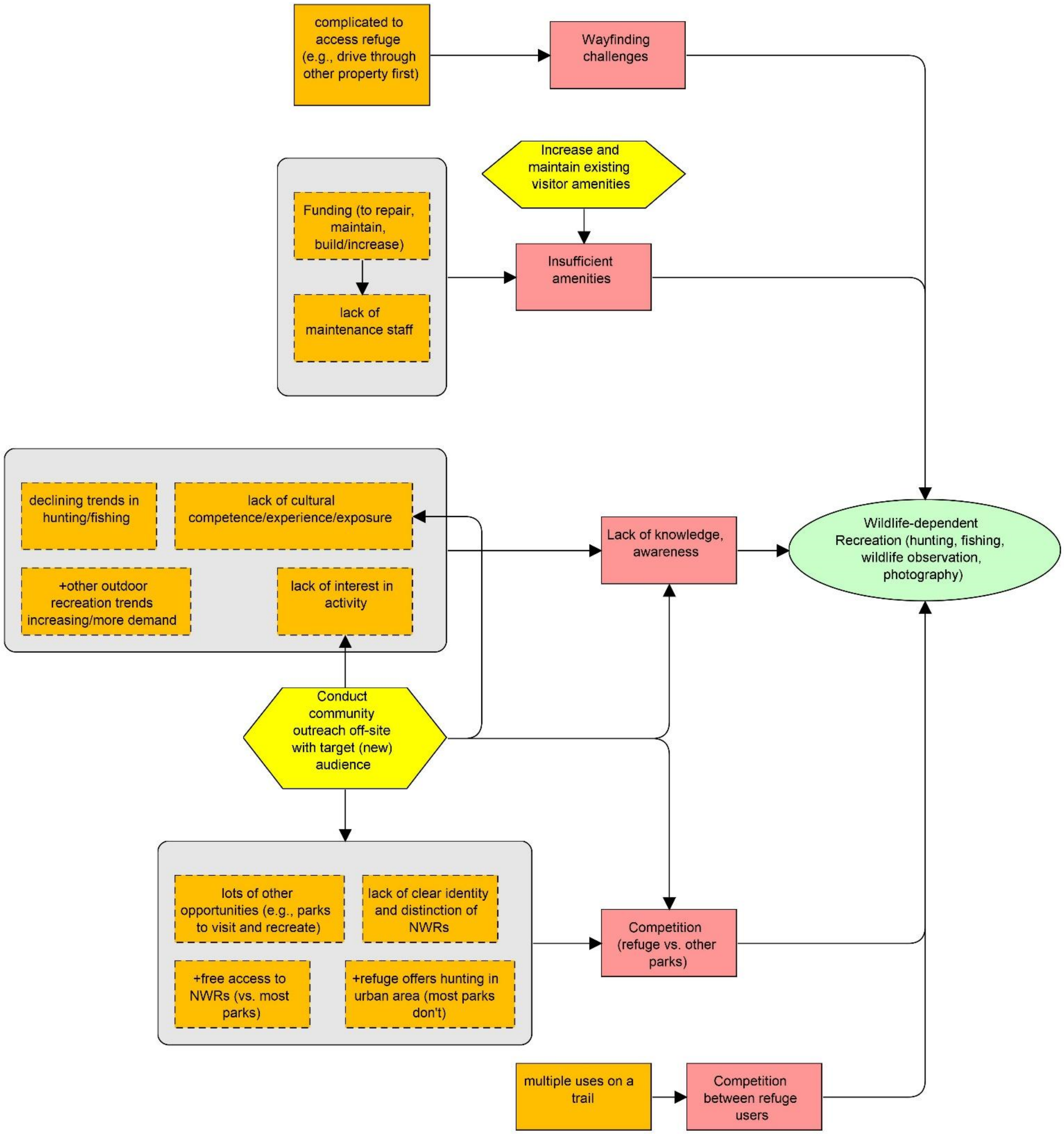


Figure 27. Conceptual models of the four human well-being targets across the San Francisco Bay National Wildlife Refuge Complex depicting the most critical threats and strategies aimed at addressing them.

Notes: Legend: green oval = human well-being target; pink box = direct threat; orange box = contributing factors; yellow hexagon = conservation strategy.

5.7 Priority Surveys for the Human Well-Being Targets

Surveys needed to measure whether we are achieving our human well-being goals and the effectiveness of Refuge management strategies (objectives) are presented below (table 40). Surveys are listed in order of priority to conduct based on survey prioritization in 2017.

Table 40. Surveys linked to human well-being goals and objectives in the San Francisco Bay National Wildlife Refuge Complex 5-year work plan.

Survey Name	*PRIMR ID*	*Status*	*Survey Frequency*	*Goal or Objective Informed by Survey (ID)*	*Survey Lead*
Participation rates for hunting, fishing, wildlife observation, and photography	New	New	3 years	HWB_G01	DE_MGR
Environmental education student evaluation: measure increased knowledge and awareness	New	New	Annual	HWB_G08	COM_EE
Environmental education/interpretation participant evaluation: measure increased knowledge and awareness; percent of participants that are target city groups and residents	New	New	Annual	HWB_G08, HWB_O05	COM_ORP
Habitat restoration-learning participant evaluation: measure increased knowledge and awareness	New	New	Annual	HWB_G08	COM_EE
Participant evaluation: measure behavior change	New	New	5 years	HWB_O18	COM_PAO
Survey effectiveness of community outreach	New	New	5 years	HWB_G07, HWB_O20	COM_ORP
Accessible amenities: evaluation by advisory group	New	New	10 years	HWB_O17	COM_DPL
Visitor survey: satisfaction with wayfinding tools	New	New	5 years	HWB_O24	COM_ORP
Visitor survey: satisfaction	New	New	10 years	HWB_G06	DE_MGR

Note: Status based on whether the survey was in the PRIMR survey database as of 2017 and identified as *current*. If a survey was not in PRIMR, it is tagged here as *new*.

Chapter 6—Plan Implementation and Evaluation

This chapter summarizes how the NRMP and IMP will become operational through annual work planning and evaluation practices. It also summarizes existing commitments of resources that will continue to influence Refuge Complex operations and the resources available to address priorities. Lastly, we provide a brief overview of some of the changes to refuge-specific activities resulting from the NRMP-IMP process and potential consequences.

6.1 Annual Evaluation and Work Planning

As described previously (chapter 2), we used the Open Standards for the Practice of Conservation planning process to support development of the Complex NRMP and IMP and guide implementation of the priority strategies and actions identified herein. The NRMP and IMP represent steps one and two of the iterative process and provide refuge staff with a framework for practicing adaptive management—a dynamic process for regular review, learning, and adaptation.

The extensive and in-depth planning that went into developing the NRMP and IMP and associated Five-Year Work Plan was not meant to be a one-time event; rather, the iterative management cycles require us to evaluate, learn, and adjust (if needed) the original core assumptions behind our conservation and human well-being strategies and surveys. New and emerging threats, shifting priorities, important research findings, and innovations may help inform and refine Refuge Complex goals and objectives, strategies, and surveys. In order to implement a more adaptive approach, we must also modify our business practices and foster a culture of learning and sharing among staff and partners—what is working as well as what is not working. This requires a shift in the paradigm of reallocating scarce resources from reacting to immediate needs and demands to the more proactive and long-term work of adaptive management.

Since the completion of the NRMP, IMP, and five-year work plan, we have adopted the following business practices to ensure consistency, transparency, accountability, and shared governance around our collective responsibility for its implementation:

- Revised the Refuge Complex Leadership Team's monthly meeting agenda to focus discussions on annual work planning to facilitate regular review and ensure coordination, learning and adaptation at the complex level; and created monthly status report for tracking accomplishments by strategy.
- Adjusted Quarterly all Hands Meeting schedule to align with work planning schedule and budget year; revised the meeting format to focus on annual work planning updates, cross-team coordination, and evaluation.

- Established target teams that will meet regularly to facilitate regular review, learning and adaptation at the conservation or human well-being target level.
- Established Complex-Wide Strategy teams to address the common issues and develop coordinated efforts and best management practices, including Data Management, Invasive Plant Management, and Native Plant Nursery Management.
- Added work planning as an activity in staff time allocations in the five-year work plan to ensure everyone gives adequate time and attention to participating in teams and keeping the work plan active and relevant.
- Added strategy/activity codes to Refuge Complex's Budget Request Approval process to track funding needs and expenditures.
- Added performance standards to Employee Performance Appraisal Plans to ensure implementation of assigned work plan strategies and activities.
- Evaluated five-year work plan to develop rationale for recruitment and staffing needs that support priority strategies and activities, in addition to R8 NWRS Workforce Plan.
- Conducted outreach to various partners about the Refuge Complex NRMP and IMP to seek technical assistance and leverage funding for implementing priority strategies.

The NRMP clearly articulates the optimal set of management strategies the Service should implement with its limited resources over the next 15 years while also addressing the potential impacts of climate change expected over the next 5 years. Refuge management strategies, along with measures of progress, maximize conservation priority surveys (inventory, monitoring, and research) to inform NRMP goals and objectives and to improve our knowledge about the natural resources we manage and evaluate if we are effectively engaging the public as a conservation constituency through the human well-being strategies. Both the NRMP and IMP are dynamic plans and should be evaluated and improved over time as we assess progress toward our desired conservation and public engagement goals and deepen our knowledge about the priority ecosystems and associated key ecological indicators, as well as new and emerging threats.

6.2 Balancing Commitments

The strategies and surveys laid out in this NRMP, and companion IMP and 5-year work plan (FY2018–2022), provide an adaptive management framework that seeks to advance evidence-driven conservation at the Refuge Complex. While selected priorities (targets, strategies, surveys) are forward-facing and ambitious, they must be balanced with the continuing demands of many longstanding commitments and non-discretionary administrative requirements of the daily operations and maintenance of a large and widely dispersed complex of public lands. This chapter provides an overview of several major commitments that must be balanced within the optimal allocation of resources (personnel, funding, and equipment) to the priority targets identified in the previous chapters. The allocation of staff responsibilities, time and funding needed is accounted for under Other Commitments in the Refuge Complex work plan.

6.2.1 Central Coast Common Murre Restoration Project

The Common Murre Restoration Project was initiated in late 1995 with the goal to restore breeding colonies of seabirds along the central coast of California, especially those of common murres (*Uria aalge*), that were harmed by the 1986 *Apex Houston* oil spill as well as by gill net fishing and other impacts. The Refuge Complex has coordinated the project since its inception in cooperation with Humboldt State University (HSU).

From 1995 to 2005, the primary goals were to restore the previously extirpated Devil's Slide Rock murre colony near San Francisco by using social attraction techniques and to assess restoration needs at additional central California colonies. Since 2005, efforts have focused on monitoring the successful recolonization of Devil's Slide Rock and recovery of other colonies at Point Reyes and Big Sur Coast, including seabird productivity, seabird attendance patterns, and relative population sizes. In addition to murres, data are also collected on Brandt's cormorant, pelagic cormorant, western gull, pigeon guillemot (*Cepphus columba*), and American black oystercatcher (*Haematopus bachmani*). Additionally, standardized procedures for the surveillance and assessment of human disturbance (mainly aircraft and watercraft) have been incorporated into daily survey methods in order to evaluate the effectiveness of education, outreach, and regulatory efforts by the Seabird Protection Network (coordinated by the Greater Farallones National Marine Sanctuary).

The project is funded entirely through the original *Apex Houston* settlement fund as well as subsequent support from the 1998 *Command* oil spill restoration fund (2005–2010) and the *Luckenbach* oil spill restoration fund (since 2011). Funding currently supports 0.5 FTE for a project coordinator (refuge employee) and 1.0 FTE for an assistant coordinator (an HSU employee), in addition to seasonal field crews (hired by HSU). Primary workload includes coordinating with partners, managing financial assistance agreements, training and oversight of seasonal field staff (five), database management, and report writing. The project is expected to end in 2030, given funds approved to date.

Regional Context

The monitoring data collected as a component of the Common Murre Restoration Project, in addition to data from the Marine Islands Ecosystem discussed in chapter 4, "Conservation Target Summaries," has informed several regional efforts focused on seabird conservation. The human disturbance assessment informed the establishment of special closures within the statewide network of marine protected areas created under the 1999 California Marine Life Protection Act. These data and respective survey protocols are also key components of the Service's current effort to integrate data management and protocol development across Alaska, California, Hawaii, Oregon, and Washington in support of the Pacific Region Seabird Conservation Plan (USFWS, 2005).

6.2.2 Alameda Point California Least Tern Colony Management

The California least tern colony is located on the former Naval Air Station Alameda in the central part of San Francisco Bay. The endangered California least terns (*Sternula antillarum browni*) have nested between two of the runways since at least 1976. Since 1979, the Navy conducted management activities for the benefit of the least tern, including fencing around the 6-acre colony; enhancing the nesting substrate with gravel, soil, sand and oyster shells; and controlling vegetation and predators. In 2004, the colony site was expanded to 9.7 acres, new fence was installed, and substrate enhancements were added. In 2012, the Navy transferred the property to the Department of Veterans Affairs (VA). The Refuge Complex has been assisting in the long-term management of the least tern colony at Alameda since about 1999 through an interagency reimbursable agreement previously with the Navy and now with the VA.

Pursuant to the Defense Base Closure and Realignment Act of 1990, the Navy sought to dispose and transfer excess property at Naval Air Station Alameda to the City of Alameda for reuse and development. The Navy retained an area comprising 624 acres of the former airplane tarmac including and surrounding the tern colony for eventual transfer to the Service to become a National Wildlife Refuge; however, the transfer never occurred due to unresolved contamination and remediation issues. Subsequently, the Navy transferred the area to the VA for the purpose of constructing and operating a VA outpatient clinic and national cemetery complex. The VA then became legally responsible under Section 7 (a) of the Endangered Species Act for protection of endangered species and management of the least tern colony, pursuant to the incidental take and conservation measures in a Biological Opinion issued by the Service in 2012.

The long-term conservation of least terns at Alameda requires the following measures: vegetation control and weed removal in and around the colony; maintenance of the security fence surrounding the colony; placement of coarse sand, gravel, shells, and other measures to enhance nesting habitat quality; breeding season monitoring of the least terns; and control of terrestrial and avian predators. The 5-year interagency reimbursable agreement currently provides funding to the Refuge Complex for carrying out these measures, including 1.0 FTE for a wildlife biologist (refuge employee) and associated contract services and operations, as well as provides building space for office, equipment storage, shelter, and restroom facilities.

Regional Context

The Alameda breeding colony is one of the most important breeding sites for the California Least Tern. As the largest and most stable breeding colony in San Francisco Bay consistently producing large numbers of fledglings, it serves as a source population for least terns in the region contributing to other active breeding colonies at Hayward Regional Shoreline, Napa-Sonoma Marshes Wildlife Area, and Montezuma Wetlands (Suisun Bay). The long-term protection of the Alameda colony has allowed it to be one of the most successful least tern breeding colonies in the world over the past 20 years. This success is primarily attributed to the large buffer zone surrounding the colony that is off limits to public access, lacks vegetation and structures which subsequently reduces predation pressure (the most significant threat to least terns), and allows unobstructed access to foraging areas in the open waters offshore (Caffrey 2005).

6.2.3 Haying/Grazing Program

Haying and grazing are common habitat management tools for upland plant communities. Grazing occurs on the Vernal Pools Grassland Ecosystem discussed in chapter 4, "Conservation Target Summaries." This section is specific to the San Pablo Bay NWR. The haying and grazing program on San Pablo Bay NWR was grandfathered in when the Sonoma Land Trust conveyed two upland parcels to the Service in February 2014. Sonoma Land Trust had purchased the properties and worked with local operators to continue the haying and grazing practices as a means to manage the land and uphold the long-standing traditional use of the properties. The refuge has subsequently continued the grazing and haying in order to: 1) provide foraging habitat for migratory birds, 2) control non-native weeds, and 3) reduce wildland fire fuels. During our work planning and prioritization process documented in this plan, the upland habitats represented on the 488-acre Sears Point Unit and 259-acre North Parcel Unit did not score as high priority conservation targets. However, management of these units must continue in some manner for the near future, and that represents a continuing commitment of resources.

Specific objectives of the haying and grazing program at San Pablo Bay NWR include providing winter and spring migration foraging habitat for long-billed curlew (*Numenius americanus*), whimbrel (*Numenius phaeopus*), Canada geese (*Branta canadensis*), and other migratory birds as the haying fields are tilled revealing assorted arthropods and roots. The hay is an oat-wheat-barley mix where harvesting deposits seeds, providing summer and fall forage for a variety of migrating and resident songbirds. Grazing operations maintain shorter vegetation providing shorter flame-lengths during wildland fire and forage habitat for migratory raptors such as western burrowing owl, white-tailed kite, ferruginous hawk, northern harrier, and red-tailed hawk. Controlling invasive plants such as yellow star thistle (*Centaurea solstitialis*), perennial pepperweed (*Lepidium latifolium*), and medusahead (*Taeniatherum*) is accomplished through grazing.

In 2019, the refuge will develop CLMAs with the local operators that are carried out on a share-in-kind basis when such agreements are in aid of or benefit to the wildlife management of the area (50 CFR Part 29.2). This share-in-kind approach helps reduce the allocation of refuge personnel and funding to managing these units by placing the responsibility for operations and maintenance associated with the haying and grazing on the local cooperator(s). Examples of share-in-kind work include cleaning out drainage ditches, ensuring stormwater pumps operate properly, maintaining fencing and cattle troughs, conducting weed control, and ensuring security of the water well, paddocks, pastures, equipment, and barn.

Regional Context

In addition to recognizing their present condition and uses and the ecosystem services currently provided, these upland habitats are also important in the context of climate adaptation. These areas were once part of the historic tidal marsh ecosystem that ringed San Francisco Bay up until the late 1800s but were later diked and converted to agricultural uses and human settlements. The protected open space and agricultural lands of the North Bay are widely recognized as the best opportunity to ensure the resiliency of the baylands in the face of increasing sea levels (Goals Project 2015). As the rate of sea-level rise increases, the upland topography adjacent to marshes plays an increasingly important role in providing transition zone habitat to a diversity of wildlife species as well as allowing the landward migration of tidal baylands (notwithstanding current barriers such as highways and railroads). Therefore, these upland units on San Pablo Bay NWR represent critically important future migration space to allow marshes to migrate landward as sea levels rise toward the end of the 21st century. Future work planning efforts should reconsider whether the upland habitats are a priority conservation target; consequently, we would need to develop KEAs, indicators, goals, strategies, and activities to include in the Refuge Complex work plan.

6.2.4 Permit Monitoring Requirements

Many of the conservation target strategies involve the implementation of habitat management projects, including restoration and enhancement activities. These projects may require extensive environmental compliance, especially if wetlands or listed species are impacted. Permitting authorities derive from multiple state and federal laws, including but not limited to the Clean Water Act, Endangered Species Act, Magnuson-Stevens Fishery Conservation and Management Act, Rivers and Harbors Act, Coastal Zone Management Act, California Endangered Species Act, California Water Code, California Department of Fish and Wildlife, San Francisco Bay Basin Plan, and McAteer-Petris Act.

In particular the majority of tidal marsh ecosystem strategies (chapter 4, "Conservation Target Summaries") strive to benefit marsh-dependent species such as the endangered California RIRA and SMHM through the conversion of former salt ponds and diked baylands to tidal wetlands, or enhancement of existing tidal marshes through various means. Additionally, waterbirds strategies (chapter 4) include the enhancement and management of former salt ponds, including the manipulation of water levels and salinity to benefit a diversity of waterfowl and shorebirds. Further, various maintenance and constructions projects on the refuges may affect wetland or coastal habitats and listed species. Regardless of project size, these actions require some level of consultation and authorization from one or more of the following agencies: U.S. Army Corps of Engineers, National Marine Fisheries Service, U.S. Fish and Wildlife Service's Bay-Delta Fish and Wildlife Office, U.S. Environmental Protection Agency, CDFW, San Francisco Bay Regional Water Quality Control Board, San Francisco Bay Conservation and Development Commission (BCDC), and potentially the California State Lands Commission and California Coastal Commission.

In addition to the workload and funding associated with applying for and submitting annual reports for these authorizations, regulatory agencies frequently require field monitoring for 5–10 years to ensure that each project is meeting its stated goals and complying with the agencies' respective regulatory requirements. Many of the agency monitoring requirements do not directly address the management goals and objectives for the KEAs that we have identified for the Refuge Complex NRMP and IMP. Consequently, these permit monitoring requirements represent a major commitment that substantially influences refuge staff's workload and limits our capacity to advance our own priority conservation strategies across the Refuge Complex. We have identified a total of 34 surveys (25 current, 9 future) that are associated with these permit requirements but which **do not** address our own goals or objectives, 9 of which are conducted by refuge staff and accounted for in their respective time allocations (the remaining are conducted by partners or contractors) (USFWS 2019, in prep).

Regional Context

There are two noteworthy efforts in the San Francisco Bay area that are currently addressing the issues associated with permitting and monitoring that refuge staff should continue to engage in to inform and improve these efforts:

- **San Francisco Bay Coordinated Permitting Approach for Multi-Benefit Wetland Restoration Projects**. Its purpose is to improve the permitting process for multi-benefit wetland restoration projects and associated flood management and public access infrastructure in San Francisco Bay. To do so, the project will dedicate agency representatives to review project information and prepare permit applications for consideration as a team in the most efficient manner. It includes the formation of a Bay Restoration Regulatory Integration Team (BRRIT) to coordinate project analysis and permitting through a joint permit application process. The BRRIT will be comprised of one staff member from six different regulatory agencies—U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service's Bay-Delta Fish and Wildlife Office, National Marine Fisheries Service, CDFW, BCDC, and Regional Water Quality Control Board. A policy and management team made up of agency leadership and other key stakeholders such as the U.S. Environmental Protection Agency and State Coastal Conservancy will coordinate with the BRRIT as necessary to resolve policy issues and provide direction for any elevated project decisions. This new coordinated permitting process is expected to be fully functioning by the end of 2019 and should reduce timeline and staff workload associated with applying for restoration permits.
- **San Francisco Bay Wetland Regional Monitoring Program**. The San Francisco Estuary Partnership is leading the development of a pilot program to monitor mature and restored tidal marsh habitat, with the goals of improving the efficiency of monitoring of voluntary tidal wetland restoration projects and evaluating the condition of tidal marsh ecosystem at a regional scale. The Steering Committee is assessing the best available science and technology, institutional relations and governance structures, and budgetary needs for creating a regional monitoring program that will address key questions shared by regulators and land managers about tidal marsh protection and restoration, particularly in the face of climate change. This effort will hopefully align with and/or improve our ability to monitor key ecological indicators associated particularly with the tidal marsh ecosystem and waterbird conservation targets. Refuge staff are actively engaged in the development of this program.

6.2.5 Landscape Conservation

As discussed in Section 1.4, "the Physiographic and Ecological Summary," the Refuge Complex protects a diversity of iconic and unique habitats that are representative of the natural heritage of California. In some cases, the refuge lands protect all or the majority of the last remnants of habitat for one or more species, such as the Lange's metalmark butterfly at Antioch Dunes NWR and the Santa Cruz long-toed salamander at Ellicott Slough NWR. In other cases, refuge lands represent a portion of more broadly extant habitat, yet they still contribute substantially to the conservation, restoration, or recovery of one or more species across an ecosystem, such as the tidal marshes of the Don Edwards San Francisco Bay NWR and San Pablo Bay NWR. There are also major threats that span our refuge boundaries such as invasive species and climate change. Therefore, it is critically important that we seek opportunities to collaborate with partners both within and beyond our refuge boundaries in order to leverage expertise and funding, resulting in a greater collective impact across these landscapes.

Establishing and fostering partnerships and participating in various regional initiatives requires a lot of staff time, especially for attending meetings, including travel time in the Bay Area's notorious traffic. Attending even a 2–3-hour meeting or workshop anywhere in the Bay Area often results in a full day's commitment. We will therefore endeavor to be more selective about which partnerships we will actively engage in based on our Refuge Complex priorities, and we will be more strategic in identifying which staff to send as a representative for the whole group. Table 41 lists many (but not all) of the partnerships and initiatives that we are actively engaged in as of 2018.

Table 41. Landscape conservation partnerships of the San Francisco Bay National Wildlife Refuge Complex.

Partnership/Initiative	*Purpose*	*Refuge Role(s)*
San Francisco Bay Joint Venture	Partnership that seeks to protect, restore, increase and enhance all types of wetlands, riparian habitat and associated uplands throughout the nine Bay Area counties for the benefit of birds, fish, and other wildlife	Executive Committee, Management Board, Working Groups (Conservation Delivery, Science, Communications, Government Affairs), and Implementation Plan Revision Team members
San Francisco Bay Estuary Partnership	Collaboration of local, state, and federal agencies; nongovernmental organizations; academia; and business leaders working to protect and restore the San Francisco Bay-Delta Estuary	Implementation Committee alternate agency representative, Wetland Regional Monitoring Program Science Advisory Team member
San Francisco Bay Restoration Authority	Regional agency charged with raising and allocating local resources for the restoration, enhancement, protection, and enjoyment of wetlands and wildlife habitat in San Francisco Bay and along its shoreline, and associated flood management and public access infrastructure	Advisory Committee member
Adapting to Rising Tides Bay Area Regional Working Group	Multi-sector, cross-jurisdictional effort to build local and regional capacity in the San Francisco Bay area to identify how current and future flooding will affect communities, infrastructure, ecosystems, and economy, and to plan for and implement adaptation responses	Participant
San Francisco Bay Regional Climate Hazards Adaptation and Resiliency Group (CHARG)	Organization of flood control managers and scientists responsible for reducing flood risk in the San Francisco Bay area seeking to advance the technical, scientific, and engineering analysis needed for the region to implement adaptation projects and build resilience to sea level rise and climate change	Participant
San Francisco Estuary Invasive Spartina Project	Coordinated regional effort among local, state, and federal organizations dedicated to preserving California's extraordinary coastal biological resources through the elimination of introduced species of *Spartina* (cordgrass)	Project Management Team member
Tidal Marsh Recovery Implementation Team	Provide context, leadership, and guidance for the implementation of recovery actions in support of the Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California	Participant
Bay Area Open Space Council Conservation Lands Network	Network of land trusts and public agencies seeking to achieve more together toward the long-term protection of sensitive habitat and open space lands in the Bay Area	Conservation Lands Network Science Expansion Steering Committee member
San Francisco Bay Wildlife Society Friends Group	Refuge Friends Group that supports the Refuge Complex	Board liaison

Partnership/Initiative	*Purpose*	*Refuge Role(s)*
Friends of San Pablo Bay National Wildlife Refuge	Refuge Friends Group that supports the San Pablo Bay, Marin Islands, and Antioch Dunes NWRs	Board liaison
Citizens Committee to Complete the Refuge	Citizen group that seeks to save San Francisco Bay's remaining wetlands by working to place them under the protection of the Don Edwards San Francisco Bay NWR and to foster worldwide education regarding the value of all wetlands	Board liaison
Mid-Peninsula Environmental Education Alliance	Informal association of environmental educators who together maximize resources and achieve common goals	Participant
Santa Clara Valley Urban Runoff Pollution Prevention Program	Multi-jurisdictional cooperative effort among the County, the Santa Clara Valley Water District, and thirteen north county cities, all working to improve the water quality of south San Francisco Bay and the streams of Santa Clara County, by reducing nonpoint source pollution in storm water runoff and other surface flows	Participant
Sonoma Land Trust Lower Sonoma Creek Baylands Strategy	Strategy for landscape-scale restoration, flood protection, and public access in the Lower Sonoma Creek portion of the San Pablo Baylands	Science Advisory Committee member
State Route 37 Baylands Group	Unified, multi-organization approach to continue developing San Pablo Baylands conservation and restoration recommendations associated with potential State Route (SR) 37 corridor changes	Participant
Napa Sonoma Marsh Restoration Group	Provide technical oversight, agency review, and regional data information sharing on restoration projects throughout North Bay	Participant
Greater Farallones National Marine Sanctuary	Advises the sanctuary superintendent on priority issues and connects local communities with the sanctuary, providing an opportunity for information exchange on issues affecting the health of the sanctuary and representing a variety of interests, from fishing to science to conservation	Sanctuary Advisory Council agency representative, Seabird Protection Network participant
San Mateo Marine Protected Area Collaborative	Partnership that seeks to assist the State of California with protection, outreach, information needs, and enforcement of the state Marine Protected Areas in San Mateo County	Participant
Golden Gate Marine Protected Area Collaborative	Partnership that seeks to assist the State of California with protection, outreach, information needs, and enforcement of the state Marine Protected Areas between Bodega and Half Moon Bay	Participant
Resource Conservation District of Santa Cruz County's Larkin Valley Technical Advisory Committee	Coordination of data compilation and restoration efforts for Santa Cruz Long-Toed Salamander and California Red-Legged Frog in Santa Cruz County	Participant
Monterey Bay Area Western Snowy Plover Coordination Group	Multi-agency and stakeholder initiative to coordinate monitoring and management of nesting areas for western snowy plovers in the Monterey Bay area	Participant

Partnership/Initiative	*Purpose*	*Refuge Role(s)*
San Francisco Bay Vegetation Restoration Working Group	Informal coalition of land managers, restoration practitioners, native plant specialists, and landscapers from government agencies, non-governmental organizations, and commercial businesses that meet annually to share information and lessons learned	Participant
South San Francisco Bay Burrowing Owl and Salamander Groups	Multi-agency and stakeholder workgroups that meet to discuss management of these species in the area	Participant

6.3 Management Changes and Consequences

The most important aspect of the NRMP process is to identify the highest priorities on which to focus our limited resources. Accordingly, it is just as important to document what we will no longer pursue in order to focus our efforts on the highest priority conservation and human well-being targets. Even within our priority conservation targets, we chose to discontinue certain strategies or surveys that are not a priority or simply do not inform our management goals or objectives. In some cases, those activities may be deferred for future years when new resources (such as personnel, funding, and partners) become available or when there is a change in priorities as determined through annual evaluation and adaptive management. Alternatively, we may choose to discontinue some activities altogether because of new standards, information, or technology, a change in species status, or there is no other foreseeable need. The following section summarizes some of the natural resources, management strategies, and surveys that were not selected for implementation under the current NRMP and IMP, and the associated consequences. It also summarizes some of the changes to our public engagement strategies related to human well-being targets.

6.3.1 Farallon Islands National Wildlife Refuge

The Farallon Islands NWR is entirely encompassed within the Marine Islands Ecosystem Target. It is unique among all of the priority conservation targets in having an intensive long-term monitoring program substantially supported by our partner, Point Blue Conservation Science. The work planning process has helped to identify the highest priority strategies and surveys for the Refuge Complex to pursue, but additional surveys covering more species are expected to continue by Point Blue Conservation Science with matching funds. If Point Blue is unable to continue its long-term monitoring due to lack of funding, important information that these environmental indicators provide would be lost; in particular, these measures greatly help us understand the impacts that both short-term and long-term climate change have on these trust resources and the entire Pacific coast ecosystem. Another consequence of reducing monitoring activities that currently occur year-round would be the periodic or seasonal closing of the SEFI field station, resulting in deterioration or failure of equipment (such as derricks, boats, generators, and water pumps) if not regularly operated and maintained enough to be trustworthy for dependable and safe use. In that case, we would likely incur additional costs in repair and maintenance of island infrastructure and/or need to invest in new methods to safely access and occupy the island. Furthermore, the absence of on-island personnel may result in illegal trespassing that will lead to wildlife disturbance, nest trampling, and vandalism.

As a result of the human well-being target prioritization, environmental education and interpretation with community groups will be expanded at the refuge. The current volunteer program would be enhanced and outreach to new communities will also begin.

6.3.2 Don Edwards San Francisco Bay National Wildlife Refuge

The tidal marsh and vernal pool grassland ecosystem targets and waterbirds target encompass the predominant habitat types of the Don Edwards San Francisco Bay NWR. We have chosen to discontinue surveys for SMHM, harbor seal, SNPL, western burrowing owls, wintering waterfowl, and several breeding waterbird species (e.g., black-necked stilt and Caspian tern), instead relying on existing or new partnerships to monitor or study those resources as needed. Other notable natural resources that will not be directly surveyed include passerines, raptors, steelhead, chinook salmon (*Oncorhynchus tshawytscha*), green sturgeon (*Acipenser medirostris*), and aquatic invertebrates. A negative consequence of not monitoring a full suite of species (especially certain specialized species or guilds) is that tidal marsh restoration of former salt ponds may have a negative impact on some species, and we will be unable to detect this in time to change restoration or management actions. However, we will reorient our efforts from collecting data on the refuge that do not inform management decisions to instead work with partners to develop standard survey protocols and monitor on a larger scale to better understand population trends and landscape dynamics. The work plan process also helped us decide to discontinue targeted rare plant surveys for Alkali Vetch, Congdon's tarplant, and San Joaquin Spearscale in lieu of monitoring the whole vernal pool grasslands community. Various species may indirectly benefit from our priority strategies; for example, restoring high quality tidal marsh under the Tidal Marsh Ecosystem Target will benefit the SMHM, and maintaining short grassland and high ground squirrel burrowing activity under the Vernal Pool Grasslands Ecosystem Target align perfectly with the requirements for burrowing owl habitat enhancement. Additionally, we chose to defer habitat management planning associated with diked or muted tidal marshes such as Mayhews Landing, LaRiviere Marsh, New Chicago Marsh, and the Muenster property, and instead focus our efforts on restoring high-quality tidal marsh and enhancing managed pond habitats under the South Bay Salt Pond Restoration Project.

As a result of the human well-being target prioritization, environmental education and habitat restoration-service learning programming at the refuge has been reduced to expand support for those programs at other refuges in the complex with that need. Conducting outreach to new communities will also be reduced. Volunteer programming at the refuge may also be reduced in order to establish volunteer programs at other refuges that have identified that need. The refuge may also reduce time on enhancing visitor amenities over the five-year work plan in order to realign existing environmental education and habitat-restoration programs in light of the conservation targets identified through this work plan prioritization. The refuge will also begin work on addressing threats such as invasive vegetation and predators through strategic communication to affect human behavior change.

6.3.3 Salinas River National Wildlife Refuge

The Coastal Sand Dune Ecosystem Target encompasses the beach and dune vegetation communities of Salinas River NWR; therefore, management of other vegetation communities found elsewhere on the refuge will not be a priority: Coyote Brush Scrub/Grassland, Central Coast Riparian Scrub, Riverine, Northern Coast Salt Marsh, and Saline Pond. The primary management activities that will not be implemented in those habitats include invasive weed control, habitat restoration or enhancement, and erosion prevention. Lack of management may negatively affect resident and migratory birds that nest or forage in one or more of these habitats, and benefits from past restoration efforts such as tree plantings will not be fully realized as invasive plants return and encroach further into native habitats. Invasive plant management will continue at a reduced level in the Northern Coast Salt Marsh habitat but planning to assess impacts of dune movement inland into salt marsh and saline pond habitats will be deferred, and waterbird surveys will no longer occur.

While numerous species were not chosen as priorities (either as nested targets or key ecological indicators), several stand out due to their federally listed status or breeding status within the Monterey Bay area: steelhead (*Oncorhynchus mykiss*), tidewater goby (*Eucyclogobius newberryi*), Yadon's wallflower (*Erysimum menziesii* ssp. *yadonii*), Monterey gilia (*Gilia tenuiflora ssp. arenaria*), and Caspian tern (*Hydroprogne caspia*). Surveys to confirm existence of these species and monitor population status on the refuge will not occur unless partners conduct the surveys or priorities shift to address new or emerging threats.

As a result of the human well-being target prioritization, environmental education and interpretation with schools and community groups, as well as habitat restoration-service learning will be expanded at the refuge. Volunteer programming at the refuge would also be expanded. The refuge will also enhance visitor amenities over the 5-year work plan as a result of the needs identified through this work plan prioritization. The refuge also identified human disturbance as a high threat to the target and will increase presence at the refuge through patrols by staff and volunteers.

6.3.4 San Pablo Bay National Wildlife Refuge

As with the Don Edwards San Francisco Bay NWR, the tidal marsh ecosystem and waterbirds conservation targets encompass the predominant habitat types of the San Pablo Bay NWR. We have chosen to discontinue surveys for SMHM (except as required by permits) and not pursue surveys of other notable natural resources such as Caspian tern, passerines, raptors, steelhead, chinook, green sturgeon, and aquatic invertebrates, instead relying on existing or new partnerships to monitor or study those resources as needed. We will also reorient our efforts from collecting data on the refuge that do not inform management decisions to instead work with partners to develop standard survey protocols and monitor on a larger scale to better understand population trends and landscape dynamics. Additionally, we chose to defer habitat management associated with diked marshes and former baylands such as Strip Marsh West, Strip Marsh East, Figueras, Lower Tubbs Island, and upland grasslands on North Parcel. We instead chose to focus our efforts on finishing current tidal marsh restoration projects in coordination with partners at Sonoma Creek, Cullinan Ranch, and Haire Ranch, and participate in the initial planning for the restoration of Skaggs Island within the larger landscape encompassing the Lower Sonoma Creek Baylands. The consequences of deferring action at new sites means that there will be a delay in restoring and conserving all potentially vulnerable marsh habitats in advance of climate change, in particular, sea-level rise. Sea-level rise poses a severe threat to the tidal wetlands as there is considerable uncertainty about whether they will be able to maintain elevations relative to future sea level (Veloz et al. 2016). Several regional planning efforts recommend immediate restoration of all potential restoration sites in order to capture passive sediment supply and allow marshes to keep pace with sea-level rise (Goals Project 2015). Consequences of not moving forward with climate change adaptation strategies at this time include not taking advantage of decreasing sediment loads, increasing risk that some of our marshes will drown, and not preparing for migration space where future marshes can move. In the North San Francisco Bay, we have more room to allow for marsh migration and to conserve tidal marsh and marsh dwelling wildlife, including endangered species, compared to central and south San Francisco Bay where marshes are immediately adjacent to developed lands. When current restoration projects are finished, we will re-evaluate our capacity and ability to begin new climate change adaptation projects and will rely heavily on partnerships to take the lead in future projects.

As a result of human well-being target prioritization, environmental education and interpretation with schools and community groups will be expanded at the refuge. A volunteer program would also be established. Less general community outreach would be conducted to focus on these efforts.

6.3.5 Ellicott Slough National Wildlife Refuge

The Ellicott Slough NWR comprises four distinct units: Ellicott, Calabasas, Harkins Slough, and Buena Vista (the latter is owned by CDFW) (figure 12). The Pajaro Valley watershed ecosystem target encompasses priority species and habitats on the Ellicott, Calabasas, and Buena Vista Units, but does not include the Harkins Slough Unit which is primarily Permanent Freshwater Marsh and Floodplain habitats. Management actions on the Harkins Slough Unit—such as much needed restoration planning for the slough/wetland and uplands, invasive plant control, and surveys for special status plant species—will be deferred. The Harkins Slough Unit is a well-known location to Monterey Bay area for its diversity of species and abundance of resident and migratory birds; therefore, deferring management actions on this unit may impact the quality and quantity of habitat available for foraging and nesting. The work plan process also helped us to focus our efforts more towards developing standard survey protocol for salamanders, and in turn discontinue current survey methods that do not inform our management goals. Furthermore, refuge staff will step back from playing a lead role or fully supporting various initiatives throughout the watershed, including the assessment and potential acquisition of private properties to protect oak woodland/grassland and ephemeral ponds, or assisting the County, State, and neighboring landowners with solutions to eradicate newly detected noxious weed infestations off-refuge before they become established and spread. Also, while numerous species were not chosen as priorities (either as nested targets or key ecological indicators), two stand out due to their federally listed status: robust spineflower and California red-legged frog. No surveys or management actions specific to these species will be pursued, although they may indirectly benefit from invasive plant management strategies under the Pajaro Valley watershed target.

As a result of the human well-being target prioritization, environmental education and interpretation with community groups, as well as habitat restoration-service learning will be expanded at the refuge. Conducting outreach to new communities will also begin.

6.3.7 Marin Islands National Wildlife Refuge

The native plant community of the Marin Islands NWR is addressed under the Estuarine Island Ecosystem Target, and the heron and egret rookery is addressed under the Waterbirds Target. The Marin Islands NWR management boundaries also encompass rocky intertidal, extensive mudflats, subtidal, and open bay habitats, which did not rank as high priorities due to their broad distribution elsewhere in San Francisco Bay. We chose to discontinue monitoring of black oystercatcher because it did not rank as a high priority ROC, despite its limited breeding distribution. We chose to discontinue our participation in oil spill planning and response coordination meetings with the CDFW’s Office of Spill Prevention and Response (OSPR), as well as our Rocky Intertidal Baseline survey (in partnership with OSPR), and all associated plans for species specialist reconnaissance surveys. The Marin Islands are recognized as sensitive environmental resources within the northern boundary of the highest oil spill spread area in the San Francisco Bay due to its proximity to local refineries and major maritime transportation routes. In the event an oil spill does occur, we will almost certainly coordinate with OSPR for the specific event, but we will have no baseline information with which to compare pre-oil spill conditions in the Rocky Intertidal. We will also defer consideration of opportunities for incorporating Living Shoreline features such as eelgrass beds and oyster reefs to reduce impacts of sea level rise on the nearshore mudflat, rocky intertidal, and intertidal marsh-beach habitats. This may result in negative consequences for black oystercatchers, nearshore fish, and aquatic invertebrate populations that are important food sources for herons and egrets that nest on the islands and wintering waterfowl that raft near the islands.

As a result of the human well-being target prioritization, environmental education and interpretation with schools and community groups will be expanded at the refuge. A volunteer program would also be established. Less general community outreach would be conducted to focus on these efforts.

6.3.6 Antioch Dunes National Wildlife Refuge

Antioch Dunes NWR is entirely encompassed within the riverine sand dune ecosystem target, focusing on the remnant dune habitat with its unique stands of native plants that support three endangered species: LMB, ADEP, and CCW. The work planning process helped to focus efforts on recovery of the butterfly species primarily through restoration of the historic dune conditions. This meant that refuge staff would step back from conducting time-consuming surveys for individual ADEP and CCW plants in lieu of monitoring the whole dune plant community. Additionally, other dune-dependent species such as invertebrates, reptiles, and amphibians will not receive special attention from refuge staff, except as may occur through partners and academic research. Natural resources of the refuge that were not selected for management attention are the littoral zone and riparian habitat and associated fish and wildlife species found on the refuge's northern boundary running along the Sacramento–San Joaquin River.

As a result of the human well-being target prioritization, habitat restoration-service learning will be expanded at the refuge and the current volunteer program would be enhanced. Less general community outreach would be conducted to focus on these efforts.

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Chapter 5—Human Well Being Target Summaries

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Appendix A
Glossary

adaptive management—The rigorous application of management, research, and monitoring to gain information and experience necessary to assess and modify management activities. A process that uses feedback from refuge research and monitoring and evaluation of management actions to support or modify objectives and strategies at all planning levels (USFWS 2002).

conservation target—ecosystem, community, or species that is a focus of conservation within a specified spatial scope. Synonymous with priority resource of concern.

cultural services— a type of ecosystem service; these are nonmaterial benefits people get from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences.

goal—a formal statement detailing a desired outcome in terms of conservation or human well-being targets and associated attributes. Unlike refuge comprehensive conservation plans, goals here are SMART (specific, measure able, achievable, results-oriented, and time-bound).

habitat management plan—A dynamic working document that provides refuge managers a decision-making process; guidance for the management of refuge habitat; and long-term vision, continuity, and consistency for habitat management on refuge lands. Each plan incorporates the role of refuge habitat in international, national, regional, tribal, State, ecosystem, and refuge goals and objectives; guides analysis and selection of specific habitat management strategies to achieve those habitat goals and objectives; and utilizes key data, scientific literature, expert opinion, and staff expertise. Synonymous with natural resource management plan.

human well-being target— aspect(s) of human well-being on which a conservation project chooses to focus. In the context of a conservation, human well-being targets focus on those components of human well-being affected by the status of conservation targets. Though a conservation team may care about all aspects of human well-being, if its ultimate aim is conservation, it should focus on human well-being as it is derived from or dependent upon conservation.

key ecological attribute (KEA)—aspects of a conservation target's biology or ecology that define a healthy conservation target. Missing or altered KEAs would lead to the outright loss or extreme degradation of that conservation target over time. Examples include population size, reproductive success, community composition or structure, habitat connectivity, hydrological regime, sediment dynamics, and fire regime.

natural resource management plan—— A dynamic plan that provides refuge managers a decision-making process; guidance for the management of refuge natural resources and improvement of human well-being; and long-term vision, continuity, and consistency natural resource management on refuge lands. Differs from habitat management plan concept in that it expands beyond habitat (a species-specific term) to encompass conservation of biological communities and ecosystems.

objective—a formal statement detailing desired outcomes of management strategies or the reduction of threats. Objectives here focus on intermediate shorter-term results that ultimately contribute to achieving a goal. Objectives here are SMART (specific, measure able, achievable, results-oriented, and time-bound).

provisioning services— a type of ecosystem service, these relate to the products obtained from an ecosystem (e.g., food, fuel).

regulating services— a type of ecosystem service, these are obtained from the regulation of ecosystem processes (e.g., air quality regulation, climate regulation, water purification).

resources of concern (ROC)— all plant and/or animal species, species groups, or communities specifically identified in National Wildlife Refuge purpose(s), National Wildlife Refuge System mission, or international, national, regional, state, or ecosystem conservation plans or acts. For example, waterfowl and shorebirds are a resource of concern on a refuge whose purpose is to protect 'migrating waterfowl and shorebirds.' Federal or State threatened and endangered species on that same refuge are also a resource of concern under terms of the respective endangered species acts. (USFWS 2002).

strategy—a group of actions that work together to reduce one or more threats or to restore natural systems.

stress—the expression of a threat on a conservation target or how it negatively impacts the target. Examples include reduced size or extent of a population or ecosystem, reduced reproductive success, habitat loss, reduced habitat connectivity, altered community composition or structure, and altered sediment dynamics.

supporting services—a type of ecosystem service, these are necessary for the production of all other ecosystem services. They differ from *provisioning, regulating,* and *cultural services* in that their impacts to people are often indirect and occur over a very long time (e.g., soil formation), whereas others' services are relatively direct and have short-term impacts to people.

threat—a human-induced action that stresses—or has the potential to stress—one or more conservation targets. Examples include logging, contaminants, invasive species introductions, land and habitat conversion, fire suppression, altered hydrology, and human disturbance.

Appendix B

Information generated to support development of the San Francisco Bay National Wildlife Refuge Complex Natural Resource Management Plan

Item	*Description and ServCat link*
Five-year work plan	Refuge Complex management strategies and surveys; and associated activities, timeline, assignments, and budget: *https://ecos.fws.gov/ServCat/Reference/Profile/114434*
Miradi file	Miradi file containing final viability assessment, conceptual model, threat assessment, and goals and objectives for the San Francisco Bay National Wildlife Refuge Complex: *https://ecos.fws.gov/ServCat/Reference/Profile/114427*
Priority resources of concern (a.k.a. conservation targets)	Criteria and scoring used to identify priority resources of conservation concern for the San Francisco Bay National Wildlife Refuge Complex: *https://ecos.fws.gov/ServCat/Reference/Profile/114429*
Priority resources of concern (a.k.a. conservation targets)	Comprehensive list of species of conservation concern for the San Francisco Bay National Wildlife Refuge Complex: *https://ecos.fws.gov/ServCat/Reference/Profile/114433*