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Natural Resource Condition Assessment

Golden Gate National Recreation Area

Natural Resource Report NPS/GOGA/NRR—2019/2031



ON THE COVER
Golden Gate National Recreation Area
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Natural Resource Condition Assessment

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Natural Resource Report NPS/GOGA/NRR—2019/2031

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Acronyms and Abbreviations

Table E.2. Acronyms and Abbreviations used throughout the report.

Acronym	Full Name/ Term
ADCP	Acoustic Doppler Current Profiler
AIC	Akaike Information Criterion
ASBS	Areas of Special Biological Significance
BAAQMD	Bay Area Air Quality Management District
BBIRD	Breeding Biology Research And Monitoring Database
BOR	Bureau of Reclamation
CBNMS	Cordell Bank National Marine Sanctuary
CCC	Central California Coast
CDFG	California Department Of Fish And Game
CDFW	California Department Of Fish And Wildlife
CDREA	Coastal Dunes Restoration Environmental Assessment
CEPA	California Environmental Protection Agency
CFPAD	California Fish Passage Assessment Database
CMP	Comprehensive Management Plan
CNPS	California Native Plant Society
COCMP-NC	Coastal Ocean Currents Monitoring Program In Northern California
CODAR	Coastal Ocean Dynamics Application Radar
CRLF	California red-legged frog
CRFS	California Recreational Fisheries Survey
CSUMB-SFML	California State University Monterey Bay–Seafloor Mapping Lab
CVI	Coastal Vulnerability Index
DPS	Distinct Population Segments
EIS	Environmental Impact Statement
ENSO	El Niño-Southern Oscillation
EPA	Environmental Protection Agency
ESU	Evolutionary Significant Unit
GFNMS	Gulf Of The Farallones National Marine Sanctuary
GGNPC	Golden Gate National Park Conservancy
GIS	Geographic Information System
GLM	Generalized Linear Models
GMP	General Management Plan
GOGA	Golden Gate National Recreation Area
I&M	Natural Resources Inventory & Monitoring Program
IMPROVE	Interagency Monitoring of Protected Visual Environments

Table E.2 (continued). Acronyms and Abbreviations used throughout the report.

Acronym	Full Name/ Term
ISED	Invasive Species Early Detection
MAPS	Monitoring Avian Productivity and Survivorship
MARINe	Multi-Agency Rocky Intertidal Network
MLPA	Marine Life Protection Act
MMWD	Marin Municipal Water District
MOU	Memorandum Of Understanding
MUWO	Muir Woods National Monument
NCCOS	National Centers For Coastal Ocean Science
NEPA	National Environmental Policy Act
NMDS	Non-metric multidimensional scaling
NMFS	National Marine Fisheries Service
NOAA	National Oceanic And Atmospheric Administration
NPS	National Park Service
NRA	National Recreation Area
NRCA	Natural Resource Condition Assessment
ORV	Off-Road Vehicles
PAH	Polyaromatic Hydrocarbon
PBCS	Point Blue Conservation Science
PISCO	Partnership For Interdisciplinary Studies Of Coastal Oceans
PORE	Point Reyes National Seashore
RCDT	Rancho Corral De Tierra
RecFIN	Recreational Fisheries Information Network
RSS	Resource Stewardship Strategy
RWQCB	Regional Water Quality Control Board
SEED	Safety Evaluation of Existing Dams
SFAN	San Francisco Bay Area Network
SFBAAB	San Francisco Bay Area Air Basin
SFPUC	San Francisco Public Utilities Commission
SMCA	State Marine Conservation Areas
SMR	State Marine Reserves
TMDL	Total Maximum Daily Load
UNESCO	United Nations Educational, Scientific, And Cultural Organizations
USDA	United States Department of Agriculture
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Service

Executive Summary

The Natural Resource Condition Assessment (NRCA) Program aims to provide documentation about the current conditions of important park natural resources through a spatially explicit, multi-disciplinary synthesis of existing scientific data and knowledge. The objectives of this assessment are to evaluate and report on current conditions of key park resources, to evaluate critical data and knowledge gaps, and to highlight selected existing stressors and emerging threats to resources or processes. This report and the spatial datasets provided with it are intended to inform and support Golden Gate National Recreation Area (GOGA) managers and scientists in developing recommendations for improving or maintaining natural resource conditions in the park.

Golden Gate National Recreation Area was established by Congress on October 27, 1972 as part of a movement to make NPS resources more accessible to urban populations and bring "parks to the people". The park has grown into the largest urban national park unit in the United States, and includes under its management two additional NPS units Fort Point National Historic Site and Muir Woods National Monument. GOGA comprises approximately 80,000 acres of primarily coastal lands in the San Francisco Bay area. The park is rich in natural resources including 19 types of ecosystems in numerous distinct watersheds. The park provides habitat for many sensitive, rare, threatened, and endangered species, including the mission blue butterfly, northern spotted owl, and California red-legged frog. GOGA also has an abundance of historical and cultural assets, including sites such as early fortifications on Alcatraz Island, Forts Cronkhite and Barry in the Marin Headlands, Fort Mason, Fort Point, and the Presidio of San Francisco.

Staff from the National Park Service (NPS) and the University of California, Berkeley worked together to identify the natural resources and stressors to include in this condition assessment. The list of priority resources to include in this report was further constrained by the need for sufficient existing information to allow a meaningful analysis. While this list of focal resources is not comprehensive, it includes the natural resources and stressors that are currently of the greatest concern to park management at GOGA. Only GOGA managed lands were included in the analyses in this report. The final report includes eight focal resources:

- Amphibians/California Red-legged Frog
- Breeding Landbird Diversity
- Forests
- Invasive plants
- Landuse Context
- Rare plants
- Salmonids
- Shorebirds

Assessment of the selected resources relied on gathering and reviewing existing literature and data for each focal resource and, where appropriate, analyzing the data in order to provide summaries and

create new spatial representations. When possible, existing data for the established measures of each component were analyzed and compared to designated reference conditions. The impact of key stressors was also considered in the evaluation of current condition. The discussions of each focal resource included in Chapter 4 provide a comprehensive summary of available existing information regarding the current condition of these resources.

Each focal resource assessed in this report was characterized by one or more indicators. Following analysis of each resource indicator, lead scientists worked with NPS collaborators to assign condition levels to the indicators and combine these into an overall resource assessment (as described in Chapter 3). Where data permitted, the future trend of each resource condition was also projected. When possible and useful for understanding the condition of the resource, the focal resource condition assessments were calculated for each GOGA management zone (i.e., Diverse Opportunities Zone, Scenic Corridor Zone, Evolved Cultural Landscape Zone, Historic Immersion Zone, Interpretive Corridor, Natural Zone, Sensitive Resources Zone, and Park Operations Zone; see Table 2.7 for descriptions and desired conditions in each zone).

The final project framework included 8 focal resources and 28 indicators that were used to evaluate these resources. The condition of each indicator was rated as warranting “significant concern”, “moderate concern”, or as being in “good condition”. Where assessed, the trends were described as improving, unchanging, or deteriorating. These rankings were based on quantitative standards, qualitative descriptions of least-altered resource conditions, scientific literature, and expert opinion. For each indicator and resource, we also ranked (as high, medium, or low) the confidence associated with our assessment.

The condition of the selected resource indicators varied. The overall condition (i.e., condition for each measure of the indicator combined) of 6 indicators was determined to be of significant concern: the future forest distributions under climate change for Muir Woods and Phleger Estate, forest exotic disease progression in Muir Woods, the potential for spread of invasive plants, levels of exotic plant propagule pressure, and impacts of invasive plants on native species and ecosystems. Thirteen of the indicators were rated as warranting moderate concern: the risk of a catastrophic forest fire for Muir Woods and Phleger Estate, the potential for compounding perturbations in forests, forest biomass accumulation, forest exotic disease progression in Phleger Estate, parcel ecological integrity, intact core area, the success of rare plant introduction efforts, steelhead population size and distribution, barriers to steelhead migration, shorebird population trends, beach segment shorebird trends, and shorebird trends by management zone. Information sufficient to estimate trends was lacking for 13 of the 30 indicators. Of all the resource indicators, only the assessment of the number of extant rare plant populations and the shorebird population trends were considered to have a high degree of certainty. A detailed discussion of these designations is presented in Chapter 4 of this report.

The majority of the selected focal resources, including breeding birds, forests, landscape context, shorebirds, and steelhead, were determined to be in moderate condition. However, the analysis suggests a declining trend for both shorebirds and steelhead populations. Amphibians and rare plant species were categorized as being in good condition. Only the condition of invasive plants was considered to be of significant concern. Amphibian populations, breeding bird diversity, and forest

resources were all categorized as exhibiting a stable trend. Information was insufficient to determine the trend for invasive plant species, landscape context, and rare plant populations.

Several stressors have been identified that influence the condition of multiple priority resources within GOGA. Those of primary concern include climate change, pests and pathogens, the presence of non-native species, and habitat loss due to human activity. Improved understanding of these threats, and how they relate to the condition of the assessed focal resources, can help GOGA to prioritize management objectives and better focus conservation strategies to maintain the integrity of park ecosystems.

Chapter 1. NRCA Background Information

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, hereafter "parks." NRCAs also report on trends in resource condition (when possible), identify critical data gaps, and characterize a general level of confidence for study findings. The resources and indicators emphasized in a given project depend on the park's resource setting, status of resource stewardship planning and science in identifying high-priority indicators, and availability of data and expertise to assess current conditions for a variety of potential study resources and indicators.

NRCAs Strive to Provide…

- *Credible condition reporting for a subset of important park natural resources and indicators*
- *Useful condition summaries by broader resource categories or topics, and by park areas*

NRCAs represent a relatively new approach to assessing and reporting on park resource conditions. They are meant to complement—not replace—traditional issue-and threat-based resource assessments. As distinguishing characteristics, all NRCAs:

- Are multi-disciplinary in scope;[1]
- Employ hierarchical indicator frameworks;[2]
- Identify or develop reference conditions/values for comparison against current conditions;[3]
- Emphasize spatial evaluation of conditions and geographic information system (GIS) products; [4]
- Summarize key findings by park areas; [5] and
- Follow national NRCA guidelines and standards for study design and reporting products.

Although the primary objective of NRCAs is to report on current conditions relative to logical forms of reference conditions and values, NRCAs also report on trends, when appropriate (i.e., when the underlying data and methods support such reporting), as well as influences on resource conditions. These influences may include past activities or conditions that provide a helpful context for

[1] The breadth of natural resources and number/type of indicators evaluated will vary by park.

[2] Frameworks help guide a multi-disciplinary selection of indicators and subsequent "roll up" and reporting of data for measures ⇨ conditions for indicators ⇨ condition summaries by broader topics and park areas

[3] NRCAs must consider ecologically-based reference conditions, must also consider applicable legal and regulatory standards, and can consider other management-specified condition objectives or targets; each study indicator can be evaluated against one or more types of logical reference conditions. Reference values can be expressed in qualitative to quantitative terms, as a single value or range of values; they represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-up response (e.g., ecological thresholds or management "triggers").

[4] As possible and appropriate, NRCAs describe condition gradients or differences across a park for important natural resources and study indicators through a set of GIS coverages and map products.

[5] In addition to reporting on indicator-level conditions, investigators are asked to take a bigger picture (more holistic) view and summarize overall findings and provide suggestions to managers on an area-by-area basis: 1) by park ecosystem/habitat types or watersheds, and 2) for other park areas as requested.

understanding current conditions, and/or present-day threats and stressors that are best interpreted at park, watershed, or landscape scales (though NRCAs do not report on condition status for land areas and natural resources beyond park boundaries). Intensive cause-and-effect analyses of threats and stressors, and development of detailed treatment options, are outside the scope of NRCAs.
Due to their modest funding, relatively quick timeframe for completion, and reliance on existing data and information, NRCAs are not intended to be exhaustive. Their methodology typically involves an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in existing data and knowledge bases across the varied study components.

The credibility of NRCA results is derived from the data, methods, and reference values used in the project work, which are designed to be appropriate for the stated purpose of the project, as well as adequately documented. For each study indicator for which current condition or trend is reported, we will identify critical data gaps and describe the level of confidence in at least qualitative terms. Involvement of park staff and National Park Service (NPS) subject-matter experts at critical points during the project timeline is also important. These staff will be asked to assist with the selection of study indicators; recommend data sets, methods, and reference conditions and values; and help provide a multi-disciplinary review of draft study findings and products.

NRCAs can yield new insights about current park resource conditions, but, in many cases, their greatest value may be the development of useful documentation regarding known or suspected resource conditions within parks. Reporting products can help park managers as they think about near-term workload priorities, frame data and study needs for important park resources, and communicate messages about current park resource conditions to various audiences. A successful NRCA delivers science-based information that is both credible and has practical uses for a variety of park decision making, planning, and partnership activities.

Important NRCA Success Factors

- *Obtaining good input from park staff and other NPS subject-matter experts at critical points in the project timeline*
- *Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures ⇨ indicators ⇨ broader resource topics and park areas)*
- *Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings*

However, it is important to note that NRCAs do not establish management targets for study indicators. That process must occur through park planning and management activities. What an NRCA can do is deliver science-based information that will assist park managers in their ongoing, long-term efforts to describe and quantify a park's desired resource conditions and management

targets. In the near term, NRCA findings assist strategic park resource planning[6] and help parks to report on government accountability measures.[7] In addition, although in-depth analysis of the effects of climate change on park natural resources is outside the scope of NRCAs, the condition analyses and data sets developed for NRCAs will be useful for park-level climate-change studies and planning efforts.

NRCAs also provide a useful complement to rigorous NPS science support programs, such as the NPS Natural Resources Inventory & Monitoring (I&M) Program.[8] For example, NRCAs can provide current condition estimates and help establish reference conditions, or baseline values, for some of a park's vital signs monitoring indicators. They can also draw upon non-NPS data to help evaluate current conditions for those same vital signs. In some cases, I&M data sets are incorporated into NRCA analyses and reporting products.

NRCA Reporting Products…

Provide a credible, snapshot-in-time evaluation for a subset of important park natural resources and indicators, to help park managers:

- *Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations* ***(near-term operational planning and management)***
- *Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values* ***(longer-term strategic planning)***
- *Communicate succinct messages regarding current resource conditions to government program managers, to Congress, and to the general public* ***("resource condition status" reporting)***

Over the next several years, the NPS plans to fund an NRCA project for each of the approximately 270 parks served by the NPS I&M Program. For more information visit the NRCA Program website.

[6] An NRCA can be useful during the development of a park's Resource Stewardship Strategy (RSS) and can also be tailored to act as a post-RSS project.

[7] While accountability reporting measures are subject to change, the spatial and reference-based condition data provided by NRCAs will be useful for most forms of "resource condition status" reporting as may be required by the NPS, the Department of the Interior, or the Office of Management and Budget.

[8] The I&M program consists of 32 networks nationwide that are implementing "vital signs" monitoring in order to assess the condition of park ecosystems and develop a stronger scientific basis for stewardship and management of natural resources across the National Park System. "Vital signs" are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values.

Chapter 2. Introduction and Resource Setting

2.1. Introduction

Golden Gate National Recreation Area (GOGA) is one of the largest urban national parks in the world. Established in 1972, as part of a trend to make National Park Service (NPS) resources more accessible to urban populations and bring "parks to the people," while protecting the outstanding natural, cultural, and scenic resources and values of these lands. GOGA manages Muir Woods National Monument (MUWO) and Fort Point National Historic site. The North District of GOGA, comprising 19,265 acres of NPS land north of the Bolinas-Fairfax Road, is managed by Point Reyes National Seashore (PORE) under a Memorandum of Understanding. GOGA, contiguous with several other expanses of public lands, and with marine, estuarine, and terrestrial habitats, supports a rich diversity of plant and animal species, including 37 federally listed threatened and endangered species (NPS unpublished data 2014). GOGA also chronicles a rich history of Native American culture, the Spanish Empire frontier, the Mexican Republic, evolution of American coastal fortifications, maritime history, 18th century and early 20th century agriculture, military history, California Gold Rush, Buffalo Soldiers, and the growth of urban San Francisco.

2.1.1. Enabling Legislation

GOGA was established in 1972 "in order to preserve for public use and enjoyment certain areas of Marin and San Francisco Counties, California (San Mateo County added by Public Law 96-607) possessing outstanding natural, historic, scenic and recreational values…" The original enabling legislation emphasized the need to "preserve the recreation area, as far as possible, in its natural setting, and protect it from development and uses which would destroy the scenic beauty and natural character of the area." MUWO was established in 1908 with the purpose of preserving "the primeval character and ecological integrity of the old-growth redwood forest for scientific values and inspiration."

Fundamental Resources and values were identified in our 2014 update to the General Management Plan for GOGA and MUWO including:

- Recreational and Educational Opportunities (stressing diverse park settings and park access)
- Coastal Corridor (highlighting the ocean and bay environment, coastal ecosystems, threatened and endangered species, and water resources)
- Military Installations and Fortifications
- Alcatraz Island
- Scenic Beauty (focusing on dramatic settings and the compelling historical stage)
- Physical Landforms (stressing geologic resources)
- Coast Miwok and Ohlone People (focusing on archeological sites)
- Muir Woods (highlighting old growth forest and the conservation movement)

The information presented in the remainder of this document will assist NPS and its partners in understanding, preserving and interpreting these Fundamental Resources.

2.1.2. Geographic Setting

Golden Gate National Recreation Area parklands are a patchwork of open space and culturally significant features that are interspersed with other public lands and urban development in Marin, San Francisco, and San Mateo Counties in California (Figure 2.1 and 2.2). GOGA's legislative boundary comprises nearly 80,000 acres of coastal lands, with approximately 550 acres in Muir Woods. This acreage includes beaches, coastal cliffs and headlands, some remnant dunes, grasslands, large areas of shrublands, wetlands, and forests, as well as marine, estuarine, and rocky intertidal habitats (Figure 2.3). As a marine park, GOGA has 91 miles of shorelines (Figure 2.4 and 2.5). GOGA shares management of some marine waters with the Greater Farallones and Monterey Bay National Marine Sanctuaries.

This document covers only the lands within GOGA's legislative boundary that are actually managed by GOGA. North of the Golden Gate, GOGA-managed lands include: Stinson Beach, Muir Woods, Muir Beach, the Marin Headlands and Point Bonita, and Fort Baker. The North District of GOGA, comprising 19,265 acres of NPS land north of the Bolinas-Fairfax Road, is managed by Point Reyes National Seashore (PORE) under a Memorandum of Understanding. Located within the City and County of San Francisco are Alcatraz Island, Fort Point NHS, Fort Miley, Fort Funston, Lands End and Sutro Properties, Fort Mason, and Ocean Beach. In addition, within San Francisco, the Presidio Trust manages the interior lands of the Presidio, and GOGA manages the coastal areas. San Mateo County lands were added to the GOGA boundary beginning in 1980 with Sweeney Ridge (est. 1,500 acres), Milagra Ridge (240 acres), and the San Francisco Watershed lands (est. 20,000 acres). The San Francisco Watershed lands are located within the GOGA authorized boundary but managed by the County of San Francisco and public access is restricted; however GOGA holds a scenic and recreational easement over the watershed lands. In 1992, the Phleger Estate, an estimated 1,000 acres, was acquired. The 105-acre Mori Point (located near Pacifica) was acquired in 2002 and more recently, the GOGA boundaries have been enlarged to include San Pedro Point and Rancho Corral de Tierra in San Mateo County. GOGA now owns and manages 3,858 acres of Rancho Corral de Tierra.

Adjacent land uses in Marin and San Mateo Counties are a mix of private residential and agricultural lands, publicly held watershed, and parks and open space. San Francisco lands are typically bordered by urban development. Approximately 38 miles of GOGA boundary adjoin residential communities in the three counties (NPS 2005, Curdts 2011). In southern Marin County, adjacent lands include the unincorporated communities of Marin City, Muir Beach, Stinson Beach, Tamalpais Valley, and Homestead Valley, and the incorporated towns of Mill Valley and Sausalito. San Mateo parkland is mostly located in the northern part of the county adjacent to the city of Pacifica. Bay Areapopulation increases are expected to increase in the next 20 years. It is estimated that by the year 2020, the San Francisco Bay Area will be home to more than 8 million people, a 16 percent increase over the 2000 population census (Association of Bay Area Governments 2000).



Figure 2.1. Overview of areas managed by GOGA. Marine boundary extends ¼ mile from shore in both the Pacific Ocean and San Francisco Bay for most of our lands (NPS unpublished data).

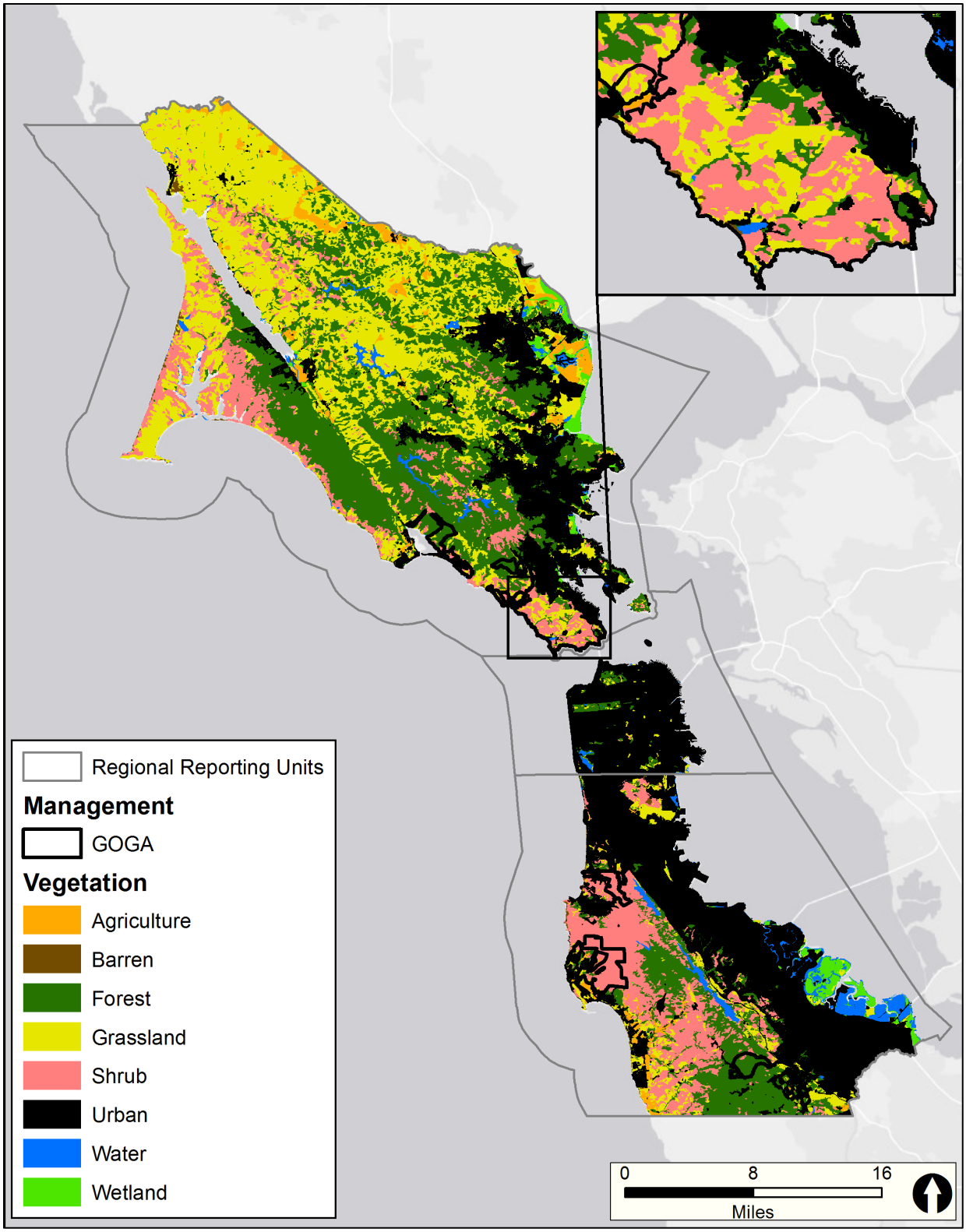


Figure 2.2. Land cover types for GOGA. Note the significant areas of urbanization bordering the park (Bay Area Open Space Council 2011).

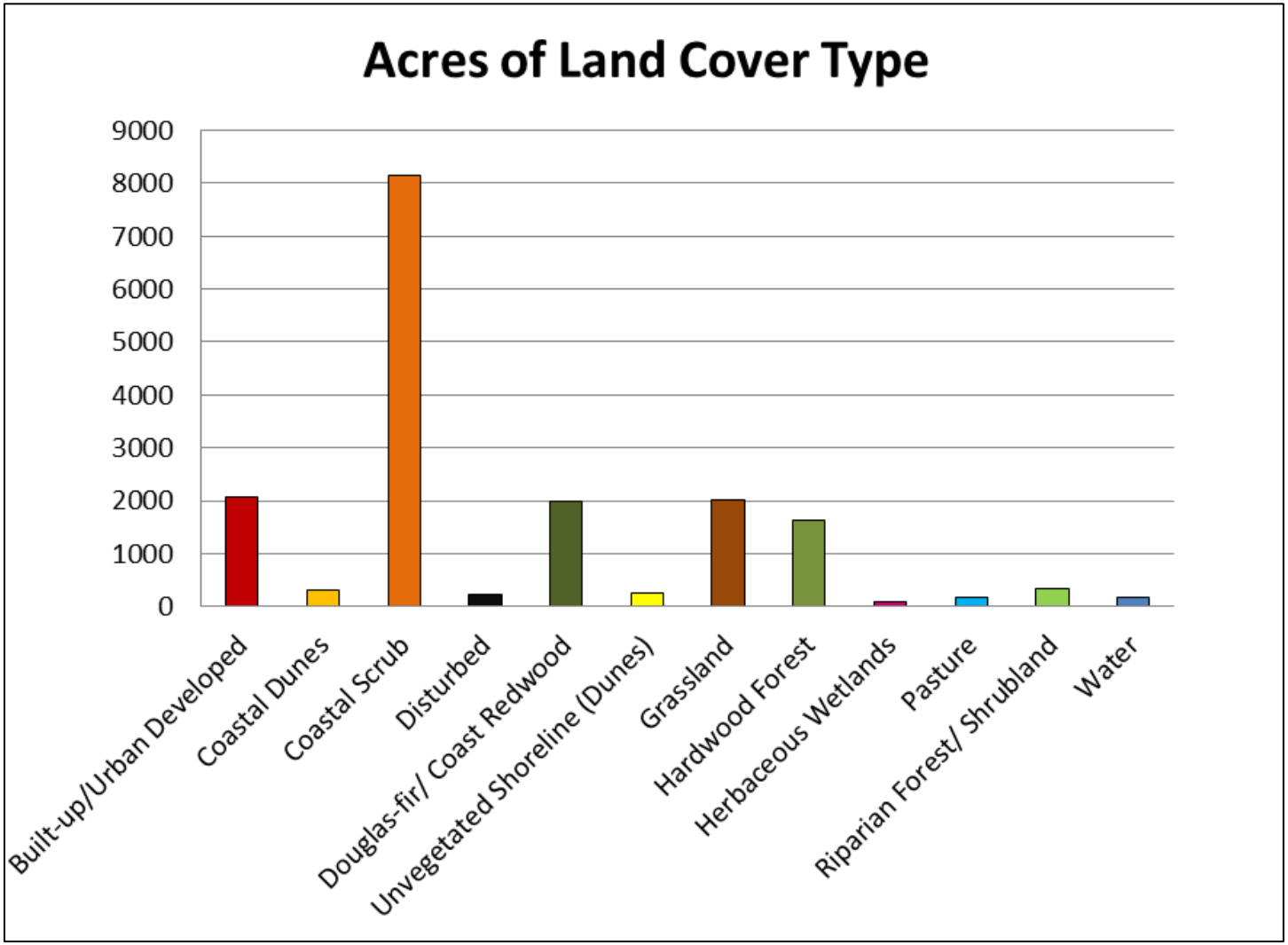


Figure 2.3. Land cover types for GOGA watersheds. More detail can be found in Chapter 4 (Pawley and Lay 2013).

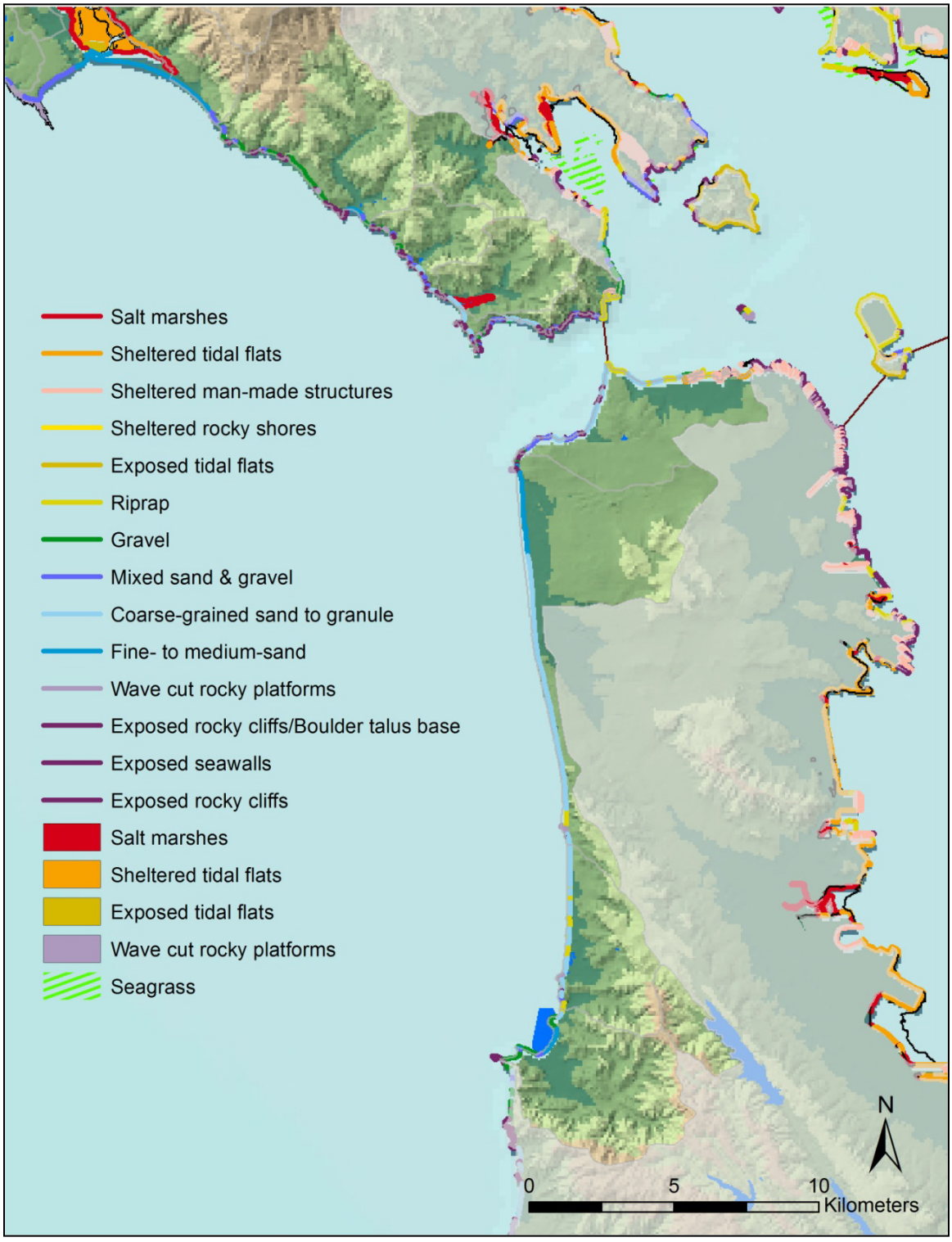


Figure 2.4. GOGA coastal shoreline substrate and habitats. Park boundaries not shown (Reproduced from Pawley and Lay 2013).

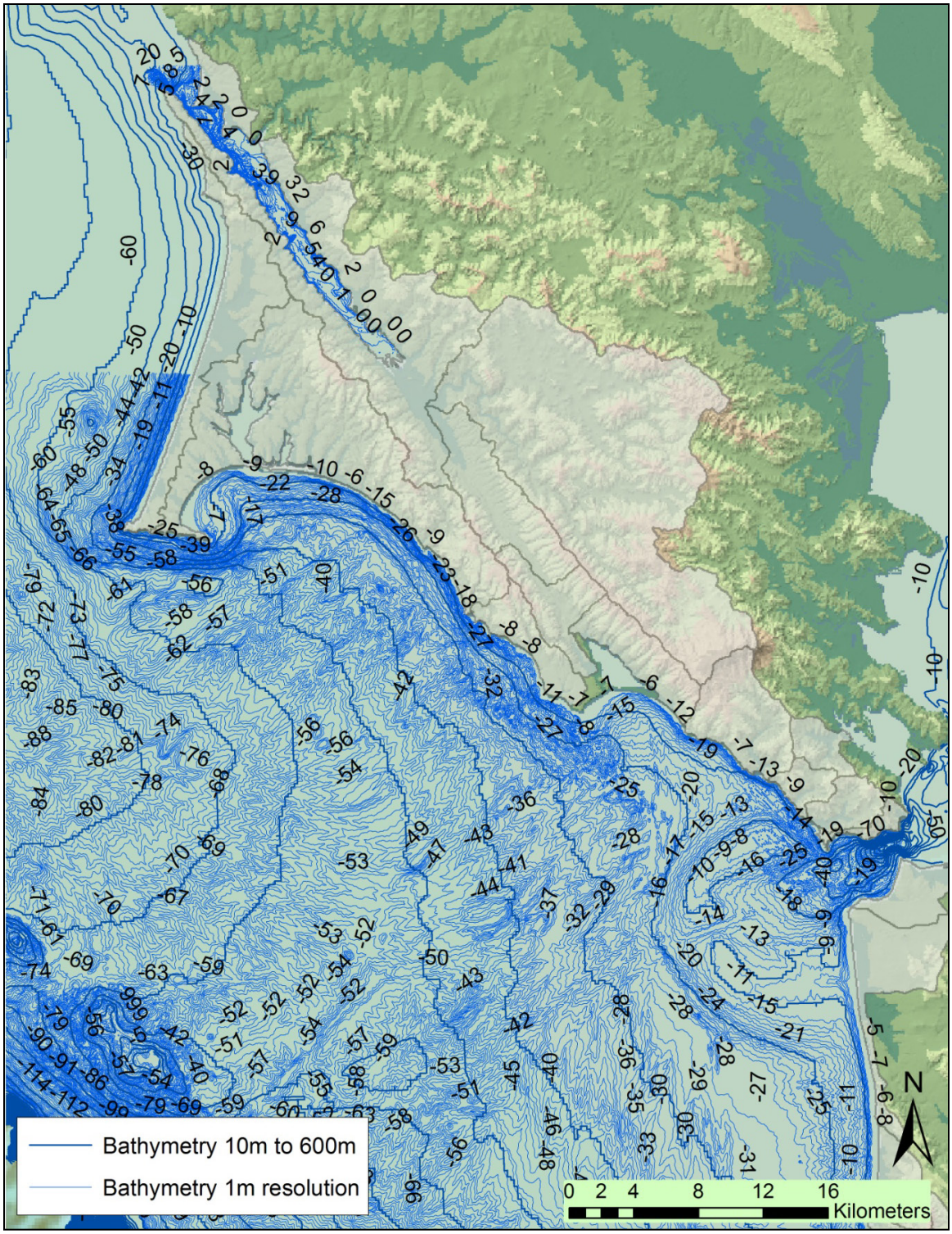


Figure 2.5. Coastal bathymetry at the 1-m scale for PORE and GOGA. Data source: 10–600 m from CDFG and 1 m (Chase et al. 1991).

2.1.3. Visitation Statistics

The Golden Gate National Recreation area attracts 16 to 20 million visitors each year, making GOGA one of the most highly-visited NPS units (Figure 2.6). Visits to Muir Woods National Monument and Alcatraz Island are high priorities for many people. Trips to the park account for nearly 50% of all visits to the 29 national park system units in California. In addition, GOGA has a significant number of local, repeat visitors, as many GOGA lands are adjacent to neighborhoods. Each year, park visitors contribute hundreds of millions of dollars to the Bay Area economy. This money directly sustains the revenue stream and jobs at hotels, restaurants, and stores that serve park visitors (Stynes 2011). Economic modeling indicates that in 2014, park visitors spent more than $350 million in the local economy and supported around 4,400 local jobs (Cullinane Thomas et al. 2015).

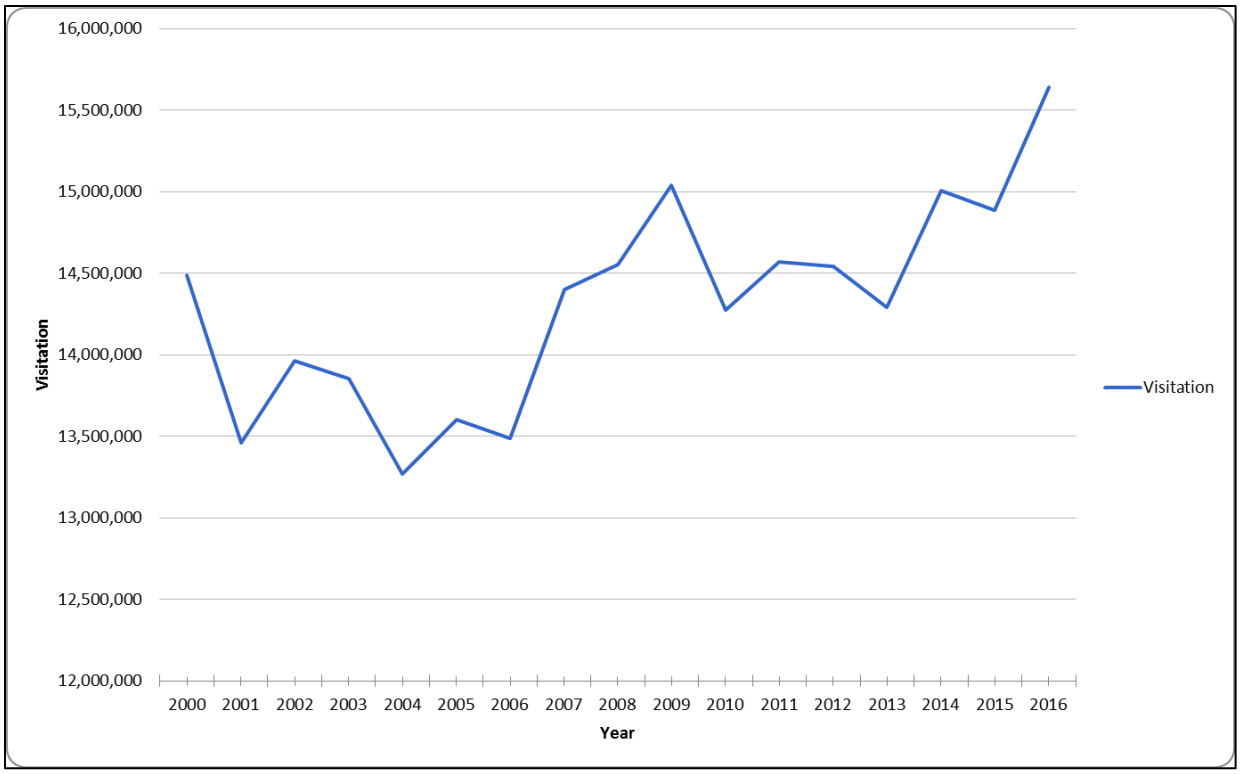


Figure 2.6. Annual visitation statistics GOGA (NPS 2017).

2.2. Natural Resources

Golden Gate National Recreation Area is part of the California Floristic Province (characterized by Mediterranean vegetation) and a zone of overlap of marine provinces (Californian and Oregonian) leading to a wide diversity of terrestrial and aquatic habitats (Bakker 1984). The natural communities of the park support a diversity of habitats extending from the Pacific Ocean to the coastline, sea cliffs to sand dunes, mud flats to salt marshes, chaparral and coastal scrub to grasslands, redwood forests and oak woodlands (Figure 2.2, 2.7). Aquatic associated habitats include ephemeral and perennial freshwater streams, groundwater seeps and springs and seasonal wetlands, as well as tidal and brackish saline wetlands grading into estuaries, and the marine environment. Habitats grade from one to another, and many species utilize multiple habitat types.



Figure 2.7. Watershed map of streams and kelp forests in the region (Reused from Pawley and Lay 2013).

2.2.1. Ecological Units at Golden Gate National Recreation Area

The PORE and GOGA Coastal Watershed Assessment (Pawley and Lay 2013) provides detailed descriptions, history, important species, and management issues related to most of GOGA's habitats. Major habitat types are listed below, but detailed descriptions are not repeated here.

Nearshore Marine Habitats

- Subtidal Zone
- Rocky Reef and Kelp Forest
- Soft and Sandy Bottom

Intertidal Zone Habitats

- Rocky Intertidal
- Sandy Intertidal Beaches

Seacoast Habitats

- Cliffs and Headlands
- Coastal Dunes

Bay and Estuary Habitats

- Seagrass Communities
- Tidal Flats
- Tidal Salt Marshes
- Brackish Marshes

Freshwater Habitats

- Streams
- Lakes, Ponds, and Lagoons
- Freshwater Wetlands

Upland Habitats

- Coastal Dunes
- Grasslands
- Coastal Scrub
- Riparian Forest/Shrubland
- Hardwood Forest
- Douglas-fir/Coast Redwood Forest

2.2.2. Resource Issues Overview

The Coastal Watershed Assessment (Pawley and Lay 2013) identified and discussed GOGA's past, current, and future potential stressors and resource impact issues. These include:

- Climate Change and Sea Level Rise
- Human Population Growth
- Air Quality Degradation
- Development/Land Use Change
- Agricultural Uses
  - Grazing
  - Dairies and Ranching
  - Cultivation (limited)
- Resource Extraction
  - Mining*
  - Oil Development*
  - Oil Spills
  - Logging*
  - Fishing and Harvesting
  - Hydrologic and Geomorphic Alteration
- Erosion/Sedimentation
- Water Quality Pollution
- Invasive Species

*Not currently occurring in park but may occur nearby.

Ocean acidification may also present a future stressor on park marine and estuarine resources (Gazeau et al. 2007). Many of these issues impact specific resource topics addressed in chapter 4.

2.3. Resource Stewardship

2.3.1. Management Directives and Planning Guidance

The Foundation Statement for GOGA states:

> *"The purpose of Golden Gate National Recreation Area is to offer national park experiences to all, including a large and diverse urban population, while preserving and interpreting the outstanding natural, historic, scenic, and recreational values of the park lands."*

Significant components of the Park's natural and cultural landscapes include:

- GOGA supports internationally recognized biodiversity due to its dynamic geology, mosaic of terrestrial and marine environments, and its location at one of the four major coastal upwelling

zones in the world. The park protects thousands of plant and animal species, many of which are threatened or endangered. The 37 federally listed threatened and endangered species that occur at GOGA are the third most in the NPS, behind only Hawaii Volcanoes and Haleakala National Parks in Hawaii.

- GOGA spans the Golden Gate, where the San Francisco Bay estuary meets the Pacific Ocean. Bolinas Lagoon is recognized as a Wetlands of International Importance (Ramsar Convention 2017). Other key wetlands in the park include Rodeo Lagoon in the Marin Headlands and the restored Crissy Marsh in San Francisco.
- MUWO protects the only remnant old growth redwood forest in Marin County. Just a short distance from San Francisco, MUWO supports high levels of visitation year round. The Woods provide inspiration and played an important role in the conservation movement. MUWU supports a variety of species including federally endangered coho salmon, and federally threatened Northern Spotted Owls and Steelhead.
- Alcatraz Island is a National Historic Landmark District with a period of significance from the Civil War through the end of the federal penitentiary era and Indian occupation in 1969. The Island receives about 5,000 visitors a day. The Island also supports regionally significant populations of breeding seabirds and waterbirds, including one of the largest Brandt's cormorant colonies on the central California coast and a growing snowy egret rookery.
- Representing more than 8,000 years of human history, GOGA chronicles a rich history of Native American culture, the Spanish Empire frontier and the Mexican Republic, agriculture and ranching, and the growth of urban San Francisco. Rapid development during the Gold Rush led to the decline and demise of many wildlife species that were overexploited.
- GOGA preserves, protects, and rehabilitates some of the finest examples of military installations and fortifications on the West Coast, including Fort Point National Historic Site, the Presidio of San Francisco, Fort Cronkhite and the Nike Missile Site at the Marin Headlands, and numerous batteries.
- The geology of GOGA inspires both visitors and scientists. The park sits along the San Andreas Fault, which heads northwest from Fort Funston into the Pacific Ocean and comes back onshore at Bolinas Lagoon. This active seismic region is responsible for the rugged terrain and topographic relief found at GOGA. Classes and visitors come to view the chert beds exposed in the Marin Headlands. The California State Rock, serpentinite, is found in the Presidio, where it supports a community of rare plants.
- With its close proximity to the San Francisco Bay metropolitan area, the relatively undeveloped scenic coastal landscapes and rich biodiversity of GOGA offer opportunities to visitors from around the world for inspiration, recreation, education, and research, and a chance to join us in stewarding these lands.
- GOGA places an extremely high value on partnerships and volunteerism to assist us in meeting our mission. A key partner is the Golden Gate National Parks Conservancy (GGNPC) that runs the Park Stewardship Program, which manages several GOGA sites, and four GOGA native plant nurseries. In addition, the Golden Gate Raptor Observatory, part of the GGNPC, has monitored

migratory raptors in the Marin Headlands for over 25 years. Furthermore, GOGA leads the National Park Service in volunteer hours contributed each year.

2.3.2. Status of Supporting Science

GOGA has strong internal and external research, inventory and monitoring programs. Approximately 45 research permits are active each year for non-NPS researchers using the park as a natural laboratory while providing important information to park managers for better park management. NPS also conducts extensive monitoring programs for many important species, communities and environmental parameters including:

- Coho & Steelhead Salmon
- Harbor Seals (Pinnipeds)
- Invasive Plants (Early Detection)
- Landbirds
- Northern Spotted Owls
- Plant Communities
- Rocky Intertidal Habitat
- Streamflow Characteristics
- Western Snowy Plovers
- Water Quality (Freshwater)

Many additional programs monitoring wildlife, vegetation, paleontology, and other resources are conducted by the park. Data from these programs are available on the San Francisco Bay Area Inventory & Monitoring Network and GOGA websites.

2.4. Literature Cited

Bakker, E. 1984. An island called California, an ecological introduction to its natural communities, 2nd edition. University of California Press, Berkeley, CA.

Bay Area Open Space Council. 2011. The Conservation Lands Network: San Francisco Bay Area Upland Habitat Goals Project Report. Berkeley, CA.

Cullinane Thomas, C., C. Huber, and L. Koontz. 2015. 2014 National Park visitor spending effects: Economic contributions to local communities, states, and the Nation. Natural Resource Report NPS/NRSS/EQD/NRR—2015/947. National Park Service, Fort Collins, Colorado.

Curdts, T. 2011. Shoreline length and water area in the ocean, coastal and Great Lakes parks: Updated statistics for shoreline miles and water acres (rev1b). Natural Resource Report NPS/WASO/NRR—2011/464. National Park Service, Fort Collins, CO.

Gazeau, F., C. Quiblier, J. M. Jansen, J. Gattuso, J.J. Middelburg and C.H.R. Heip. 2007. Impact of elevated CO_2 on shellfish calcification. Geophysical Research Letters 34.

National Park Service (NPS). 2005. Final Fire Management Plan Environmental Impact Statement. Golden Gate National Recreation Area, San Francisco, CA.

National Park Service (NPS). 2017. Public use statistics. Available from https://irma.nps.gov/Stats/ (accessed March 2017).

Ramsar Convention. 2017. Intergovernmental treat, Convention on Wetlands. Available from https://www.ramsar.org/about-the-ramsar-convention (accessed March 2017).

Pawley, A. and M. Lay. 2013. Coastal watershed assessment for Golden Gate National Recreation Area and Point Reyes National Seashore. Natural Resource Report NPS/PWR/NRR—2013/641. National Park Service, Fort Collins, Colorado.

Stynes, D. J. 2011 *Economic benefits to local communities from national park visitation and payroll*, 2010. Natural Resource Report NPS/NRSS/EQD/NRR— 2011/481. National Park Service, Fort Collins, CO.

U.S. Congress. 1972. Golden Gate National Recreation Area enabling legislation. Public Law 92-589. Washington, D.C.; Author.

U.S. Congress. 1980. Golden Gate National Recreation Area enabling legislation. Public Law 96-607. Washington, D.C.; Author.

Chapter 3. Study Scoping and Design

In March of 2012, PORE and GOGA released a draft statement of work and request for statements of interest from potential collaborators. A team of researchers from the Department of Environmental Science, Policy, and Management at the University of California, Berkeley (UCB) was selected to partner with PORE and GOGA to complete this project. The stated project objective was to interpret and translate existing scientific information into a form that park managers can readily apply for use in park decision making and resource planning. The original statement of work included Natural Resource Condition Assessments for both Point Reyes National Seashore and Golden Gate National Recreation Area.

This NRCA project was a collaborative effort between the National Park Service and researchers in the Department of Environmental Science, Policy, and Management at the University of California, Berkeley. Before beginning this NRCA project, it was necessary to identify the specific roles of NPS and UC Berkeley. This chapter describes the project's scoping process, the rationale for how focal resources were selected for assessment, the hierarchical and spatial frameworks used for organizing, analyzing, and presenting information, and outlines the methods used to assess resources.

3.1. Preliminary Scoping

The first scoping meeting occurred on November 12, 2013 with the principals from all institutions present (PORE, GOGA, and UC Berkeley). The purpose of each scoping meeting was to review the priority natural resources, to identify and prioritize indicators of the natural resources and their stressors, and to develop a plan for creating and completing an assessment of the conditions of GOGA natural resources. The scoping meeting was attended by 21 people from NPS and UC Berkeley. The meeting began with an overview of the Natural Resource Condition Assessment goals and objectives, consideration of how to manage and analyze resource elements common to both GOGA and PORE, and a general discussion of reference conditions and how to develop and use them as part of the resource assessments.

A key early decision was to write separate reports for the two parks rather than a single integrated report. The two parks share a common boundary, protect many similar resources (e.g., coastal grasslands, salmonids), and face many of the same stressors (e.g., invasive species). Moreover a single report would minimize administrative and production costs. At the same time, the parks diverge in important dimensions. Specifically, PORE is a spatially contiguous coastal reserve while GOGA consists of many individual land holdings dispersed through three Bay Area counties that span rural-to-urban and coast-to-inland-gradients. These differences in landscape context raise park-specific questions even when the resource is similar in both parks (e.g., coastal forests, rare plants). Thus we produced two separate reports. However to make the most of limited resources, we commissioned a single analysis when the focal resource and landscape context did overlap and included the single analysis in both reports.

At the initial scoping meetings, UC Berkeley and NPS staff reviewed the purpose of the NRCA reports, namely: 1) to assess the current conditions of important park natural resources, 2) to identify critical data and knowledge gaps, and 3) to determine the primary factors that are influencing park

resource conditions. We also discussed the constraints placed on the NRCA, including the need to rely on existing data and avoid rigorous trend analysis. These constraints contributed significantly to the selection of the final list of focal resources selected for inclusion in the NRCA report. We also began the process of prioritizing the focal resources for PORE at this first meeting. A second scoping meeting held on May 21, 2014 focused on GOGA with significant input from PORE.

Finalizing the list of focal resources and research leads for each resource was a primary objective of both scoping meetings. Prior to the scoping meetings Point Reyes National Seashore and Golden Gate National Recreation Area staff outlined a list of priority natural resources for consideration in the NRCA (Table 3.1). During the scoping meetings, this list was narrowed down to the final list of resources based primarily on the availability of sufficient data, the ability to conduct a useful analysis of each resource within the constraints of the NRCA, and the need for assessment of each resource. For instance, both parks had recently completed Coastal Watershed Condition Assessments (Pawley and Lay 2013). This report assessed the status of nearshore marine and estuarine habits. In the process, it also summarized the status of the physical components of the park (e.g., air quality, water quality, soil stability). Thus, for the NRCA, the resource managers prioritized the assessment of biological resources in the terrestrial communities.

To guide the selection of focal resources, park staff completed a standard summary template. The template identified existing data, spatial information, critical questions, and relevant prior analyses and reports for each priority resource. These templates informed the subsequent discussion on priorities.

Following the scoping meetings, the UC Berkeley research leads worked with the NPS resource experts to draft a work plan for each focal resource that established the study scope and needed analyses. These plans were developed through individual meetings and discussions between NPS resource experts and UC Berkeley resource lead investigators. The completed work plans were submitted to NPS staff for review before resource assessments were initiated.

Table 3.1. Priority resource elements selected by PORE and GOGA staff. Level 1 refers to the classification of the resource in the NPS Ecological Monitoring Framework.

Resource Element	General Category	PORE rank	GOGA rank	Level 1 (Framework)
Freshwater wetlands and riparian*	Vegetation/terrestrial	1.00	1.0	Biotic integrity
T&E Plant Species*	Vegetation/terrestrial	1.00	1.0	Biotic integrity
Breeding landbird diversity*	Vertebrates/birds	1.00	1.0	Biotic integrity
Amphibians*	Vertebrates/land	1.00	1.0	Biotic integrity
T&E salmonids (coho, steelhead)*	Vertebrates/fish	1.00	1.0	Biotic integrity
Coastal dune	Vegetation/terrestrial	1.00	3.0	Biotic integrity
Native coastal prairie, serpentine grassland	Vegetation/terrestrial	1.50	1.0	Biotic integrity
Forests (Bishop pine, Doug fir, bays, oaks, redwood)	Vegetation/terrestrial	1.75	1.0	Biotic integrity
Rocky intertidal	Invertebrates	1.50	1.5	Biotic integrity
Snowy plovers	Vertebrates/birds	2.00	1.0	Biotic integrity
Shorebird and waterbird	Vertebrates/birds	1.50	1.5	Biotic integrity
Northern spotted owls	Vertebrates/birds	1.50	1.5	Biotic integrity
Bat diversity	Vertebrates/land	1.50	1.5	Biotic integrity
Water quality – freshwater	Water	1.50	1.5	Water
Tidewater goby	Vertebrates/fish	2.00	1.0	Biotic integrity
Invasive plants	Vegetation/terrestrial	–	1.0	Biotic integrity
Bank swallow	Vertebrates/birds	–	1.0	Biotic integrity
Mission blue and other endangered butterflies	Invertebrates	–	1.0	Biotic integrity
Land cover and use, fragmentation/edge	Spatial Ecology	–	1.0	Landscapes

* Resources that were ranked first by both PORE and GOGA, also shown in yellow shading (NPS unpublished data 2014).

3.2. Study Design

3.2.1a. Assessment Framework Used in This Study

Golden Gate National Recreation Area staff selected the NPS Ecological Monitoring Framework as the preferred hierarchical, assessment framework for this NRCA. The National Park Service Ecological Monitoring Framework is used to organize and report National Park Service Inventory and Monitoring vital signs. The NPS Ecological Monitoring Framework is a systems-based, hierarchical, organizational tool that includes 6 categories: 1) Air and Climate, 2) Geology and Soils, 3) Water, 4) Biological Integrity, 5) Human Use, and 6) Landscapes (ecosystem pattern and processes). The majority of priority natural resources selected for inclusion in the GOGA NRCA were in the biological integrity category. The NPS Ecological Monitoring Framework is included here for reference (Table 3.2).

Table 3.2. The Ecological Monitoring Framework is a systems-based, heirarchical, organizational tool for promoting communication, collaboration, and coordination among parks, programs, and agencies involved in ecological monitoring.

Level 1 Category	Level 2 Category	Level 3 Category	Comments
Air and Climate	Air Quality	Ozone	–
		Wet and Dry Deposition	–
		Visibility and Particulate Matter	–
		Air Contaminants	–
	Weather and Climate	Weather and Climate	–
Geology and Soils	Geomorphology	Windblown Features and Processes	–
		Glacial Features and Processes	–
		Hillslope Features and Processes	–
		Coastal/Oceanographic Features and Processes	–
		Marine Features and Processes	–
		Stream/River Channel Characteristics	–
		Lake Features and Processes	–
	Subsurface Geologic Processes	Geothermal Features and Processes	–
		Cave/Karst Features and Processes	–
		Volcanic Features and Processes	–
		Seismic Activity	–
	Soil Quality	Soil Function and Dynamics	–
	Paleontology	Paleontology	–
Water	Hydrology	Groundwater/ Surface Water Dynamics	–
		Marine Hydrology	–
	Water Quality	Water Chemistry	–
		Nutrient Dynamics	–
		Toxics	–
		Microorganisms	–

Table 3.2 (continued). The Ecological Monitoring Framework is a systems-based, heirarchical, organizational tool for promoting communication, collaboration, and coordination among parks, programs, and agencies involved in ecological monitoring.

Level 1 Category	Level 2 Category	Level 3 Category	Comments
Water	Water Qualtiy (continued)	Aquatic Macroinvertebrates and Algae	–
Biological Integrity	Invasive Species	Invasive/Exotic Plants	–
		Invasive/Exotic Animals	–
	Infestations and Disease	Insect Pests	–
		Plant Diseases	–
		Animal Diseases	–
	Focal Species or Communities	Marine Communities	Includes coral communities
		Intertidal Communities	–
		Estuarine Communities	–
		Wetland Communities	Marshes, swamps, bogs
		Riparian Communities	–
		Freshwater Communities	Standing water (inland ponds and lakes) and flowing water (rivers and streams); emphasis on aquatic biota
		Sparsely Vegetated Communities	–
		Cave Communities	Cave flora and fauna
		Desert Communities	–
		Grassland/Herbaceous Communities	Includes tundra and alpine meadows, lichens, fungi
		Shrubland Communities	–
		Forest/Woodland Communities	–
		Marine Invertebrates	–
		Freshwater and Terrestrial Invertebrates	–
		Fishes	–
		Amphibians and Reptiles	–
		Birds	–

Table 3.2 (continued). The Ecological Monitoring Framework is a systems-based, heirarchical, organizational tool for promoting communication, collaboration, and coordination among parks, programs, and agencies involved in ecological monitoring.

Level 1 Category	Level 2 Category	Level 3 Category	Comments
Biological Integrity (continued)	Focal Species or Communities (continued)	Mammals	–
		Terrestrial Complex (use sparingly)	Catch-all category to be used in rare cases
	At-risk Biota	T&E Species and Communities	–
Human Use	Point Source Human Effects	Point Source Human Effects	–
	Non-point Source Human Effects	Non-point Source Human Effects	–
	Consumptive Use	Consumptive Use	–
	Visitor and Recreation Use	Visitor Use	–
	Cultural Landscapes	Cultural Landscapes	–
Landscapes (Ecosystem Pattern and Processes)	Fire and Fuel Dynamics	Fire and Fuel Dynamics	–
	Landscape Dynamics	Land Cover and Use	Includes landscape pattern, fragmentation
	Extreme Disturbance Events	Extreme Disturbance Events	Records of floods, windthrow, ice storms, hurricanes, etc.
	Soundscape	Soundscape	–
	Viewscape	Viewscape/Dark Night Sky	–
	Nutrient Dynamics	Nutrient Dynamics	–
	Energy Flow	Primary Production	–

3.2.1b. Selected Focal Resources

As noted above, the Golden Gate National Recreation Area staff outlined a list of priority natural resources for consideration in the NRCA (Table 3.1). During the scoping meetings, this list was narrowed down to the final list of resources. The criteria used to prioritize resources included: 1) availability of data including spatial and temporal extent; 2) determination of the level of priority or concern of each resource to park management; 3) the ability to conduct a useful analysis of each resource within the constraints of the NRCA; 4) the need for assessment of each resource; and 5) the expertise of scientists and NPS staff working on the project.

Following these criteria, the selected focal resources were:

- Amphibians/California Red-legged Frog
- Breeding Landbird Diversity
- Forests
- Invasive plants
- Land Use/Fragmentation
- Rare plants
- Salmonids/Steelhead
- Shorebirds

3.2.1c. Selection of Reference Conditions

A reference condition is a benchmark to which current values of a given component's measures can be compared to determine the condition of that component. It is this comparison between reference value and current status that is the basis for assigning a relative condition for each metric. A reference condition may be a historical condition (e.g., flood frequency prior to dam construction on a river), an established ecological threshold (e.g., EPA standards for air quality), or a targeted management goal/objective (e.g., a bison herd of at least 200 individuals) (adapted from Stoddard et al. 2006). A reference value is necessary to perform a scientifically credible condition assessment.

Reference conditions in this project were identified during the assessment process using input from NPS resource staff. The reference value was determined independently for each resource or stressor by consulting regulatory standards, peer-reviewed literature, status of reference sites, status at a past time period, status across a broader region that includes the parks, or other scientifically defensible baseline for comparison. Thus, the relative condition of a resource or stressor is defined as a degree of departure away from the reference state based on thresholds defined by scientifically defensible methods. In some cases, reference conditions represent a historical reference before human activity and disturbance was a major driver of ecological populations and processes, such as "pre-fire suppression." In other cases, peer-reviewed literature and ecological thresholds helped to define appropriate reference conditions. The methodology for establishing reference conditions and assigning a relative condition based on the reference value varied by focal resource. Table 3.3 lists the reference condition selected for each assessment. More detailed explanations for each resource are found in Chapter 4.

Table 3.3. Golden Gate National Recreation Area natural resource condition assessment framework.

Monitoring Framework: Level 1 Category	Focal Resource	Reference Condition	Stressors
Biotic Integrity	Amphibians	Pre-European settlement conditions	• Habitat loss • Introduced species • Disease • Contaminants • Overharvest
	Breeding Landbird Diversity	California Breeding Bird Survey	• Introduced species • Climate change
	Forests	• Biomass: theoretical & regional standards • Baseline conditions • Historic conditions	• Climate change • Pests and pathogens • Altered fire regime
	Invasive Plants	Pre-European settlement conditions (no invasives)	• Land-use/ Fragmentation • Climate change • Altered fire regime • Pests and pathogens
	Rare Plants	Historic conditions	• Habitat loss • Introduced species • Pests and pathogens • Genetic bottleneck • Trampling by humans & pets • Climate change
	Salmonids/Steelhead	Historic conditions	• Migration barriers • Lack of suitable habitat
	Shorebirds	Focal species trends	• Human activity • Climate change • Contaminants
Landscapes	Land Use	Ecological integrity	• Road density • High fragmentation • Low core area

3.2.2. Reporting Areas

Analyses for GOGA are scaled up by the management zones defined in the Park's new General Management Plan (NPS 2014). Each zone defines a set of desired conditions for natural and cultural resources, visitor experience, and general levels of development and visitor use (Figures 3.1, 3.2, and 3.3). These desired conditions are different in each management zone and reflect the overall focus of that particular zone. Eight management zones have been developed: Diverse Opportunities Zone, Scenic Corridor Zone, Evolved Cultural Landscape Zone, Historic Immersion Zone, Interpretive Corridor, Natural Zone, Sensitive Resources Zone, and Park Operations Zone (see Table 2.7 for descriptions and desired conditions in each zone). Our analysis emphasized the zones with significant natural resources.

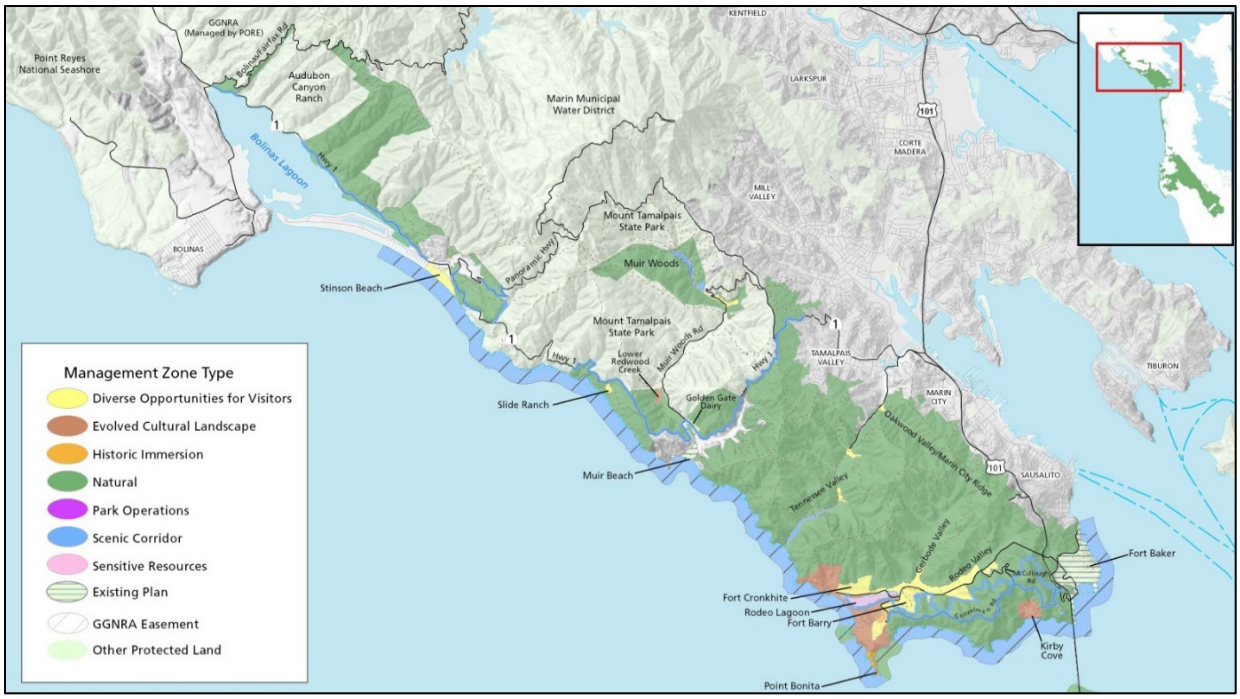


Figure 3.1. Map of eight management zones for GOGA lands in Marin County (NPS 2014).



Figure 3.2. Map of eight management zones for GOGA lands in San Francisco (NPS 2014).

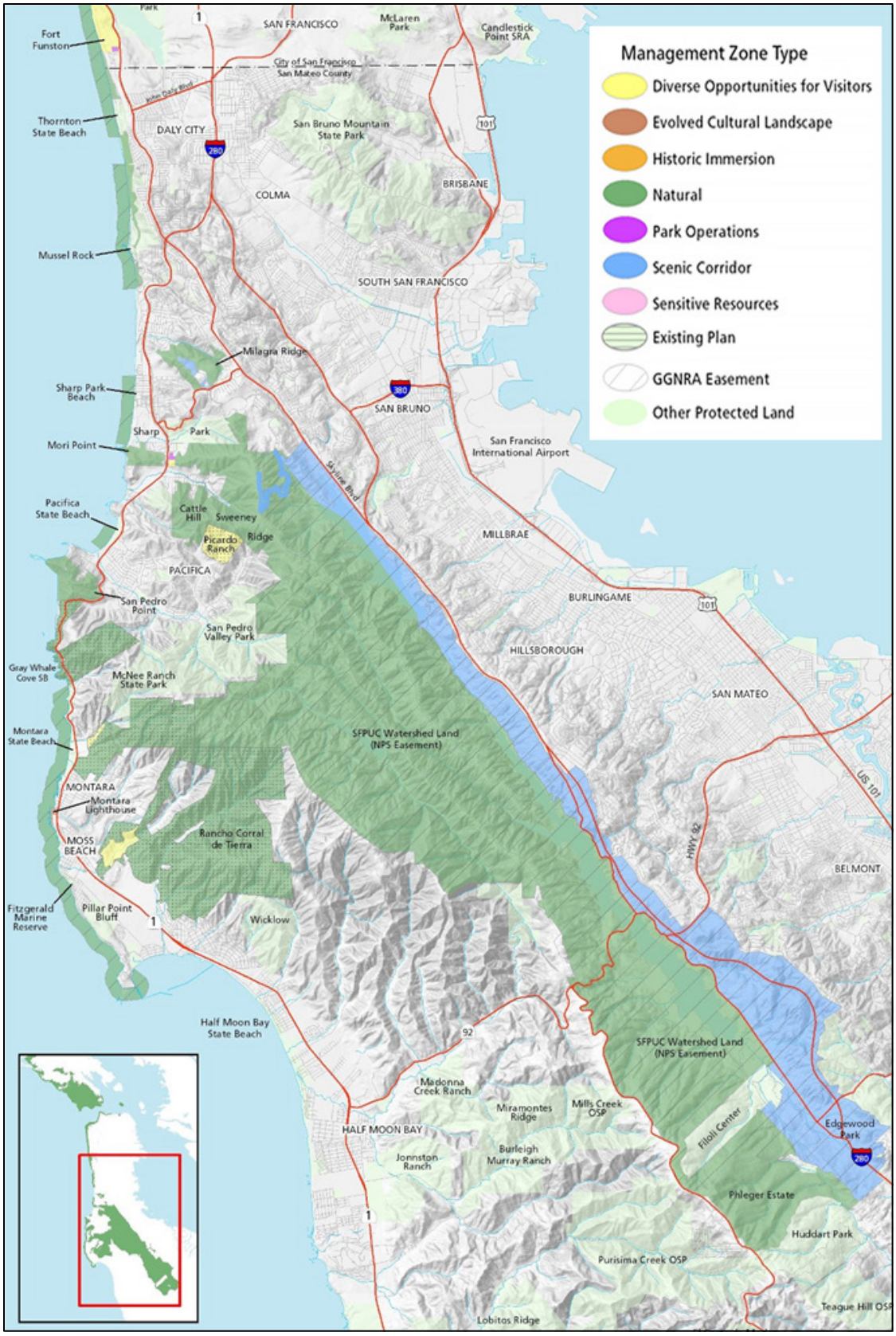


Figure 3.3. Map of eight management zones for GOGA lands in San Mateo County (NPS 2014).

3.2.3. General Approach and Methods

Assessment of the selected resources relied on gathering and reviewing existing literature and data for each focal resource and, where appropriate, analyzing the data in order to provide summaries or to create new spatial representations. After literature review and data analysis of current resource conditions, a comparison of reference state and current condition was performed. The impact of key stressors was also considered in the evaluation of current condition. Where data permitted, the future trend of each resource condition was also projected. Below we provide a general overview of our approach. Specific details for each resource are provided in Chapter 4.

Information Gathering

Acquiring the relevant literature and data for each focal resource began prior to the initial scoping meeting with completion of a template for each resource that identified many of the existing databases, reports, and publications. Following the scoping meeting, external research leads continued to work with NPS resource experts to transfer relevant data and literature including: NPS reports and monitoring plans, reports from various state and federal agencies, published and unpublished research documents, databases, tabular data, and charts. For resources with existing spatial data, GIS databases were transferred to UC Berkeley researchers by GOGA staff.

Critical Questions

To help focus the assessment, critical questions regarding the status of the resource were identified. These questions emerged from the scoping effort and initial reviews of the available literature and information availability. They were developed early in the process in collaboration with Park resource managers.

Data Analyses

Data development and analyses were highly specific to the focal resource and depended largely on the amount of information and data available and the critical resource questions developed in conjunction with GOGA staff. Specific approaches to data development and analysis can be found within each component assessment located in Chapter 4 of this report.

Geographic information systems (GIS) technology was utilized to graphically depict the status and distribution of selected resources. Extensive spatial analyses were performed resulting in many new spatial datasets and products. These spatial products will be integrated into the park dataset to facilitate future access.

Resource Condition

Following analysis of each focal resource, lead scientists worked with NPS collaborators to assign condition levels to the overall resource and to scale these condition assessments up to the management zone level. General condition maps scaled by park management zones are provided for each focal resource or stressor. Lead scientists developed these maps for each resource by applying their expertise in the resource to make informed decisions about appropriate condition thresholds, scaling from the available data, and the level of certainty in the condition assessment. These were not necessarily quantitative decisions, but rather required a consistent expert strategy applied to each of the management zones. These decisions were based on all the available literature and data reviewed

for the component, as well as communications with park and outside experts. Details for each resource are presented in Chapter 4.

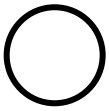
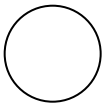
Resource Assessment Format

All resource component assessments are presented in a standard format. The format and structure of these assessments is described below:

Condition Graphic

Although the PORE and GOGA NRCAs were initiated prior to 2014, both parks opted to follow the updated NPS guidelines required for newer NRCA reports by using the standard symbol set for resource condition reporting (Figure 3.4). The condition graphic provides a visual representation of the condition of the indicator within the park. These graphics are used to give readers a quick representation of the authors' assessment of resource condition but do not replace the written statements of condition which provides a more in-depth description.

Table 3.4. Standard symbol set for resource condition reporting.

Condition Status		Trend in Condition		Confidence in Assessment	
	Warrants Significant Concern		Condition is Improving		High
	Warrants Moderate Concern		Condition is Unchanging		Medium
	Resource is in Good Condition		Condition is Deteriorating		Low
No Color	Current condition is Unknown or Indeterminate	No arrow	Trend in Condition is Unknown or Not Applicable	–	–

For this NRCA, investigators took the additional step of aggregating resource-level findings to summarize condition status by management zones. We adopted the suggested terminology and aggregation rule set used in State of the Park reporting, which the national State of the Park guidance describes as follows:

The overall assessment of the condition for a Priority Resource or Value may be based on a combination of the status and trend of multiple indicators and specific measures of condition. A set of rules are proposed for summarizing the overall Status of a particular Priority Resource based on assessments of Status for two or more specific measures of condition, and for summarizing the overall Trend for the resource based on multiple Trend arrows. The proposed set of rules is as follows:

Condition

To determine the combined condition, each red symbol is assigned zero points, each yellow symbol is assigned 50 points, and each green symbol 100 points (Table 3.5). Open (uncolored) circles are omitted from the calculation. Once the average is calculated, apply the scale below to determine the resulting color.

Table 3.5. Scale of scores determining condition status for each resource.

Score 0 to 33	Score 34 to 66	Score 67 to 100
Red	Yellow	Green

Trend

To determine the overall trend, subtract the total number of down arrows from the total number of up arrows. If the result is 3 or greater, the overall trend is up. If the result is -3 or lower, the overall trend is down. If the result is between 2 and -2, the overall trend is unchanged. Sideways trend arrows and cases where trend is unknown are omitted from this calculation.

Description

The description provides background information about the resource, places the resource in the context of its importance to GOGA, and summarizes the primary objectives of the resource-specific assessment. This section explains characteristics of the indicator that help the reader understand subsequent sections of the document. For example, a component may represent a unique feature of the park, it may be a key process or resource in park ecology or it may be a resource that is of high management priority in the park. Also emphasized are interrelationships that occur among the featured component and other resource components included in the NRCA.

Measures

The measures used to define the condition of the indicator, as outlined in the framework, are listed in this section. Those measures deemed most appropriate for assessing the current condition of a component are listed in this section, typically as bulleted items.

Data and Methods

This section describes the existing datasets used for evaluating the indicator. Methods used for processing or evaluating the data are also discussed where applicable. If adjustment or processing of data involved an extensive or highly technical process, these descriptions are included in an appendix for the reader or in a GIS metadata file for future users of the data.

Reference Conditions/Values

This section explains the reference condition determined for each resource component as it is defined in the framework. Explanation is provided as to why specific reference conditions are appropriate or logical to use. Also included in this section is a discussion of any available data and literature that explain and elaborate on the designated reference conditions.

Current Condition and Trend

The condition section of the indicator assessment provides a summary of the condition of the indicator and any trends based on available literature, data, and expert opinions of park staff. This section highlights the key information used in defining the overall condition for each indicator. It also provides a summary of the stressors to an indicator and outlines data needs, which if addressed, would be beneficial in determining the condition of a given indicator in future assessments.

The overall objective of this approach is to assess and articulate the present condition of each focal resource based on a reasonably thorough review of available information (e.g., data, publications, and reports) generated by park staff, and by research and monitoring cooperators.

Stressors

This section identifies important threats and stressors impacting the focal resource.

Level of Confidence

A statement regarding confidence in each condition assessment is included.

Gaps in Understanding

The information and data needs-gaps subsection is used to identify gaps in presently available data as well as suggest additional sampling and data collection that could be useful for better assessing the condition of a resource.

Sources of Expertise

Key resources used in each indicator assessment are identified in this section.

3.3. Literature Cited

National Park Service (NPS). 2014. Final general management plan environmental impact statement. Golden Gate National Recreation Area and Muir Woods National Monument. San Francisco, CA.

Pawley, A. and M. Lay. 2013. Coastal watershed assessment for Golden Gate National Recreation Area and Point Reyes National Seashore. Natural Resource Report NPS/PWR/NRR—2013/641. National Park Service, Fort Collins, Colorado.

Stoddard, J. L., D. P. Larsen, C. P. Hawkins, R. K. Johnson, and R. J. Norris. 2006. Setting expectations for the ecological condition of streams: the concept of reference condition. Ecological Applications 16(4):1267–1276.

Chapter 4. Resource Conditions

4.1. Amphibians

Pond-breeding amphibians are widespread, but little is known about stream-breeding amphibians or terrestrial salamanders.



4.1.1. Why Focal Resource Was Assessed

Description

Amphibian declines are a nearly worldwide phenomenon (Blaustein and Wake 1990, Wake 1991, 2012, Stuart et al. 2004, Wake and Vredenburg 2008, Adams et al. 2013). In California, declines of several species, including California red-legged frogs (*Rana draytonii*), southern mountain yellow-legged frogs (*R. muscosa*), Sierra Nevada yellow-legged frogs (*R. sierrae*), and Yosemite toads (*Anaxyrus canorus*), have precipitated their listing as threatened or endangered by the U.S. Fish and Wildlife Service. Many factors have contributed to these declines, including loss of habitat or reduction in habitat quality (Lehtinen et al. 1999, Cushman 2006, Harper et al. 2008), introduced species (Adams et al. 2003, Vredenburg 2004, Knapp 2005, Knapp et al. 2007), diseases such as the amphibian chytrid fungus *Batracochytrium dendrobatidis* (*Bd*; Briggs et al. 2005, Vredenburg et al. 2010), and contaminants (Sparling et al. 2001, 2015, Davidson 2004, Sparling and Fellers 2007). Because of their sensitivity to these myriad threats, their biphasic life cycle that exposes them to stressors in both aquatic and terrestrial environments, and their permeable skin that further sensitizes them to environmental change, amphibians make excellent indicator species (Welsh and Ollivier 1998) that can serve as bellwethers for environmental changes. Amphibians also are an integral part of functional ecosystems, serving as primary consumers, predators at multiple trophic levels, and prey for a diversity of other organisms. The important role of amphibians in functioning ecosystems, combined with their sensitivity to environmental conditions, makes them an ideal taxon for monitoring the status and health of ecosystems.

At Point Reyes National Seashore and Golden Gate National Recreation Area, amphibians as a group are ideal candidates for monitoring and targeted study of the consequences of environmental change. The amphibian fauna in these coastal California locations includes a diverse group of species exhibiting different life cycles, from pond-breeding frogs and salamanders, to stream-breeding salamanders, to terrestrial salamanders with direct development. These species occur in a variety of habitats, thus making different groups more or less sensitive to different types of environmental changes. Furthermore, the amphibian fauna of Point Reyes National Seashore and Golden Gate National Recreation Area is relatively well-studied. This existing knowledge, combined with their diversity, means that amphibians could serve important roles for monitoring environmental changes and for more detailed assessments of the consequences of specific management actions at these National Parks. We combined the assessment of Golden Gate National Recreation Area and Point Reyes National Seashore because many of the surveys for both parks were in the same database, the

amphibian communities and habitats samples were similar, and in some of the most heavily surveyed areas, such as the Olema Valley, the parks are adjacent to one another.

Critical Questions

Despite an extensive existing knowledge base, many questions remain regarding the status and trends of amphibians at Point Reyes National Seashore and Golden Gate National Recreation Area. For this assessment, we sought to answer the following questions we deemed critical to understanding the status of amphibians at these locations:

- Where have surveys for aquatic-breeding amphibians at Point Reyes National Seashore and Golden Gate National Recreation Area been conducted, and how many surveys have been completed at each survey location over the past 20 years?
- What is the spatial distribution of records of aquatic-breeding amphibian species at Point Reyes National Seashore and Golden Gate National Recreation Area over the past 20 years?
- How is species richness of native aquatic-breeding amphibians distributed at Point Reyes National Seashore and Golden Gate National Recreation Area?
- Which amphibian species (if any) have ranges that include Point Reyes National Seashore and Golden Gate National Recreation Area, but currently do not occur within the Parks?
- Where have non-native amphibians been detected at Point Reyes National Seashore and Golden Gate National Recreation Area?
- What information gaps remain, including:
    - Unsampled or undersampled geographic areas
    - Unsampled or undersampled habitats
    - Species of concern about which little is known
    - Information gaps about species of concern
    - Drivers of change in the local distribution and abundance of amphibians

4.1.2. How Focal Resource Was Assessed

Measures

We evaluated several metrics to help understand the status of amphibians at Point Reyes National Seashore and Golden Gate National Recreation Area. To assess the latter, we examined the spatial and temporal distribution of survey effort for amphibians. We used several measures to assess the status of amphibians, including species richness of native amphibians, detections/non-detections of focal native amphibians, and detections/non-detections of non-native amphibians. Our focal native amphibians were the pond-breeding and federally-threatened California red-legged frog (*Rana draytonii*) because of its threatened status, and the stream-breeding California giant salamander (*Dicamptodon ensatus*) because of its role as a top predator in cold, clear headwater streams. Our focal non-native amphibian, the American bullfrog (*Lithobates catesbeianus*), can compete with and prey upon native species (Moyle 1973, Kupferberg 1997a, Doubledee et al. 2003, Pearl et al. 2004).

Data Sources and Methods

We assessed the status of amphibians at Point Reyes National Seashore and Golden Gate National Recreation Area using amphibian surveys conducted by USGS Point Reyes Field Station and Golden Gate National Recreation Area staff from 1993–2014. In some cases, sites that were subdivided in the database were pooled for this analysis. These cases were limited to short reaches of a stream that were treated as sub-sites in the database (longer reaches [≥ 100 m] were maintained as individual sites). We then tabulated survey effort and species detections by site, and mapped the locations of all surveys and detections of focal species. We did not use quantitative methods that account for imperfect detectability, nor did we attempt to assess abundance with the available data.

Reference Conditions/Values

No specific reference conditions or values were assumed in this assessment. In some cases, reference is made to conditions that likely occurred on the landscape prior to European settlement.

4.1.3. Condition Assessment

Condition and Trend

From 1993 through December 2014, 508 sites at Point Reyes National Seashore and Golden Gate National Recreation Area were surveyed a total of 3322 times. Survey effort was generally widespread throughout both National Parks (Figs. 4.1.1 and 4.1.2). Notable gaps in the spatial distribution of survey effort includes steep forested areas in the central part of Point Reyes National Seashore near Mount Wittenberg, and portions of Golden Gate National Recreation Area in San Francisco. The Olema Valley was particularly well-sampled. Although survey effort was broadly distributed spatially, most sites were surveyed few times since 1993 (Fig. 4.1.3). Indeed, 34% of the 508 sites surveyed were only surveyed once, and 77% were surveyed five or fewer times. One intensively-studied site has been surveyed 312 times since 1993. Usurprisingly, most sites were also only surveyed in fewer than five years between 1993 and the present (Fig. 4.1.4). The temporal distribution of surveys was also uneven, with 1993, 1995, 2000, and 2004 each having 100 or more sites surveyed (Table 4.1.1). Most surveys were of aquatic breeding sites, with marshes or ponds and streams being the dominant habitats surveyed (Table 4.1.2; Fig. 4.1.5). Surveys of most habitats were well-distributed, with most lakes occurring near the Pacific coast and most ditches occurring in low-lying areas in the Olema Valley near Tomales Bay (Figs. 4.1.6 and 4.1.7).

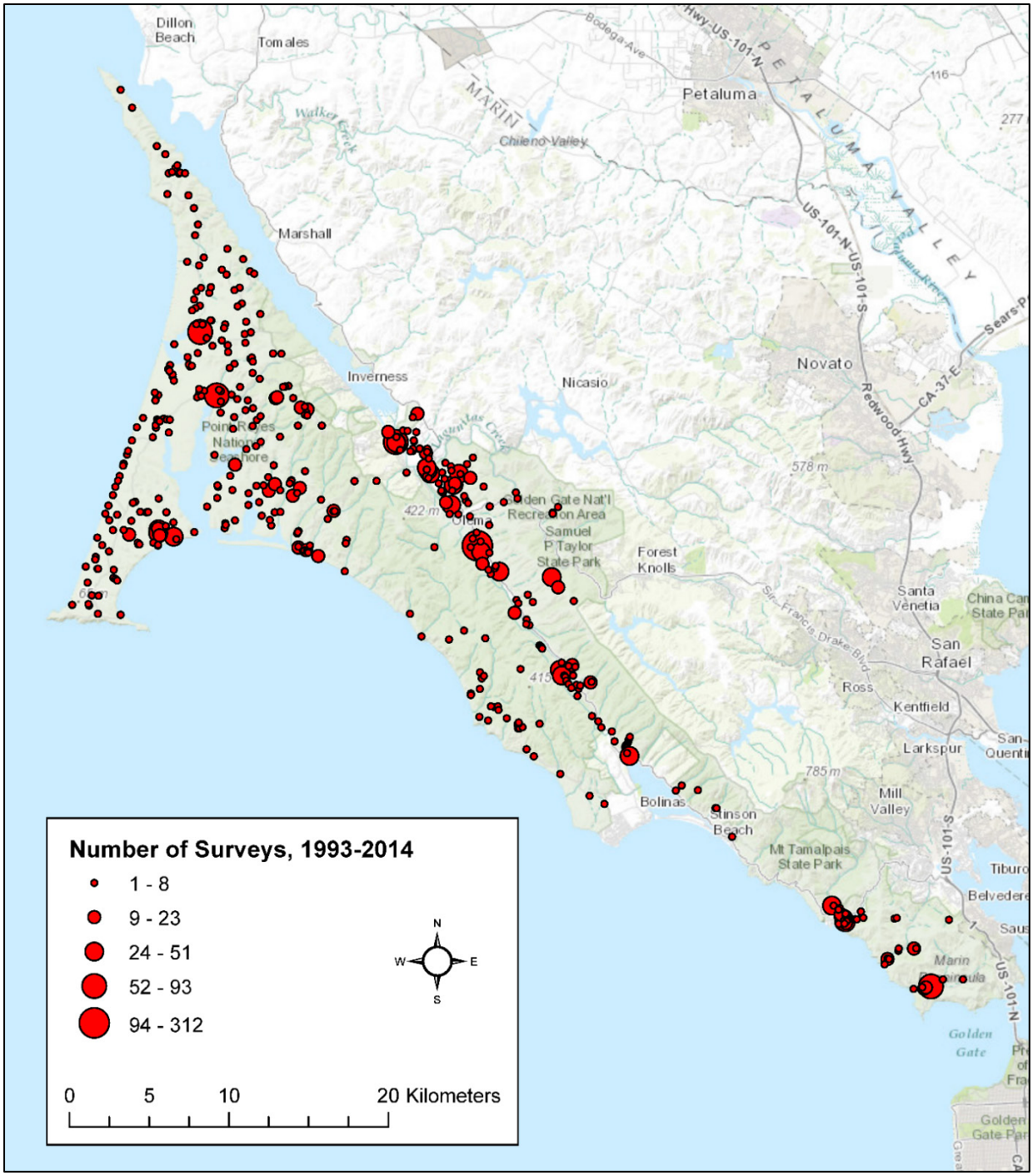


Figure 4.1.1. Distribution of survey effort for amphibians at Point Reyes National Seashore and Golden Gate National Recreation Area in Marin County, California, 1993–2014 (NPS unpub. Data 2015; USGS unpub. Data 2015).

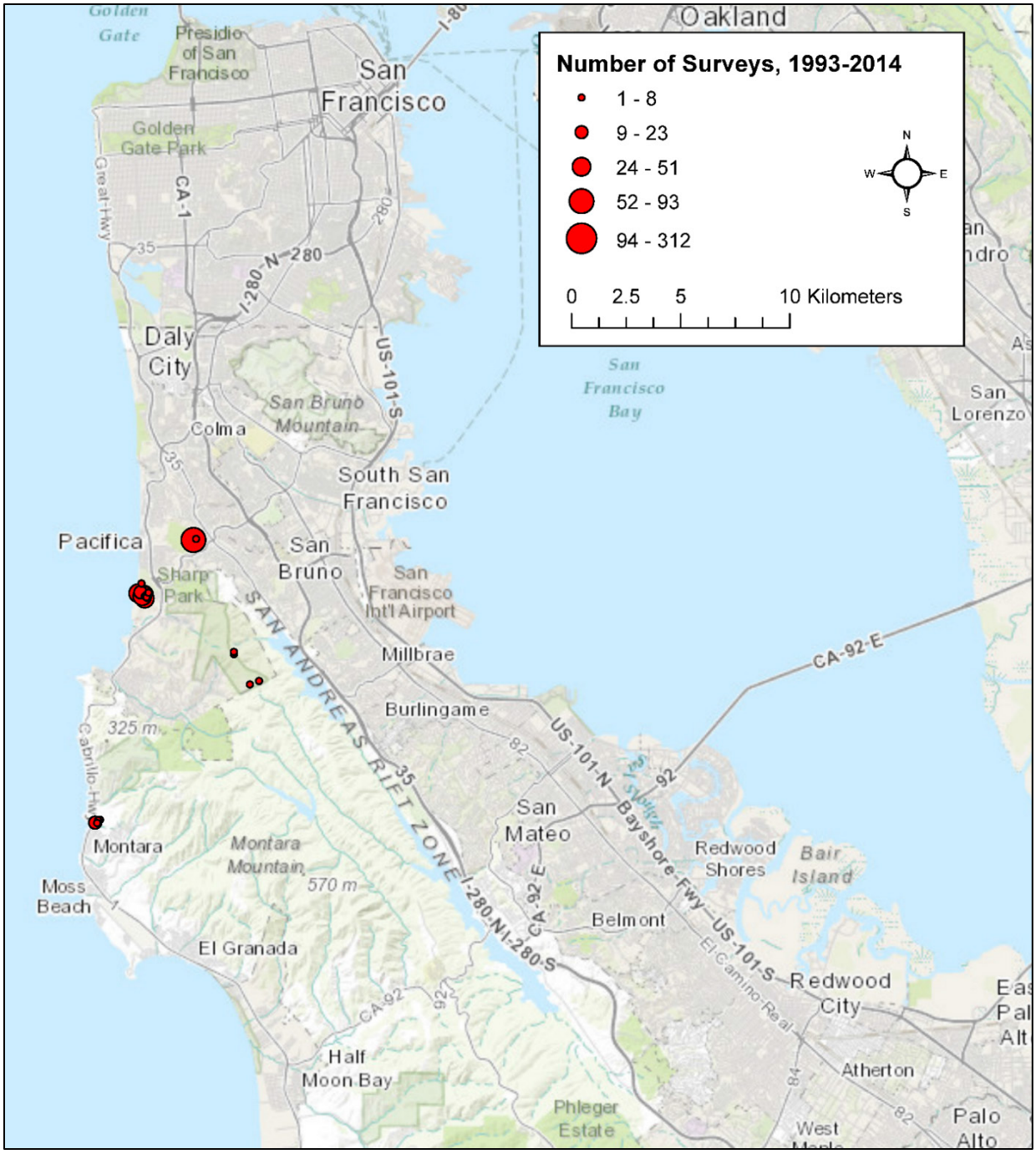


Figure 4.1.2. Distribution of survey effort for amphibians at Golden Gate National Recreation Area in San Mateo County, California, 1993–2014 (NPS unpub. Data 2015).

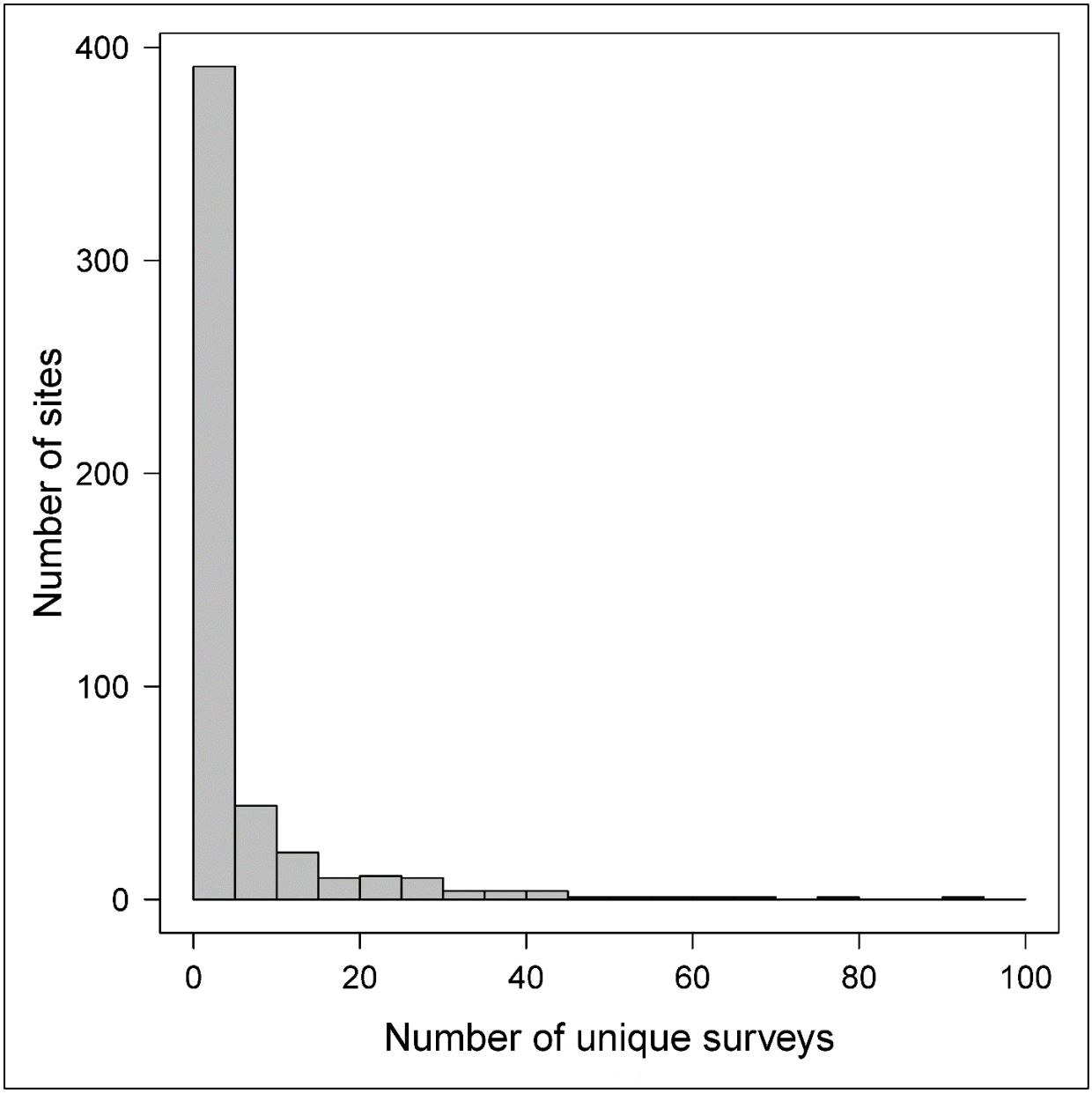


Figure 4.1.3. The number of unique surveys conducted at each individual survey site at Point Reyes National Seashore and Golden Gate National Recreation Area, 1992–2014. One site that was surveyed 312 times was omitted to better show sampling effort at the majority of sites, which had far fewer surveys (NPS unpub. Data 2015; USGS unpub. Data 2015).

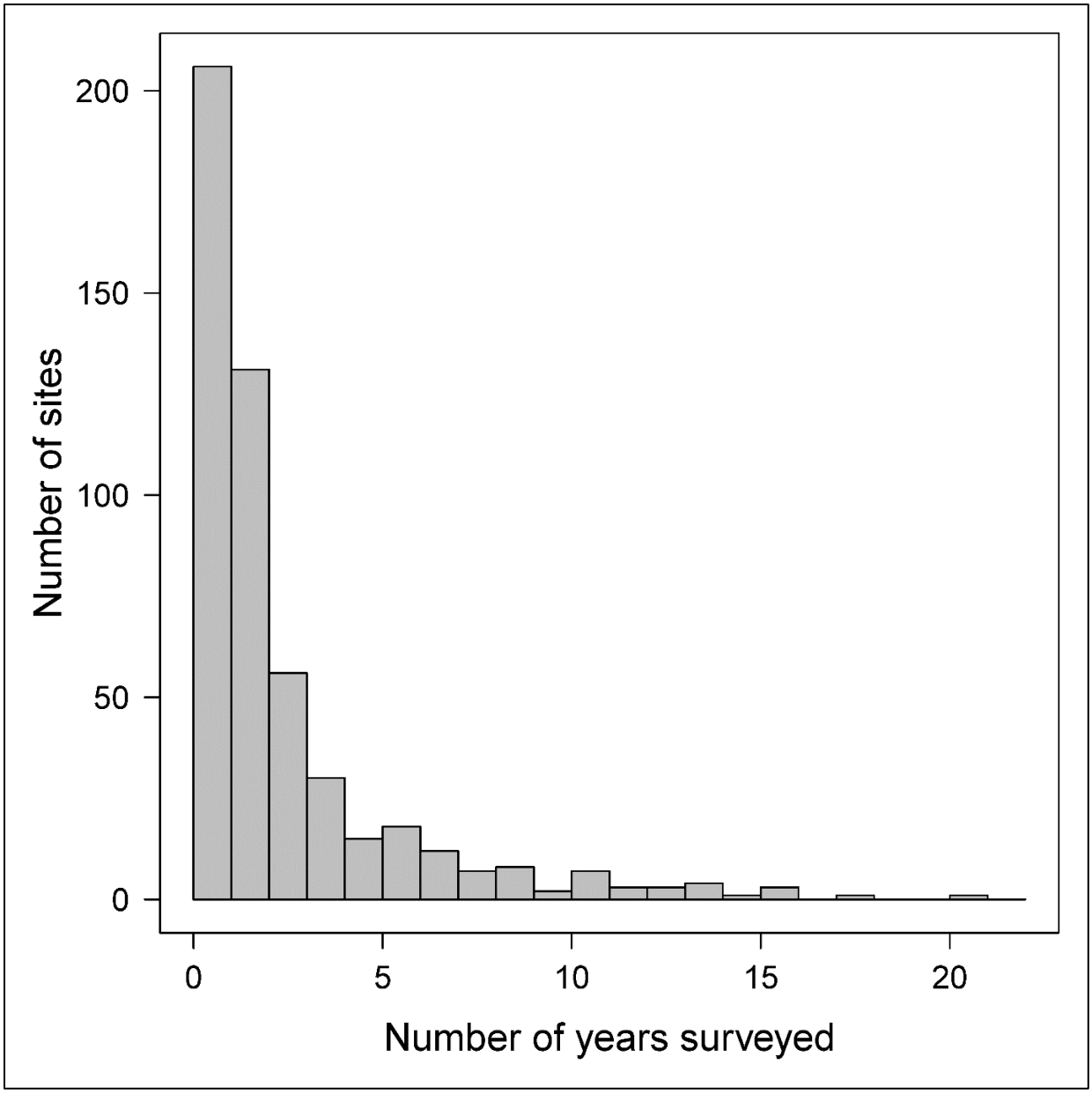


Figure 4.1.4. Number of years from 1993 through 2014 during which at least one survey was conducted at each site sampled for amphibians at Point Reyes National Seashore and Golden Gate National Recreation Area (NPS unpub. Data 2015; USGS unpub. Data 2015).

Table 4.1.1. Summary of number of sites surveyed and detections of focal species by year in Point Reyes National Seashore and Golden Gate National Recreation Area from 1993 through 2014. For California giant salamanders, only surveyed stream sites were used in the calculation of proportion of sites with detections (USGS unpub. Data 2015).

Year	Number of Sites Surveyed	Number of Sites with Detections			Proportion of Sites with Detections			Number of Native Species Detected
		American Bullfrog	California Giant Salamander	California Red-legged Frog	American Bullfrog	California Giant Salamander	California Red-legged Frog	
1993	135	4	1	46	0.03	0.03	0.34	6
1994	49	5	3	18	0.10	0.33	0.37	5
1995	100	6	0	36	0.06	0.00	0.36	5
1996	57	5	0	38	0.09	0.00	0.67	4
1997	42	4	1	26	0.10	0.08	0.62	5
1998	32	7	9	11	0.22	1.00	0.34	6
1999	40	2	2	14	0.05	0.25	0.35	5
2000	102	11	2	22	0.11	0.06	0.22	5
2001	40	1	1	19	0.03	0.06	0.48	4
2002	80	2	0	27	0.03	0.00	0.34	3
2003	38	2	0	19	0.05	0.00	0.50	4
2004	101	4	0	28	0.04	0.00	0.28	4
2005	75	3	1	18	0.04	0.13	0.24	5
2006	79	8	0	36	0.10	0.00	0.46	5
2007	86	6	0	32	0.07	0.00	0.37	4
2008	51	3	0	25	0.06	0.00	0.49	4
2009	51	2	0	26	0.04	0.00	0.51	3
2010	77	1	1	29	0.01	0.05	0.38	5
2011	51	3	0	30	0.06	0.00	0.59	4
2012	54	2	0	27	0.04	0.00	0.50	3
2013	61	3	0	31	0.05	0.00	0.51	4
2014	80	0	0	37	0.00	0.00	0.46	4

Table 4.1.2. Summary of surveys and detections of focal species by habitat at sites in Point Reyes National Seashore and Golden Gate National Recreation Area from 1993 through 2014 (USGS unpub. Data 2015).

Habitat	Number of Sites	Number of Sites with Detections			
		American Bullfrog	California Giant Salamander	California Red-legged Frog	Any Native Amphibian
Ditch	12	0	0	4	11
Grassland	15	0	0	5	8
Lake	13	1	0	6	11
Marsh or Pond	333	34	0	180	300
Spring	8	0	0	5	7
Stream	127	5	16	43	95
Total	**508**	**40**	**16**	**243**	**432**

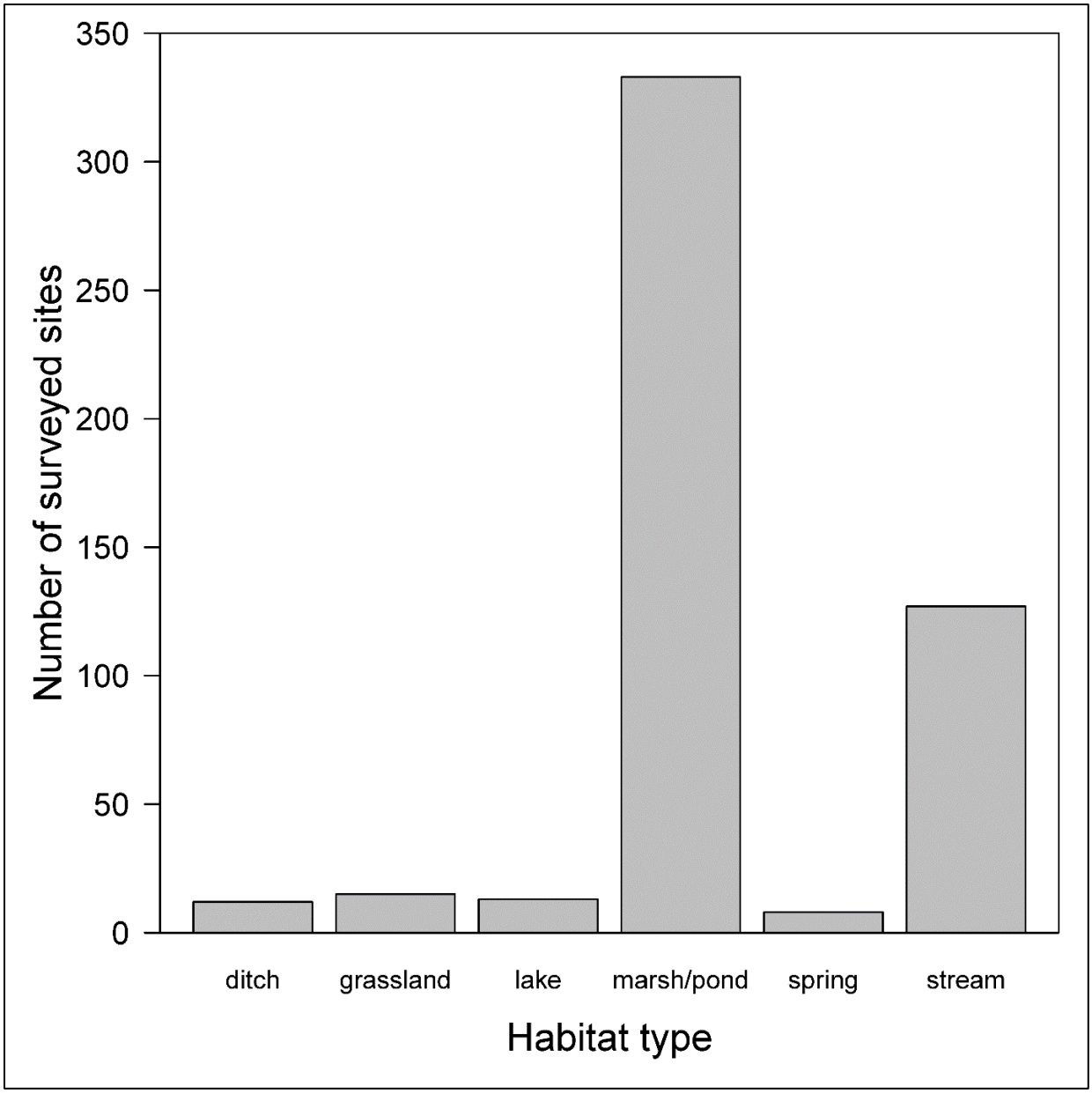


Figure 4.1.5. Number of sites of each habitat type surveyed for amphibians at Point Reyes National Seashore and Golden Gate National Recreation Area, 1993–2014 (USGS unpub. Data 2015).

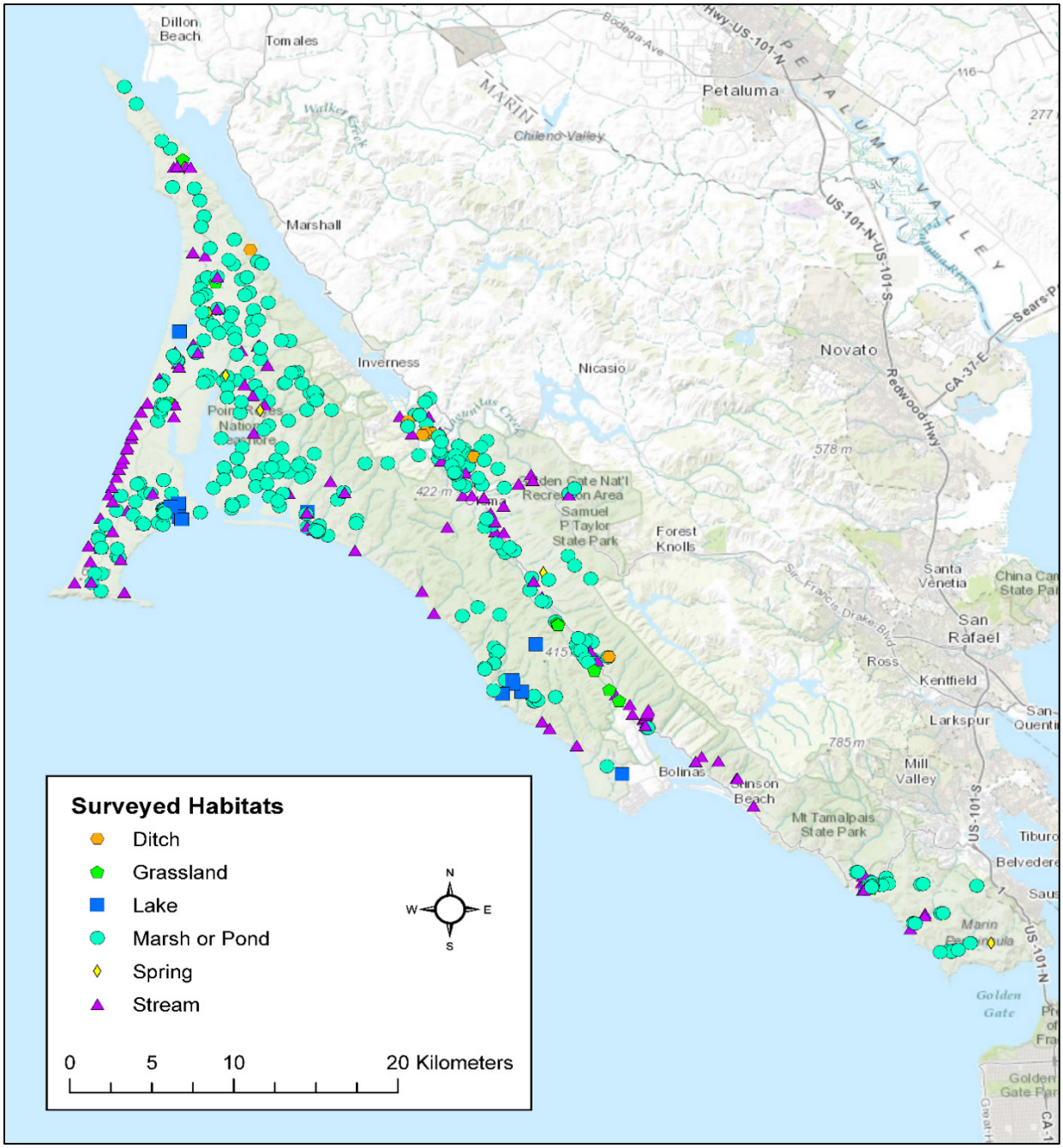


Figure 4.1.6. Spatial distribution of habitats surveyed for amphibians at Point Reyes National Seashore and Golden Gate National Recreation Area in Marin County, California, 1993–2014 (USGS unpub. Data 2015).

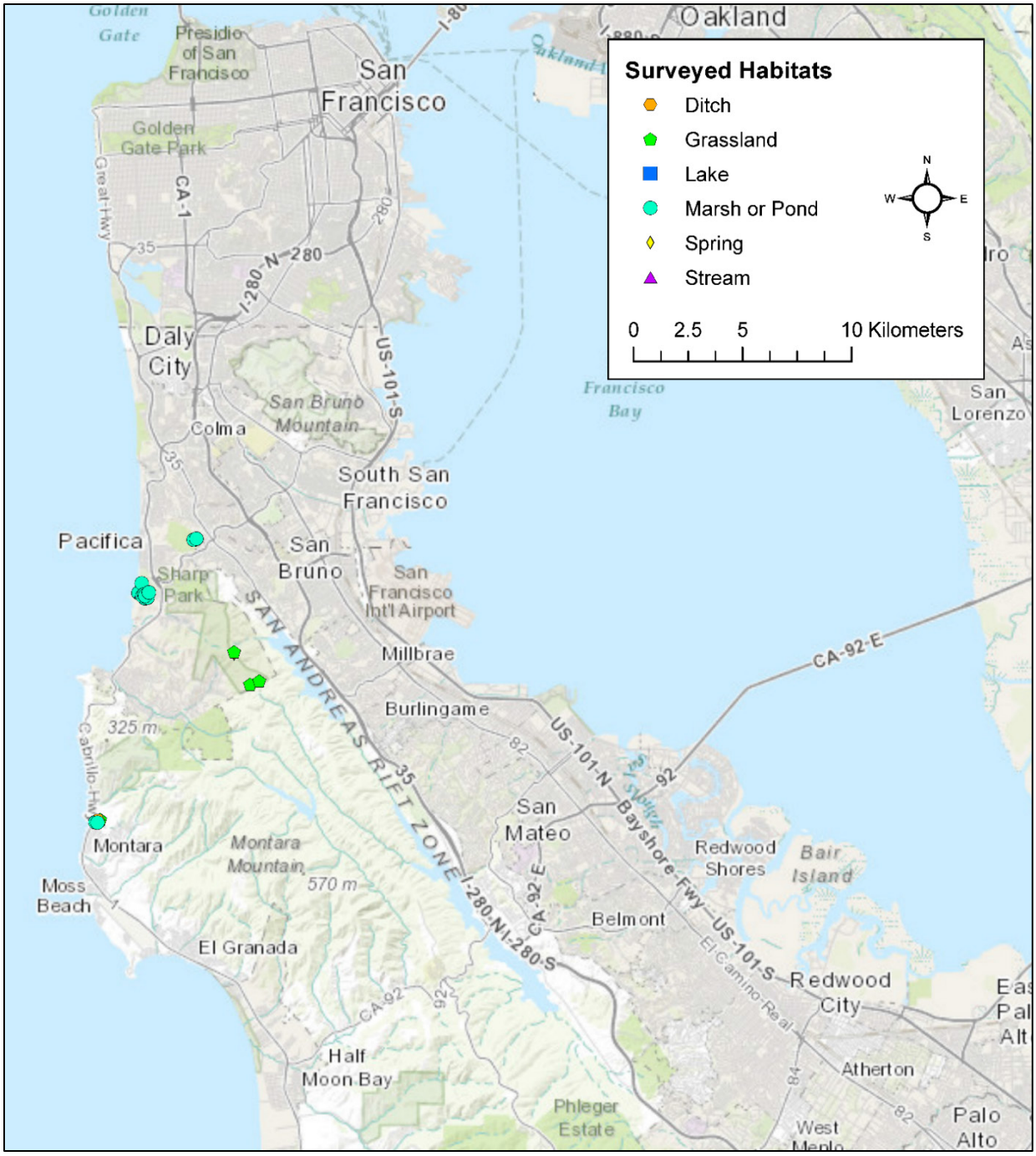


Figure 4.1.7. Spatial distribution of habitats surveyed for amphibians at Golden Gate National Recreation Area in San Mateo County, California, 1993–2014 (USGS unpub. Data 2015).

Seven aquatic-breeding amphibian species were detected during surveys: native western toads (*Anaxyrus boreas*), sierran treefrogs (*Pseudacris sierra*), California red-legged frogs, California giant salamanders, rough-skinned newts (*Taricha granulosa*), and California newts (*T. torosa*), and non-native American bullfrogs. The maximum number of native species observed at a given site was four, with one or two species most commonly observed (Fig. 4.1.8). No amphibians were observed at 15%

of the sites. No clear pattern was evident in the spatial distribution of species richness (Figs. 4.1.9 and 4.1.10). A high proportion of most habitat types surveyed had at least one native amphibian species detected (Fig. 4.1.11). Although fluctuations occurred, the proportion of sites with at least one native amphibian detected was 0.65 or greater in all years from 1993 to the present, with more than 75% of sites having at least one native amphibian detected in all but three years (Fig. 4.1.12).

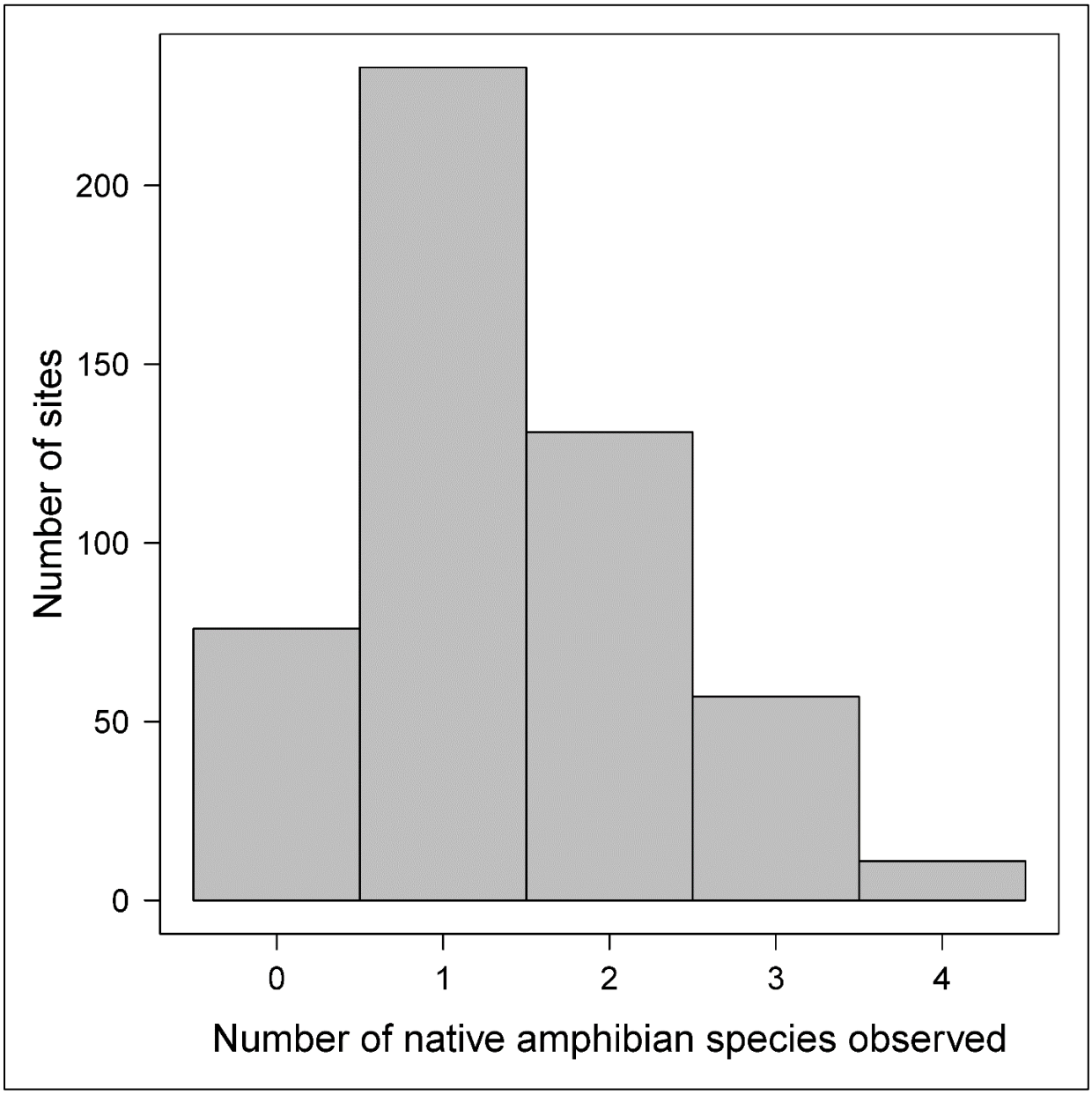


Figure 4.1.8. Distribution of species richness of native amphibians among surveyed sites at Point Reyes National Seashore and Golden Gate National Recreation Area, 1993–2014 (NPS unpub. Data 2015; USGS unpub. Data 2015).

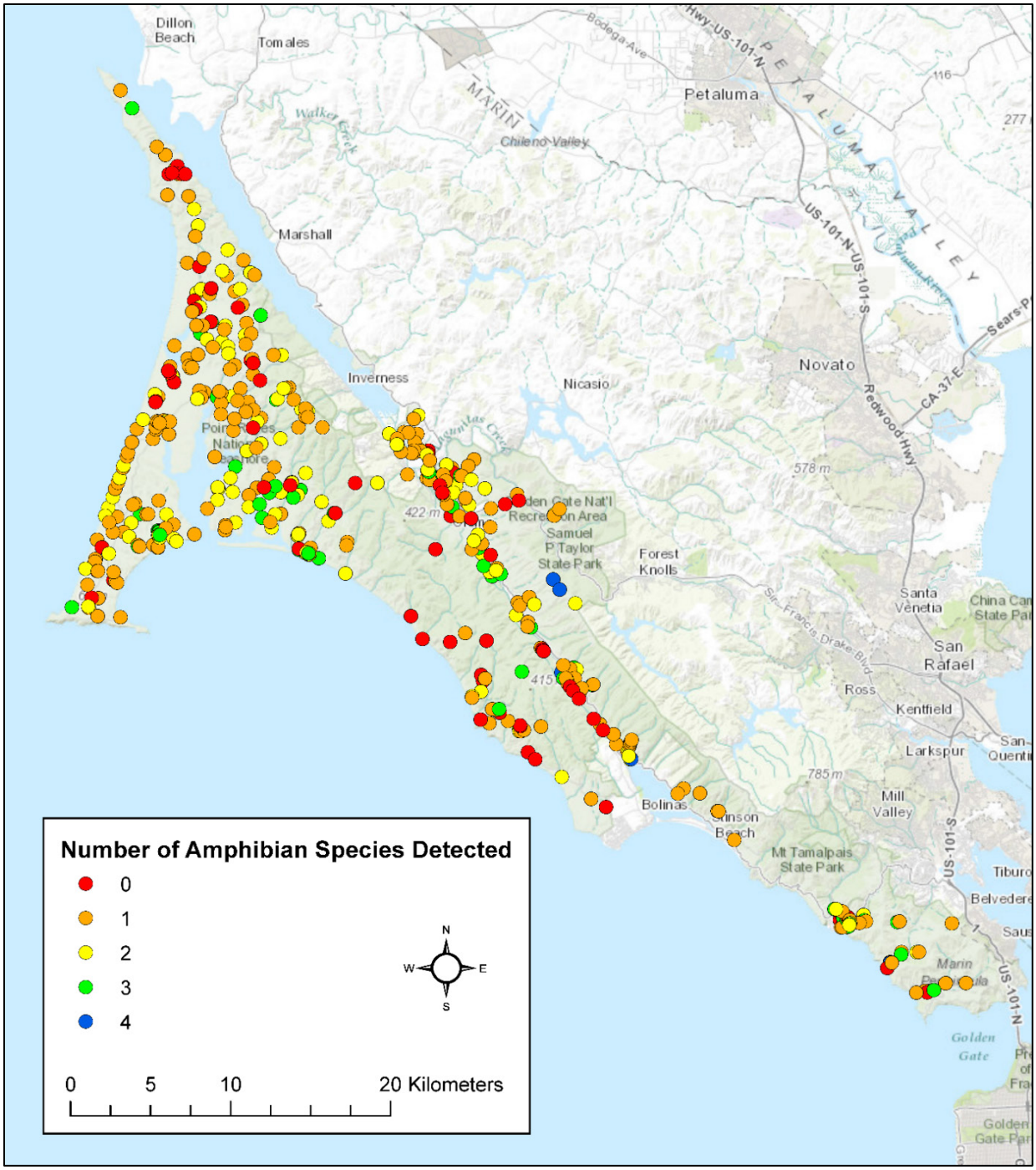


Figure 4.1.9. Spatial distribution of species richness of native amphibians at Point Reyes National Seashore and Golden Gate National Recreation Area in Marin County, California, 1993–2014 (NPS unpub. Data 2015; USGS unpub. Data 2015).

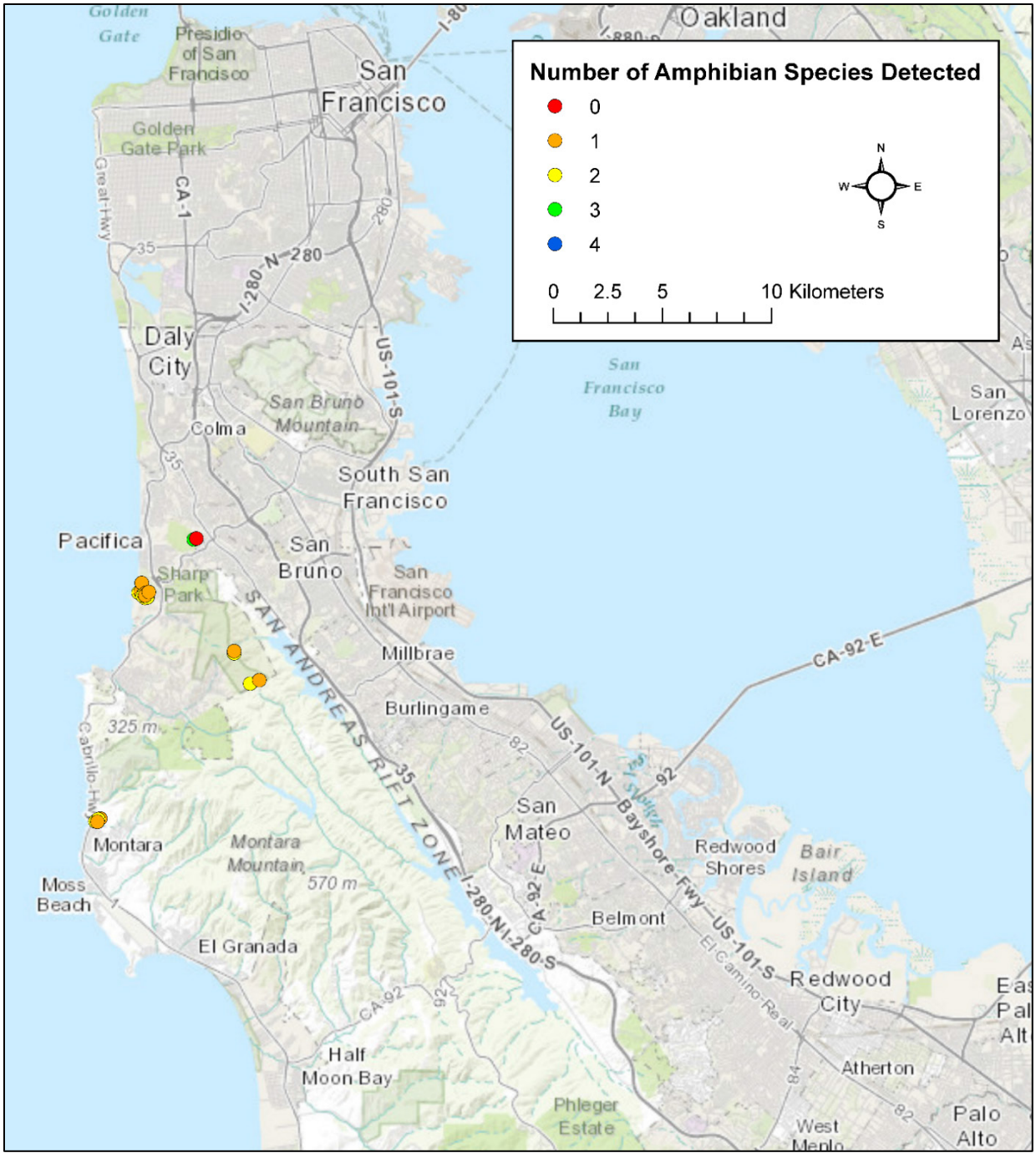


Figure 4.1.10. Spatial distribution of species richness of native amphibians at Golden Gate National Recreation Area in San Mateo County, California, 1993–2014 (NPS unpub. Data 2015; USGS unpub. Data 2015).

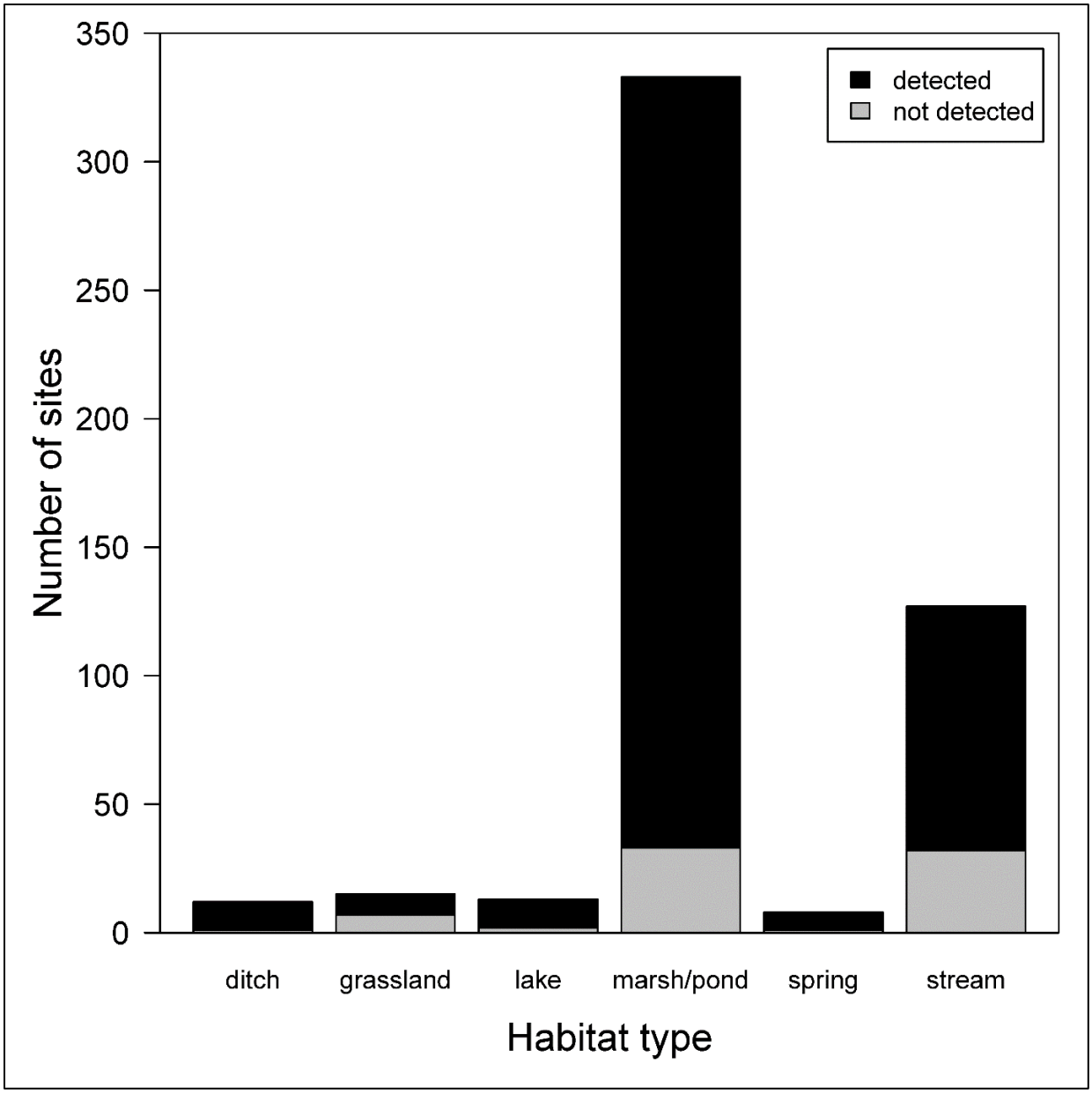


Figure 4.1.11. Distribution of detections of native amphibian species among habitats surveyed at Point Reyes National Seashore and Golden Gate National Recreation Area, 1993–2014 (USGS unpub. Data 2015).

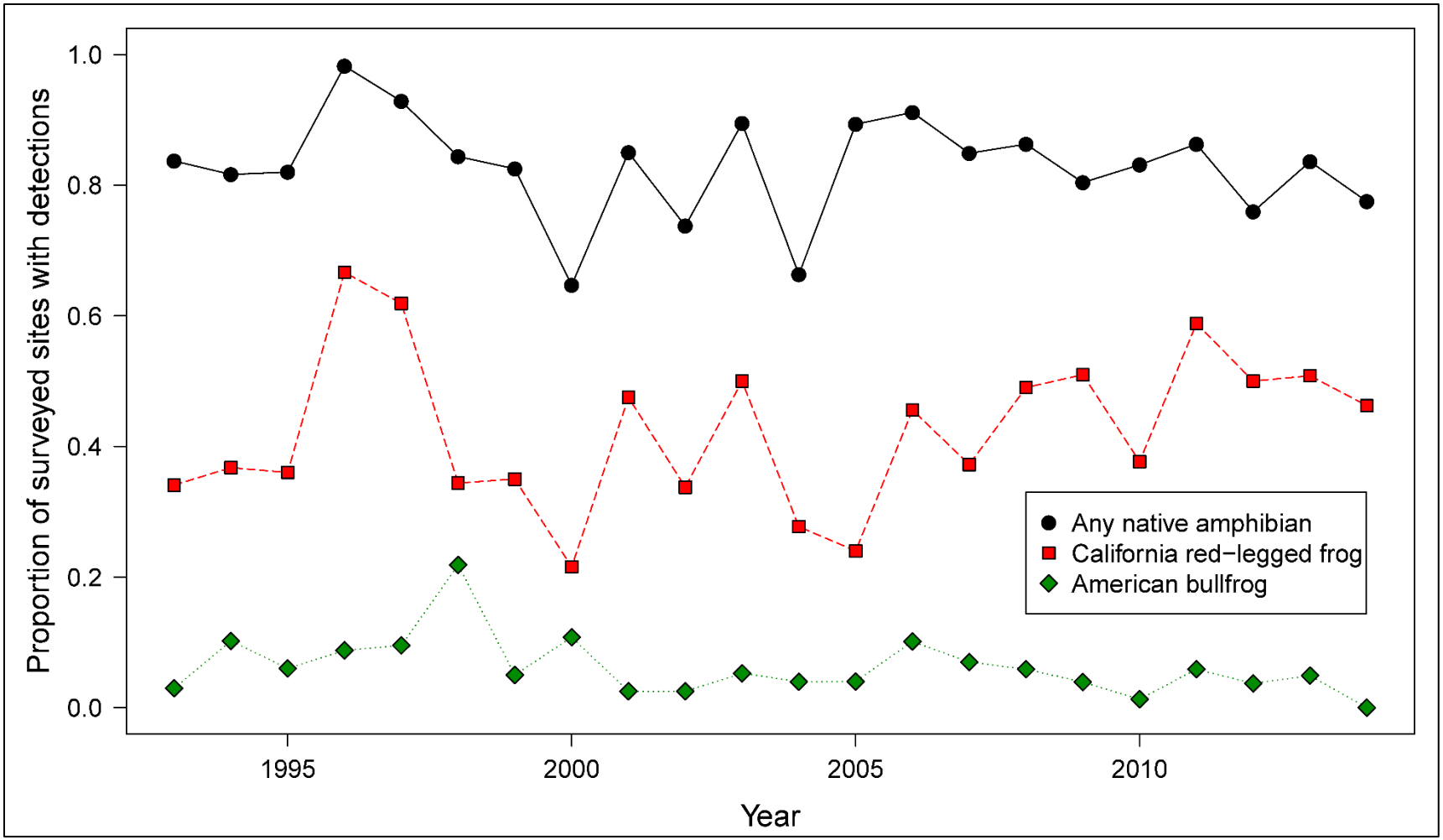


Figure 4.1.12. Annual proportion of surveyed sites with detections of at least one native amphibian species (including California red-legged frogs *Rana draytonii*; black circles), California red-legged frogs (red squares), and American bullfrogs (*Lithobates catesbeianus*; green diamonds) at Point Reyes National Seashore and Golden Gate National Recreation Area, 1993–2014 (NPS unpub. Data 2015; USGS unpub. Data 2015).

California red-legged frogs are the only state- and federally-listed amphibian species at Point Reyes National Seashore and Golden Gate National Recreation area, and have received proportionally greater survey effort and research attention than other amphibian species at these locations. They have been detected in all habitat types surveyed (Table 4.1.2), with the highest proportion of detections (0.74) occurring in marshes or ponds (Fig. 4.1.13). California red-legged frogs are widespread in both Point Reyes National Seashore and Golden Gate National Recreation Area where aquatic breeding habitat occurs (Figs. 4.1.14 and 4.1.15). The probability of detecting California red-legged frogs at surveyed sites varied among years, with a mean detection rate of 0.43 (range = 0.22–0.67; Table 4.1.1, Fig. 4.1.12). Although no trend is apparent in these data, recent breeding habitat restoration and construction efforts for California red-legged frogs have occurred at both Point Reyes National Seashore and Golden Gate National Recreation Area. For example, California red-legged frogs were extirpated from Redwood Creek watershed, but habitat restoration and reintroduction efforts were successful, and many mitigation wetlands also have been successful (confirmed breeding of California red-legged frogs; D. Hatch, personal communication 2014). Habitat enhancements at Banducci Pond, Muir Beach Lagoon expansion, Mori Point ponds, and Rancho Corral de Tierra likely have resulted in net gains in the number of breeding sites at Golden Gate National Recreation Area relative to losses at the Bolinas-Fairfax breeding site (D. Fong, personal communication 2014).

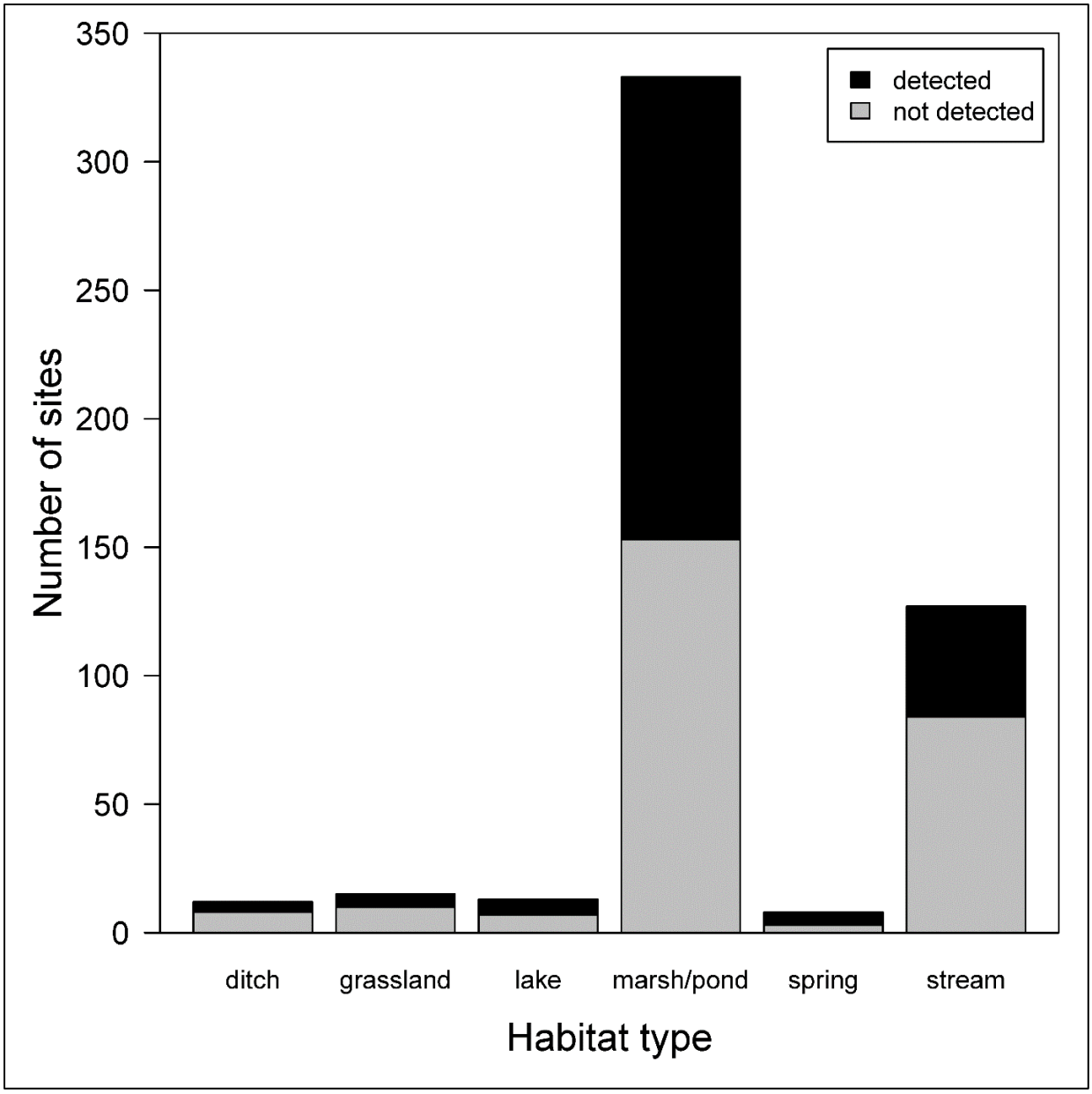


Figure 4.1.13. Proportion of sites at which California red-legged frog (*Rana draytonii*) were detected at Point Reyes National Seashore and Golden Gate National Recreation Area, 1993–2015, by habitat type (NPS unpub. Data 2015; USGS unpub. Data 2015).

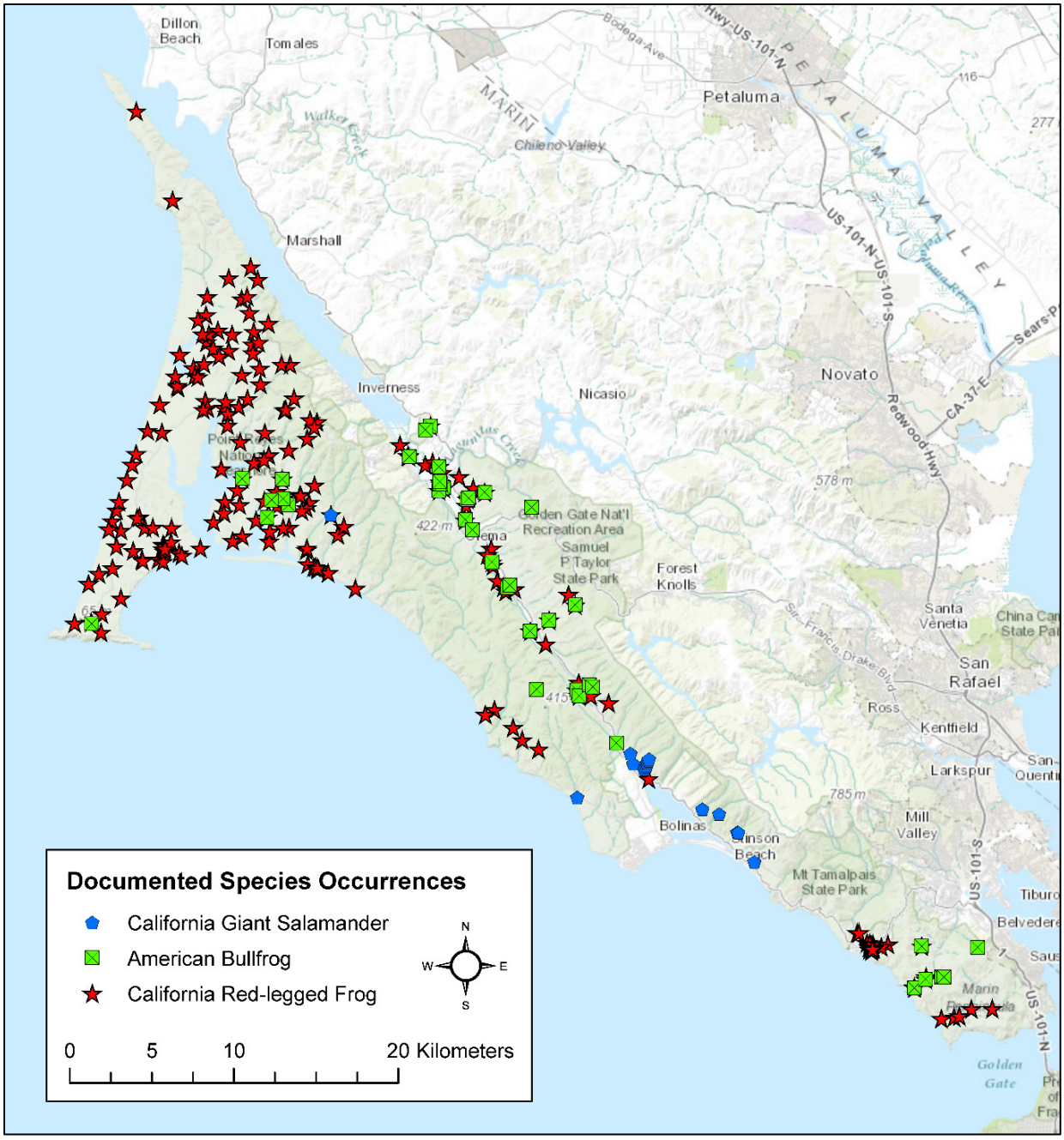


Figure 4.1.14. Spatial distribution of detections of California red-legged frogs (*Rana draytonii*; red stars), American bullfrogs (*Lithobates catesbeianus*; green squares), and California giant salamanders (*Dicamptodon ensatus*; blue pentagons) at Point Reyes National Seashore and Golden Gate National Recreation Area in Marin County, California, 1993–2014. (NPS unpub. Data 2015; USGS unpub. Data 2015).

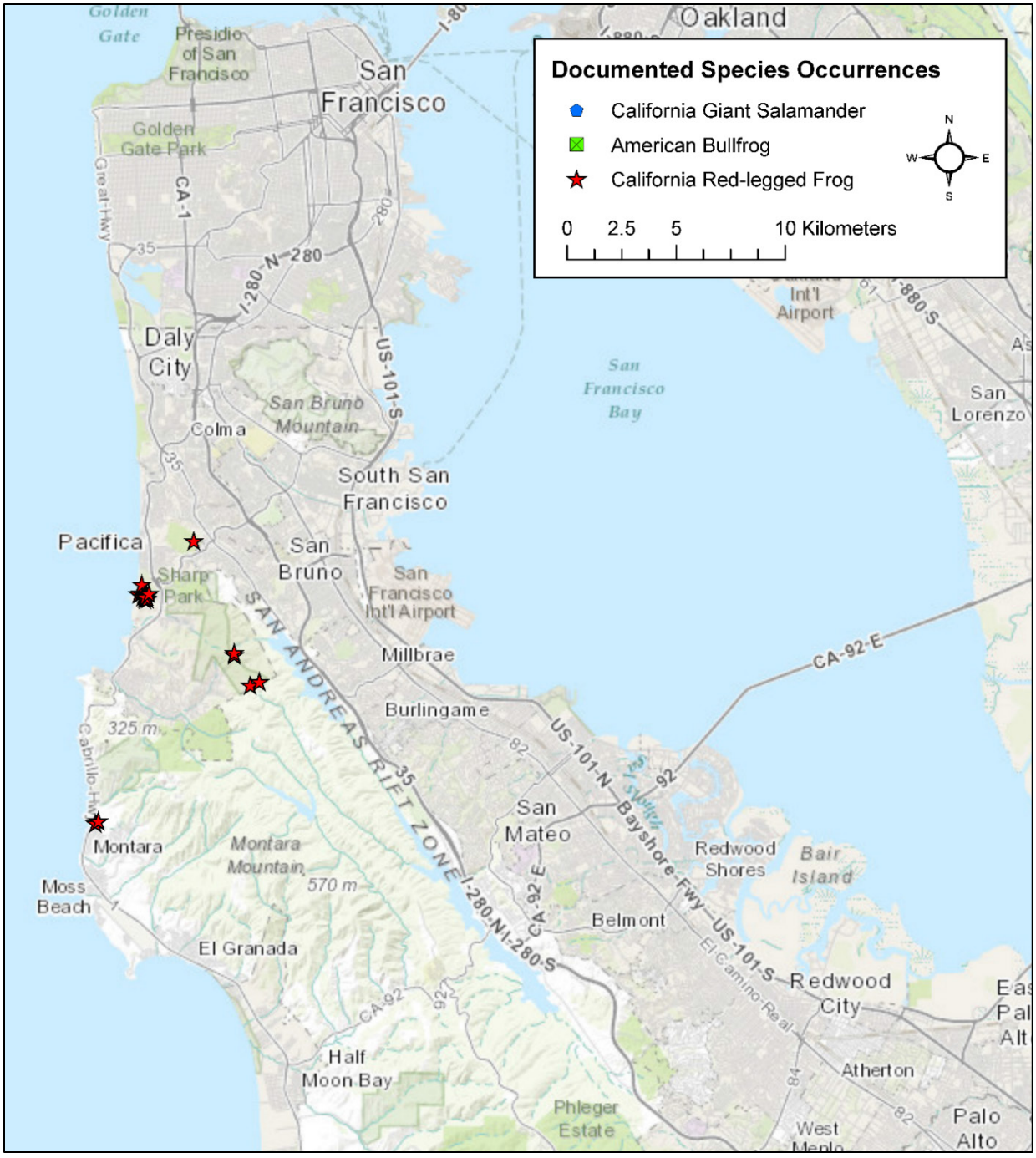


Figure 4.1.15. Spatial distribution of detections of California red-legged frogs (*Rana draytonii*; red stars), American bullfrogs (*Lithobates catesbeianus*; green squares), and California giant salamanders (*Dicamptodon ensatus*; blue pentagons) at Golden Gate National Recreation Area in San Mateo County, California, 1993–2014 (NPS unpub. Data 2015; USGS unpub. Data 2015).

California giant salamanders, in contrast, were only detected in streams, and only in a small proportion (0.13) of this habitat type (Table 4.1.2, Fig. 4.1.16). Nonetheless, California giant salamanders were detected in up to 100% of surveyed streams in a given year (Table 4.1.1). Reliably

detecting California giant salamanders is best done with targeted surveys specifically for this species, so they might have gone undetected in some occupied streams.

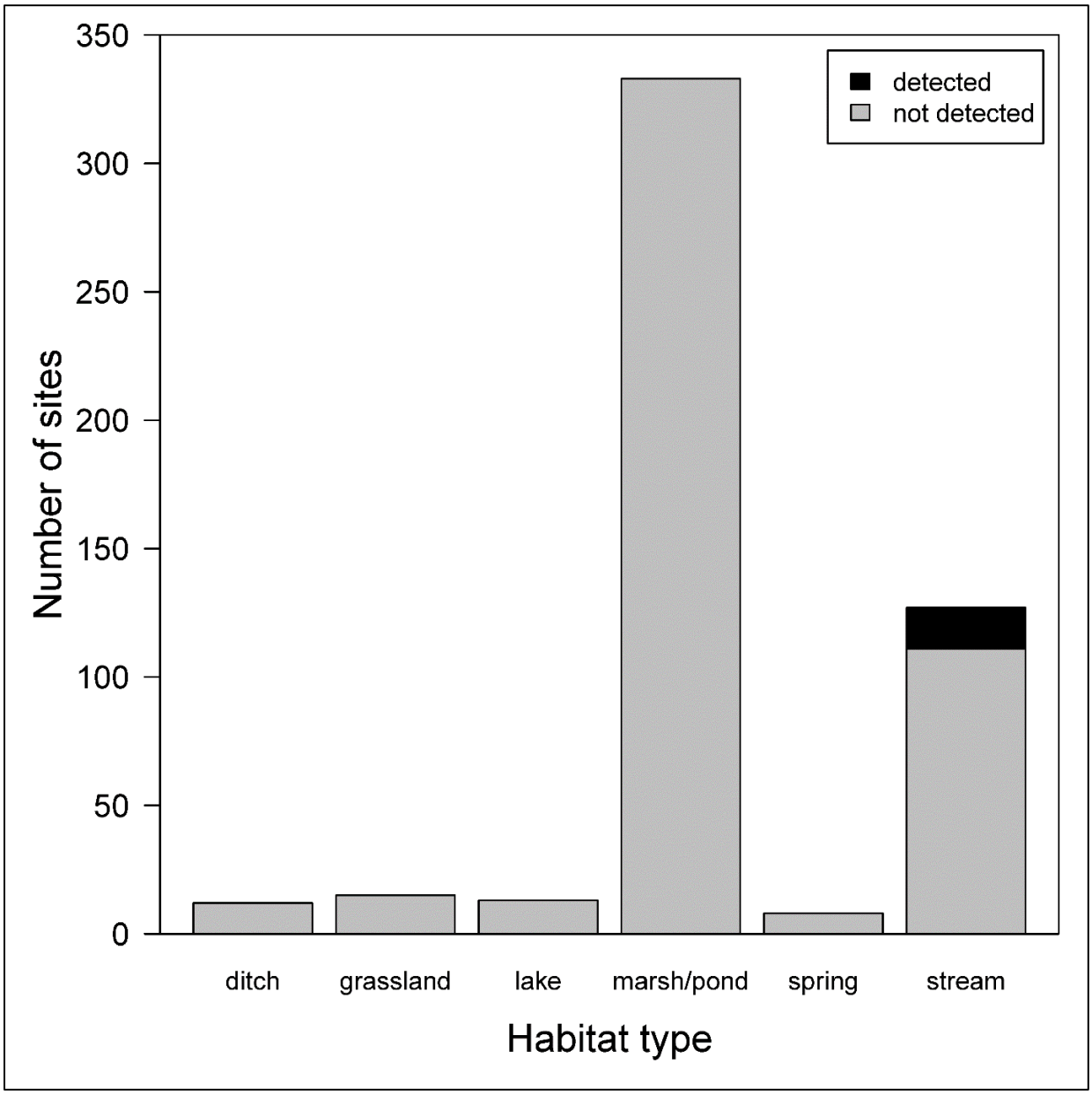


Figure 4.1.16. Proportion of sites at which California giant salamanders (*Dicamptodon ensatus*) were detected at Point Reyes National Seashore and Golden Gate National Recreation Area, 1993–2014, by habitat type (NPS unpub. Data 2015; USGS unpub. Data 2015).

American bullfrogs were the only non-native amphibian detected in surveys conducted by USGS and NPS at Point Reyes National Seashore and Golden Gate National Recreation Area. American bullfrogs were found in aquatic habitat types with longer hydroperiods (lakes, marshes or ponds, and streams; Table 4.1.2), with the highest proportion of detections (0.85) in marshes or ponds (Fig.

4.1.17). The proportion of sites at which American bullfrogs were detected was nearly an order of magnitude less than for California red-legged frogs, however. Most American bullfrog detections occurred in the Olema Valley and Bolinas Ridge, just east of Drakes Estero, and in the Marin Headlands (Figs. 4.1.14 and 4.1.15). The latter populations in the Tennessee Valley have been successfully eradicated (D. Fong, personal communication 2015). The probability of detecting American bullfrogs at surveyed sites varied among years, but was generally low, with a mean detection rate of 0.08 (range = 0.00–0.22; Table 4.1.1, Fig. 4.1.12).

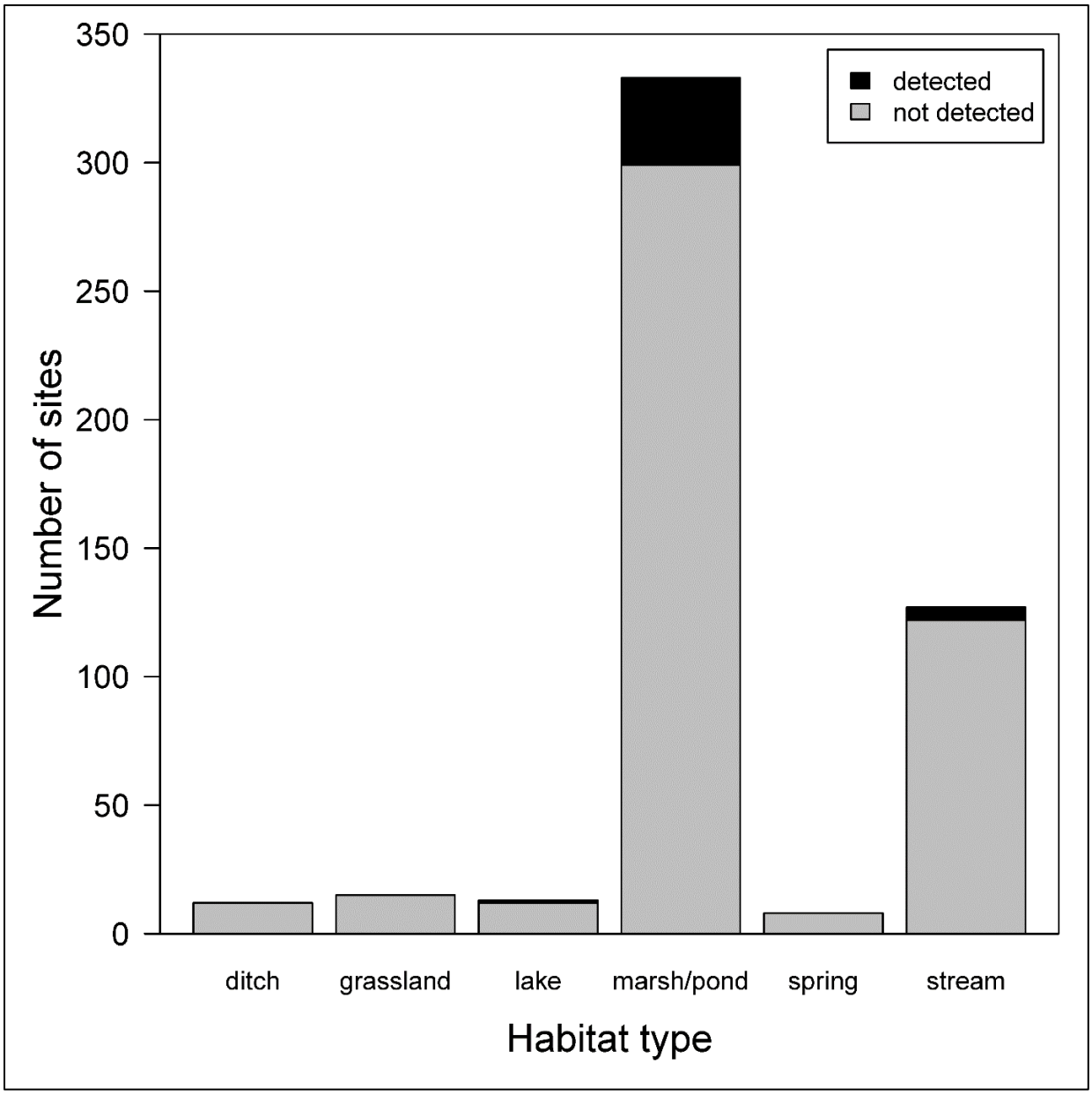


Figure 4.1.17. Proportion of sites at which American bullfrogs (*Lithobates catesbeianus*) were detected at Point Reyes National Seashore and Golden Gate National Recreation Area, 1993–2015, by habitat type (NPS unpub. Data 2015; USGS unpub. Data 2015).

The distribution of non-focal aquatic-breeding amphibians varied widely among species. Sierran treefrogs and rough-skinned newts were generally widespread (Figs. 4.1.18 and 4.1.19). California newts were more restricted in their distribution, and western toads were detected at only four sites (Figs. 4.1.18 and 4.1.19).

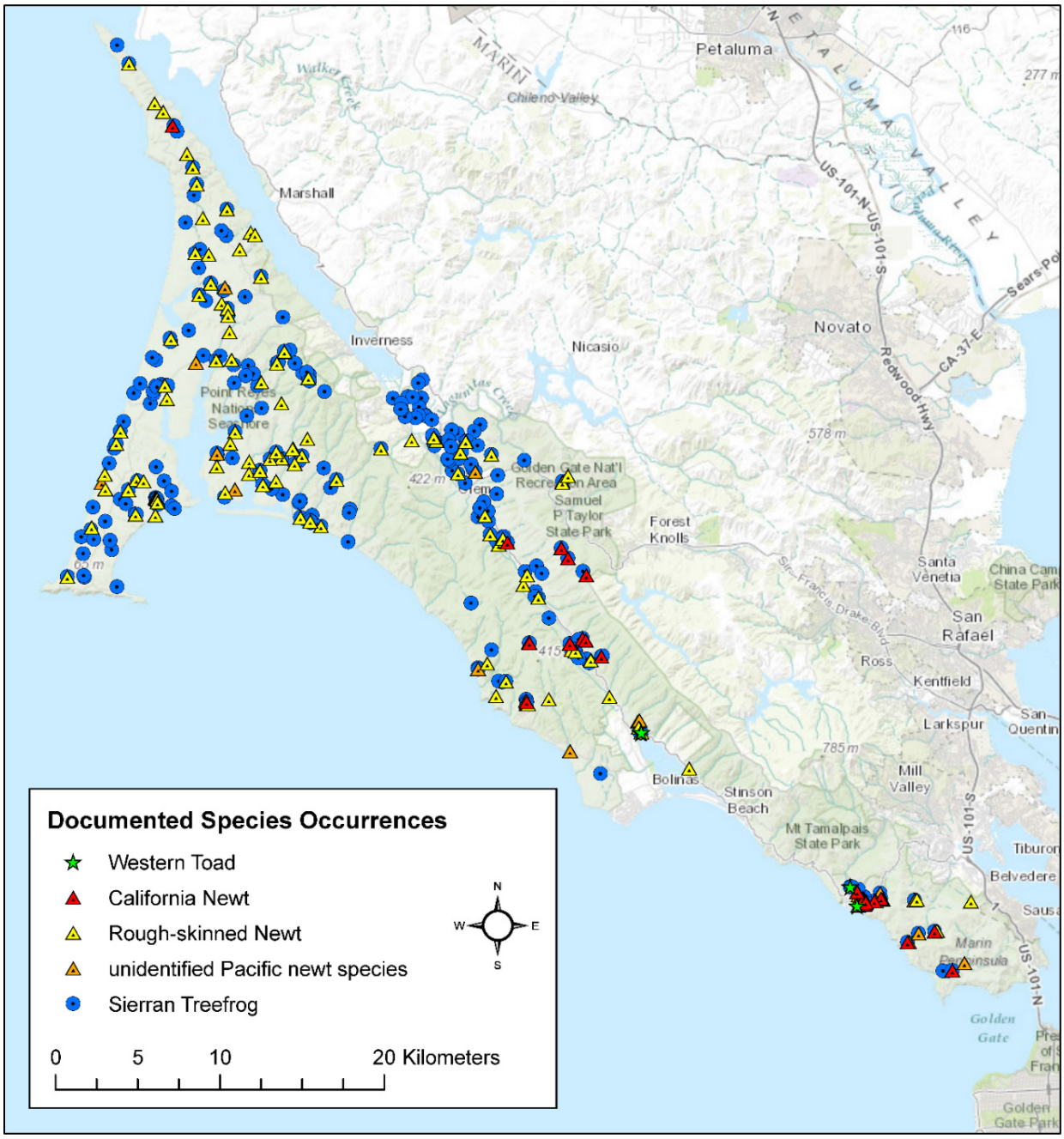


Figure 4.1.18. Spatial distribution of detections of Western toads (*Bufo boreas*; green stars), California newts (*Taricha torosa*; red triangles), rough-skinned newts (*Taricha granulosa*; yellow triangles), unidentified Pacific newts (*Taricha* spp.; orange triangles), and sierran treefrogs (*Pseudacris sierra*; blue circles) at Point Reyes National Seashore and Golden Gate National Recreation Area in Marin County, California, 1993–2014 (NPS unpub. Data 2015; USGS unpub. Data 2015).

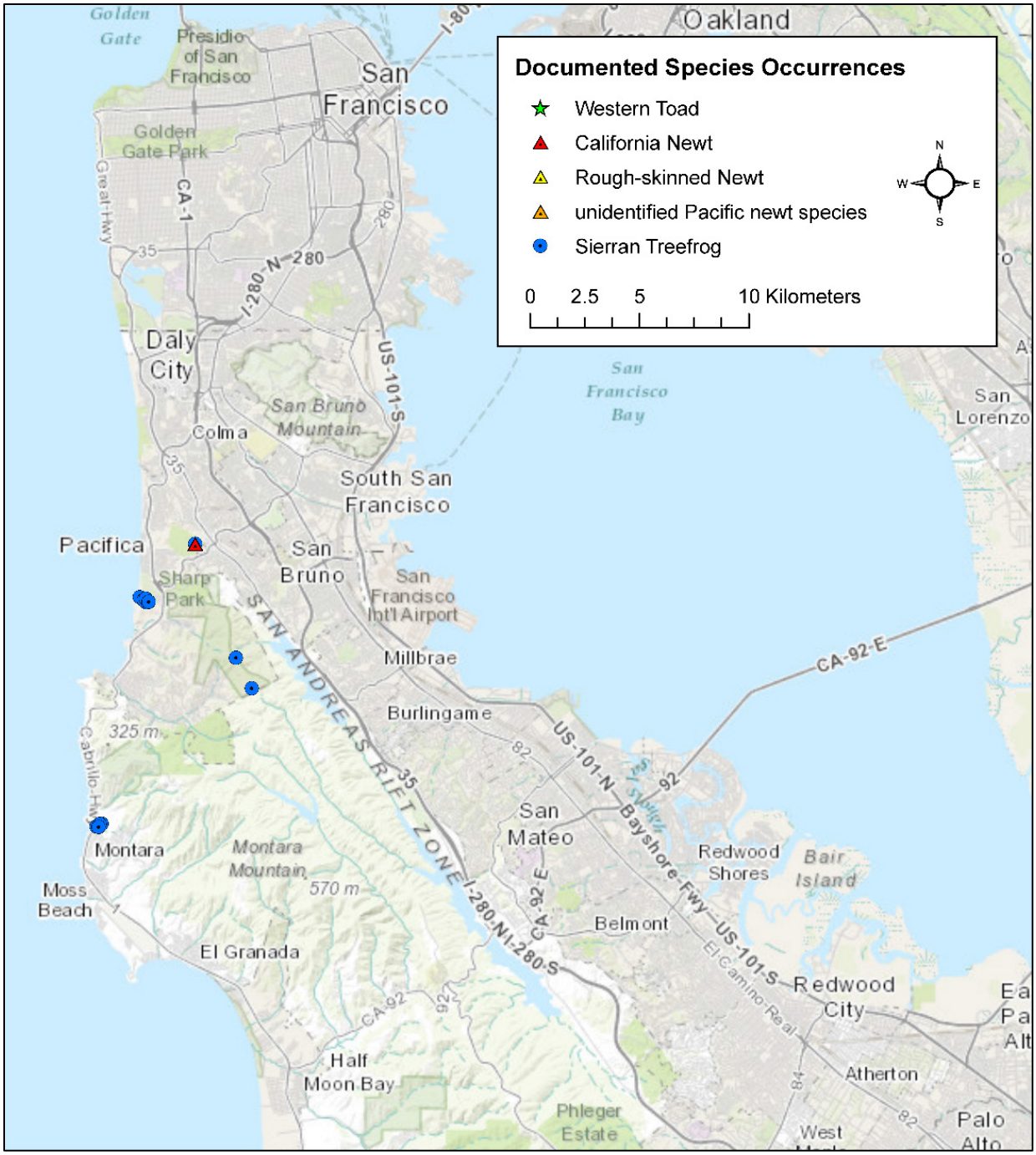


Figure 4.1.19. Spatial distribution of detections of Western toads (*Bufo boreas*; green stars), California newts (*Taricha torosa*; red triangles), rough-skinned newts (*Taricha granulosa*; yellow triangles), unidentified Pacific newts (*Taricha* spp.; orange triangles), and sierran treefrogs (*Pseudacris sierra*; blue circles) at Golden Gate National Recreation Area in San Mateo County, California, 1993–2014 (NPS unpub. Data 2015; USGS unpub. Data 2015).

Rough-skinned newts and western toads were not recorded in surveys in San Mateo County (Figs. 4.1.18 and 4.1.19). Foothill yellow-legged frogs (*Rana boylii*), a rocky stream-specialist anuran, was notably absent from all surveys.

Stressors

Many stressors affect amphibian populations worldwide. The most important of these, and their relevance to the status and trends of amphibians at Point Reyes National Seashore and Golden Gate National Recreation Area, are indicated below.

Habitat Loss and Degradation: Prior to European settlement, much of Point Reyes National Seashore and Golden Gate National Recreation Area was forested, and most aquatic breeding habitats consisted of streams and sag ponds, though some depressional marshes likely also occurred. With logging and subsequent agricultural development (primarily grazing), the canopy was opened in many places and numerous livestock watering ponds were constructed by building earthen dams across drainages. This likely resulted in a large increase in the amount of breeding habitat for pond-breeding amphibians (California red-legged frogs, sierran treefrogs, and newts), though some habitat loss and degradation might have occurred for stream-breeding amphibians (notably California giant salamanders) and terrestrial salamanders. Habitat conditions have changed relatively little at the landscape scale since 1993, though individual sites appear, disappear, or change in their suitability as breeding habitat. Currently, ranching and pond maintenance activities have the greatest influence on habitat quantity and quality for pond-breeding amphibians throughout both National Parks in Marin County, with direct Park management activities more influential in San Mateo County. Maintaining stock ponds with some emergent vegetation for cover and egg mass attachment and hydroperiods suitable for native amphibian reproduction (i.e., containing water from winter until August or later) will maintain or improve the quality of these habitats for native pond-breeding amphibians. Ironically, restoration and enhancement activities for anadromous fishes pose a threat to both pond-breeding amphibians (by removing pond habitats) and stream-breeding amphibians (introduction of predators). Another threat to the habitat of stream-breeding amphibians and terrestrial salamanders is illegal water diversions and forest disturbance caused by illegal marijuana cultivation (Bauer et al. 2015). The absence of foothill yellow-legged frogs is likely related to canopy closure in areas with rocky stream habitats, because this species requires relatively rich algal communities, which are dependent upon warmer water temperatures and sunlight, for larval growth and development (Kupferberg 1996, Kupferberg 1997a, Catenazzi and Kupferberg 2013).

Introduced Species: Although American bullfrogs are present in a variety of aquatic habitats at Point Reyes National Seashore and Golden Gate National Recreation Area, they do not appear to be widespread, and they have been detected at a relatively small proportion of sites. Where they do occur, American bullfrog tadpoles can compete with native anuran larvae for resources, and adults can be competitors and predators of native amphibians. Indeed, American bullfrogs have caused the decline and extirpation of California red-legged frogs from many breeding sites throughout their range, including some within the Olema Valley. Nonetheless, no apparent temporal trend in the proportion of surveyed sites at which American bullfrogs were detected is evident. Complete eradication of American bullfrogs is likely infeasible, though in some locations (notably the

Tennessee Valley) American bullfrogs have been successfully eradicated (D. Fong, personal communication 2015). Management of hydroperiods to limit the breeding success of American bullfrogs might be possible in some locations.

In addition to American bullfrogs, other non-native animals also affect amphibians. Introduced fishes prey upon all life stages of amphibians (Gamradt and Kats 1996, Adams et al 2003, Knapp 2005, Knapp et al. 2007) and are present in Point Reyes National Seashore and Golden Gate National Recreation Area. Non-native crayfish also can negatively affect amphibians by eating eggs and small larvae (Gamradt and Kats 1996, Gamradt et al 1997, Kats and Ferrer 2003). Vigilance against the introduction of other non-native species is warranted, especially given the recent report of a non-native Oriental fire-bellied toad (*Bombina orientalis*) at Golden Gate National Recreation Area (K. Swaim, Swaim Biological, Inc., personal communication, 2015).

Non-native plants do not appear to be a major stressor for amphibians at Point Reyes National Seashore or Golden Gate National Recreation Area. Some native species, including *Azolla* spp. (mosquitofern) and *Typha* spp. (cattails), can become overabundant and reduce the quality of breeding sites for pond-breeding amphibians. Vegetation management must be weighed against the potential risk to amphibians posed by mechanical and chemical control of plants.

Disease: The fungus that has caused the decline of many amphibian populations worldwide, *Batrachocytrium dendrobatidis*, or *Bd*, is present at Point Reyes National Seashore (Fellers et al. 2011). Although *Bd* has caused the decline of amphibian species elsewhere in California (Briggs et al. 2005, Vredenburg et al. 2010), it either does not appear to have a substantial effect on California red-legged frogs at Point Reyes National Seashore, or its effects occurred long ago and a new equilibrium state of the frogs and the disease has been achieved (Fellers et al. *In Review*). Other amphibian diseases, including Ranavirus, have also been documented at Point Reyes National Seashore (D. Green, personal communication 2014). At this time, these diseases are not a major cause for concern, but the appearance of novel pathogens is always possible. Indeed, emerging diseases like *Batrachochytrium salamandriasis* (*Bsal*), a chytrid fungus recently introduced to Europe that is causing rapid declines and extirpations of European newts (*Bsal*; Martel et al. 2014), have the potential to decimate amphibian populations if introduced into coastal California. The USGS Point Reyes Field Station, as part of the USGS Amphibian Research and Monitoring Initiative, has already begun surveillance monitoring for *Bsal* at Point Reyes National Seashore and Golden Gate National Recreation Area.

Contaminants: Contaminants have likely caused the decline of many amphibians in California (Sparling et al. 2001, 2015, Davidson 2004), particularly in the Sierra Nevada. The Sierra Nevada are directly downwind of the highly agricultural Central Valley, and many pesticides are transported by the wind to the Sierra Nevada (Davidson 2004, Sparling et al. 2015). Cattle grazing occurs at Point Reyes National Seashore and Golden Gate National Recreation Area, but widespread application of herbicides and pesticides to crops does not currently occur at either site. Effects of past applications of chemicals on the current status and distribution of amphibians at Point Reyes National Seashore and Golden Gate National Recreation Area are not known. Local application of chemicals to control invasive plants does occur, but application of chemicals follows guidelines designed to minimize

effects of chemicals on California red-legged frogs. The effects of the applications of pesticides on amphibians at Point Reyes National Seashore and Golden Gate National Recreation Area are therefore likely to be minimal and highly localized to the proximity of the area of application. Another potential source of contaminants is illegal marijuana cultivation.

Overharvest: With the exception of scientific collection for permitted research activities, amphibians are protected from collection at Point Reyes National Seashore and Golden Gate National Recreation Area. Therefore, overharvest does not currently pose a threat to amphibians in these locations. Past collecting of some species for food or other uses, however, might have caused historical declines of some species.

Level of confidence in assessment

Confidence in the assessment of pond-breeding amphibians is high. Native pond-breeding species are common and widespread. Confidence in the assessment of stream-breeding amphibians, particularly California giant salamanders, is much lower. Survey efforts must be targeted toward this species, so general amphibian visual encounter surveys, which comprise the majority of surveys, likely miss this species. Terrestrial salamanders also require targeted surveys specifically for these taxa, and were therefore not included in this assessment. The status and trends of salamanders at Point Reyes National Seashore and Golden Gate National Recreation Area remain uncertain.

This assessment was primarily based upon visual encounter surveys conducted at amphibian breeding habitats. It is always possible that a species that occurs at a site is unobserved during such surveys. Modern study design and statistical methods can account for imperfect detectability through the use of occupancy models (MacKenzie et al. 2002, 2006, Tyre et al. 2003, Bailey et al. 2004, Thompson et al. 2004). Because much of the data used in this assessment was collected prior to the development of these occupancy models, we did not attempt to correct the data for imperfect detectability. This has two potential consequences for our findings: 1) our estimates of the proportion of sites at which detections of native amphibians or focal species occurred could be less than the proportion of sites actually occupied, and 2) this difference between detections and occurrences could be greater under some conditions than others, particularly if some habitats have a high probability of occurrence, but a low probability of detection. In general, detection probabilities for most pond-breeding amphibians with visual encounter surveys is high and our findings are only slightly biased. For more difficult-to-detect species, including California giant salamanders, the probability of occurrence could be much higher than the proportion of sites with detections reported here.

This assessment also used detection of a species as the metric of interest. Underlying changes in abundance can occur with no changes in whether a species was detected at a site. Thus, stability in proportion of sites at which detections occur does not necessarily mean that abundance is stable at individual sites or throughout the study areas.

Gaps in understanding

Although much is known about the status of amphibians at Point Reyes National Seashore and Golden Gate National Recreation Area, many data gaps remain. These include:

- The status and distribution of California giant salamanders,
- The status and distribution of terrestrial salamanders with direct development,
- Variables that affect the probability of occurrence and diversity of pond-breeding amphibians
- Assessment of abundance and demography of any amphibians (with the exception of one well-studied California red-legged frog population), and
- Variables that affect the abundance and vital rates (survival, recruitment, population growth rate) of focal species.

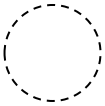
The monitoring targets and questions recommended by the San Francisco Bay Area Network Amphibian and Reptile Monitoring Workshop (Denn 2006) remain relevant, and we support the recommendations made in that document. Future amphibian monitoring and research worth emphasizing includes:

- Assessing the distribution and probability of occurrence of pond-breeding amphibians, stream-breeding amphibians, and terrestrial salamanders.
- Establishing additional abundance monitoring sites for California red-legged frogs, with selection of sites designed to assess the effects of potential stressors.
- Conducting directed research into the effects of specific stressors on species of interest, particularly for those stressors for which management actions can be taken.
- Implementing methods that quantify and account for imperfect detectability in all future research and monitoring efforts.

Condition Summary

This assessment revealed that much survey effort for amphibians in aquatic breeding habitats has occurred throughout most of Point Reyes National Seashore and Golden Gate National Recreation Area. Although spatially widespread, most sites were visited few times. Native pond-breeding amphibians appear widespread, with no apparent trends in the proportion of sites at which detections occurred. Thus, pond-breeding amphibian distribution appears stable. Little information about stream-breeding salamanders or terrestrial salamanders with direct development existed, and these species warrant further investigation into their distribution and habitat relationships (Table 4.1.3). Continued research into the distribution, population and occupancy dynamics, and effects of stressors and management practices on amphibian species will improve conservation efforts for these species at Point Reyes National Seashore and Golden Gate National Recreation Area.

Table 4.1.3. Resource Condition Summary for Amphibians.

Indicators of Condition	Specific Measures	Condition Status	Rationale
Understanding of Status	Spatial distribution of survey effort		Survey effort has been distributed over a large area
	Temporal distribution of survey effort		Most sites surveyed five or fewer times in past 20 years
Amphibian Diversity	Species richness of native amphibians		# of native amphibian species detected indicates diversity of habitats sampled, rather than changes in species richness
Occurrence of Focal Species	Detections/non-detections of California red-legged frogs		California red-legged frogs widespread in multiple habitats
	Detections/non-detections of California giant salamanders		Too few surveys targeted for California giant salamanders have occurred to assess status or trend
	Detections/non-detections of American bullfrogs		American bullfrogs are present and negatively affect native species, but they are limited to a relatively small proportion of sites
Overall Condition Status and Trend for Amphibians			**Pond-breeding amphibians are widespread, but little is known about stream-breeding amphibians or terrestrial salamanders.**

4.1.4. Information Sources

Sources of Expertise

The work of Dr. Gary Fellers was vital to this assessment, and was the primary source of information used herein. Without his substantial efforts and unparalleled expertise, this assessment would not have been possible.

Literature Cited

Adams, M. J., C. A. Pearl, and R. Bruce Bury. 2003. Indirect facilitation of an anuran invasion by non-native fishes. Ecology Letters 6:343–351.

Bailey, L. L., T. R. Simons, and K. H. Pollock. 2004. Estimating site occupancy and species detection probability parameters for terrestrial salamanders. Ecological Applications 14:692–702.

Bauer, S., J. Olson, A. Cockrill, M. van Hattem, L. Miller, M. Tauzer, and G. Leppig. 2015. Impacts of surface water diversions for marijuana cultivation on aquatic habitat in four northwestern California watersheds. PLoS ONE 10:e0120016.

Blaustein, A. R., and D. B. Wake. 1990. Declining amphibian populations: A global phenomenon? Trends in Ecology & Evolution 5:203–204.

Briggs, C. J., V. T. Vredenburg, R. A. Knapp, and L. J. Rachowicz. 2005. Investigating the population-level effects of chytridiomycosis: An emerging infectuous disease of amphibians. Ecology 86:3149–3159.

Catenazzi, A., and S. J. Kupferberg. 2013. The importance of thermal conditions to recruitment success in stream-breeding frog populations distributed across a productivity gradient. Biological Conservation 168:40–48.

Cushman, S. A. 2006. Effects of habitat loss and fragmentation on amphibians: A review and prospectus. Biological Conservation 128:231–240.

Davidson, C. 2004. Declining downwind: Amphibian population declines in California and historical pesticide use. Ecological Applications 14:1892–1902.

Denn, C. M. 2006. San Francisco Bay Area Network Amphibian and Reptile Monitoring Workshop. San Francisco, California, USA.

Doubledee, R. A., E. B. Muller, and R. M. Nisbet. 2003. Bullfrogs, disturbance regimes, and the persistence of California red-legged frogs. Journal of Wildlife Management 67:424–438.

Fellers, G. M., R. A. Cole, D. M. Reinitz, and P. M. Kleeman. 2011. Amphibian chytrid fungus (*Batrachochytrium dendrobatidis*) in coastal and montane California, USA anurans. Herpetological Conservation and Biology 6:383–394.

Gamradt, S. C., and L. B. Kats. 1996. Effect of introduced crayfish and mosquitofish on California newts. Conservation Biology 10:1155–1162.

Gamradt, S. C., L. B. Kats, and C. B. Anzalone. 1997. Aggression by non-native crayfish deters breeding in California newts. Conservation Biology 11:793–796.

Harper, E. B., T. A. G. Rittenhouse, and R. D. Semlitsch. 2008. Demographic consequences of terrestrial habitat loss for pool-breeding amphibians: predicting extinction risks associated with inadequate size of buffer zones. Conservation Biology 22:1205–1215.

Kats, L. B., and R. P. Ferrer. 2003. Alien predators and amphibian declines: review of two decades of science and the transition to conservation. Diversity and Distributions 9:99–110.

Knapp, R. A. 2005. Effects of nonnative fish and habitat characteristics on lentic herpetofauna in Yosemite National Park, USA. Biological Conservation 121:265–279.

Knapp, R. A., D. M. Boiano, and V. T. Vredenburg. 2007. Removal of nonnative fish results in population expansion of a declining amphibian (mountain yellow-legged frog, *Rana muscosa*). Biological Conservation 135:11–20.

Kupferberg, S. J. 1996. Hydrologic and geomorphic factors affecting conservation of a river-breeding frog (*Rana boylii*). Ecological Applications 6:1332–1344.

Kupferberg, S. J. 1997a. Bullfrog (*Rana catesbeiana*) invasion of a California river: The role of larval competition. Ecology 78:1736–1751.

Kupferberg, S. J. 1997b. The role of larval diet in anuran metamorphosis. Integrative and Comparative Biology 37:146–159.

Lehtinen, R. M., S. M. Galatowitsch, and J. R. Tester. 1999. Consequences of habitat loss and fragmentation for wetland amphibian assemblages. Wetlands 19:1–12.

MacKenzie, D. I., J. D. Nichols, G. B. Lachman, S. Droege, J. A. Royle, and C. A. Langtimm. 2002. Estimating site occupancy rates when detection probabilities are less than one. Ecology 83:2248–2255.

MacKenzie, D. I., J. D. Nichols, J. A. Royle, K. H. Pollock, L. L. Bailey, and J. E. Hines. 2006. Occupancy Estimation and Modeling: Inferring Patterns and Dynamics of Species Occurrence. Academic Press, Amsterdam, The Netherlands.

Martel, A., M. Blooi, C. Adriaensen, P. Van Rooij, W. Beukema, M. C. Fisher, R. A. Farrer, B. R. Schmidt, U. Tobler, K. Goka, K. R. Lips, C. Muletz, K. R. Zamudio, J. Bosch, S. Lotters, E. Wombwell, T. W. J. Garner, A. A. Cunningham, A. Spitzen-van der Sluijs, S. Salvidio, R. Ducatelle, K. Nishikawa, T. T. Nguyen, J. E. Kolby, I. Van Bocxlaer, F. Bossuyt, and F. Pasmans. 2014. Recent introduction of a chytrid fungus endangers Western Palearctic salamanders. Science 346:630–631.

Moyle, P. B. 1973. Effects of introduced bullfrogs, Rana catesbeiana, on the native frogs of the San Joaquin Valley, California. Copeia 1973:18–22.

Pearl, C. A., M. J. Adams, R. B. Bury, and B. McCreary. 2004. Asymmetrical effects of introduced bullfrogs (*Rana catesbeiana*) on native ranid frogs in Oregon. Copeia 2004:11–20.

Sparling, D. W., J. Bickham, D. Cowman, G. M. Fellers, T. Lacher, C. W. Matson, and L. McConnell. 2015. In situ effects of pesticides on amphibians in the Sierra Nevada. Ecotoxicology 24:262–278.

Sparling, D. W., and G. Fellers. 2007. Comparative toxicity of chlorpyrifos, diazinon, malathion and their oxon derivatives to larval *Rana boylii*. Environmental Pollution 147:535–539.

Sparling, D. W., G. M. Fellers, and L. L. McConnell. 2001. Pesticides and amphibian population declines in California, USA. Environmental Toxicology and Chemistry 20:1591–1595.

Stuart, S. N., J. S. Chanson, N. A. Cox, B. E. Young, A. S. L. Rodrigues, D. L. Fischman, and R. W. Waller. 2004. Status and trends of amphibian declines and extinctions worldwide. Science 306:1783–1786.

Thompson, W. L., D. I. MacKenzie, J. A. Royle, J. A. Brown, J. D. Nichols, and W. L. Thompson. 2004. Occupancy estimation and modeling for rare and elusive populations. Pages 149–172 *in* W. L. Thompson, editor. Sampling Rare or Elusive Populations: Concepts, Designs, and Techniques for Estimating Population Parameters. Island Press, Washington, D.C., USA.

Tyre, A. J., B. Tenhumberg, S. A. Field, D. Niejalke, K. Parris, and H. P. Possingham. 2003. Improving precision and reducing bias in biological surveys: Estimating false-negative error rates. Ecological Applications 13:1790–1801.

Vredenburg, V. T. 2004. Reversing introduced species effects: Experimental removal of introduced fish leads to rapid recovery of a declining frog. Proceedings of the National Academy of Sciences of the United States of America 101:7646–7650.

Vredenburg, V. T., R. A. Knapp, T. S. Tunstall, and C. J. Briggs. 2010. Dynamics of an emerging disease drive large-scale amphibian population extinctions. Proceedings of the National Academy of Sciences of the United States of America 107:9689–9694.

Wake, D. B. 1991. Declining amphibian populations. Science 253:860.

Wake, D. B. 2012. Facing extinction in real time. Science 335:1052–1053.

Wake, D. B., and V. T. Vredenburg. 2008. Are we in the midst of the sixth mass extinction? A view from the world of amphibians. Proceedings of the National Academy of Sciences of the United States of America 105 Suppl: 11466–11473.

Welsh, H. H., and L. M. Ollivier. 1998. Stream amphibians as indicators of environmental stress: A case study from California's redwoods. Ecological Applications 8:1118–1132.

4.2. Breeding Landbird Diversity

The landbird resource for GOGA is in good condition and is unchanging based on an overview of riparian habitat species population trends. However, there is a low confidence in the assessment because of the limited number of habitats where trends are available.



4.2.1. Why Focal Resource Was Assessed

The National Park Service San Francisco Bay Area Network has chosen to assess the condition of landbirds as a focal resource that is important because of its ecological integrity and substantial public interest (NPS 2015). Landbirds can be important indicators of ecosystem health (Carignan and Villard 2002, Chase and Geupel 2005) and changing ecological conditions like climate and development intensity (Gardali et al. 2012, Jongsomjit et al. 2013). Long-term monitoring can allow both baseline inventory as well as population trends over time and give managers the necessary information for adaptive management.

National parks are important comparison sites for landbird population trends because they are more insulated from local changes in land use yet are still responsive to global issues like climate change (Siegel et al. 2010). Several landbird species that occur regularly in Golden Gate National Recreation Area (GOGA) and Point Reyes National Seashore (PORE) are State Species of Special Concern (Shuford and Gardali 2008) or California Partners in Flight Focal Species (http://www.prbo.org/calpif/plans.html). This chapter provides a synthesis of literature and an analysis of the condition of landbirds in PORE and GOGA. It does not include any new analysis or modelling of data and does not include birds of prey. The reports and publications reviewed in this chapter combine surveys in PORE and GOGA for analysis and interpretation. This chapter on landbird condition assessment therefore also combines the two parks for the summary of information.

Both GOGA and PORE have a long-history of landbird monitoring and analysis by Point Blue Conservation Science (Point Blue; formerly Point Reyes Bird Observatory or PRBO). Point Blue has reported and published extensively on various aspects of landbird ecology including: natural history, long-term population trends and predictive models for climate change. These datasets are also used to prioritize management for habitat restoration and invasive plant removal. Point Blue has compared the park data with larger regional datasets to assess trends across California. This chapter will be a synthesis of their findings.

Description

The Landbird Focal Resource Condition Assessment consists of a review of reports and publications from Point Blue to create a synthesis of information available. This assessment summarizes available bird population trends for GOGA and PORE by general vegetation types or bird community habitats. The following general vegetation categories are used to assess bird communities: coniferous forest, grassland, hardwood, oak woodland, riparian, scrub, and wetland (Flannery et al. 2001, Stralberg and Gardali 2007).

Because of their high diversity, and overall distribution within GOGA and PORE, riparian landbirds were chosen as one of the vital signs indicators for the Inventory and Monitoring Program at GOGA and PORE (Gardali et al. 2010). Riparian habitat was chosen as a focus for long-term landbird monitoring because of its high level of mean species diversity and richness, broader ecosystem function, and widespread distribution within GOGA and PORE (Flannery et al. 2001, Gardali et al. 2010, NPS 2014). Based on this decision, Point Blue has recently focused on riparian species for analysis and publications as well as population analysis including riparian species trends over 1997–2011 (Humple and Porzig 2012). Point Blue also conducts long-term monitoring outside of riparian habitat, e.g. at the Palomarin Field Station in PORE, although vegetation change in this area complicates species trend information (Porzig et al. 2014).

Riparian species trend analysis includes both GOGA and PORE surveys, as well as surveys from an adjacent public landowner in Marin County, Marin County Open Space District (MCOSD). General condition assessment for breeding landbird populations uses the comparison with the California and Coastal California regions of the Breeding Bird Survey dataset where possible (Humple and Porzig 2012, Sauer et al. 2014). The chapter synthesis will focus on the following questions:

Critical Questions

- What is the current condition of the landbird resource in GOGA/PORE? Where possible how do GOGA/PORE landbird species populations compare to similar bird communities elsewhere in Marin County and in California?
- How will climate change affect habitat-specific focal species or declining species within GOGA/PORE?
- How are invasive avian and plant species influencing the condition of landbird populations in GOGA/PORE?
- What are the critical data and knowledge gaps necessary to indicate the condition of landbird populations in GOGA/PORE?

4.2.2. How Focal Resource Was Assessed

Measures

- GOGA/PORE riparian breeding focal species population trends
- Breeding Bird Survey species population trends from California and Coastal California regions (Table 4.2.1)

Data Sources and Methods

Literature review of GOGA and PORE internal reports by Point Blue and peer-reviewed journal publications. No new data analyses were conducted.

Reference Conditions/Values

The reference condition for landbird abundance within GOGA/PORE is the California region Breeding Bird Survey species population trends within Table 4.2.1. The California region Breeding Bird Survey species population trends were presented within the internal NPS report by Humple and

Porzig (2012). These trends have been updated using Breeding Bird Survey data (1966–2013), and Coastal California trends were added from Sauer et al. 2014.

4.2.3. Condition Assessment

Condition and Trend

The landbird condition was assessed with the overall trend pattern for species that are common throughout both parks.

GOGA/PORE population trends

This summary of Humple and Porzig's (2012) findings and Table 4.2.1 was limited to species that have statistically significant population trends or are common riparian species within GOGA/PORE. Humple and Porzig's (2012) analyses included in the chapter are trends for species abundance using breeding season point count data (1997–2011) and trends in capture rate using breeding, fall and winter season mist-netting data (2002–2011). The trends were calculated using a combined dataset from locations within GOGA and PORE. Other reported population trends included in this summary indicate the location of data used and show a trend for a different time period.

Riparian habitat was chosen as a focus for long-term landbird monitoring because of its high level of mean species diversity and richness, broad ecosystem function, and widespread distribution within GOGA and PORE (Flannery et al. 2001, Gardali et al. 2010, NPS 2014). Humple and Porzig (2012) found that overall the riparian focal species abundance trend was generally stable over the last 11 to 15 years. There were a few species that showed a significant decrease or increase in population (Table 4.2.1), therefore the majority of riparian species trends were neutral (close to zero) or not significant. There was no obvious evidence for the mechanism behind the trends based on life history information for these species. In other words, the species with significant trends did not have similar ranges of habitat, food preferences, or migratory status (e.g. resident, winter resident, Neotropical migrant).

Breeding season trends

Looking at the summary table (Table 4.2.1), Orange-crowned Warbler (*Oreothlypis celata*), Wilson's Warbler (*Cardellina pusilla*) and Purple Finch (*Haemorhous purpureus*) had either a statistically significant increasing abundance trend or were stable with approximately zero abundance trend. The California-wide BBS trend data, showed a declining population trend for all three species, however the more local Coastal California BBS trend data showed that Wilson's Warbler and Purple Finch both had non-significant trends in this region (Sauer et al. 2014). The breeding season capture rate (mist net data) supports a positive abundance trend for Wilson's Warbler and Purple Finch and is significant (Humple and Porzig 2012).

Table 4.2.1. Trends in riparian focal species abundance 1997–2011 for GOGA, PORE, and Marin County Open Space District (MCOSD) and California and Coastal California region Breeding Bird Survey results for 1996–2013 using point count survey data. “Five Core Transects” trends used less transects but all years; “All Transects” trends used all existing transects but included only the years 1997, 1998, and 2011. The “slope” column indicates whether the trend was positive or negative. Table adapted from Humple and Porzig (2012) Table 4, page 12.

	Five Core Transects (All Years)		All Transects (1997, 1998, 2011)		BBS CA (1966–2013)	BBS Coastal CA (1966–2013)
Species	**Slope (β)**	**p-value**	**Slope (β)**	**p-value**	**Trend (percentiles)[1]**	**Trend (percentiles)[1]**
Olive-sided Flycatcher	**-0.082[2]**	**0.034[2]**	-0.150	0.175	**-2.94 (-3.53, -2.37)[3]**	**-2.85 (-3.80, -1.84)[3]**
Warbling Vireo	0.002	0.890	0.003	0.912	**-0.90 (-1.44, -0.35)[3]**	**-1.17 (-1.98, -0.37)[3]**
American Robin	**-0.057[2]**	**0.031[2]**	-0.007	0.438	**-0.47 (-0.79, -0.14)[3]**	**0.79 (0.31, 1.30)[3]**
Swainson's Thrush	-0.002	0.883	0.000	0.989	-0.60 (NS)	**-2.11 (-3.21, -1.02)[3]**
Orange-crowned Warbler	0.016	0.302	**0.0350[2]**	**0.021[2]**	**-0.95 (-1.61, -0.29)[3]**	**-1.12 (-1.99, -0.22)[3]**
Wilson's Warbler	-0.004	0.738	0.000	0.994	**-1.80 (-2.61, -1.02)[3]**	0.65 (NS)
Song Sparrow	-0.023	0.090	-0.016	0.235	-0.01 (NS)	-0.30 (NS)
Purple Finch	0.000	0.894	-0.001	0.803	**-1.32 (-1.97, -0.70)[3]**	0.05 (NS)

[1] The BBS trend shows the annual percent change for a given species from the California BBS data. If the 2.5 and 97.5 percentiles (in parentheses) include zero, the trend is considered not-significant. Otherwise the result may be significant and the percentiles are shown in parentheses (Sauer et al. 2014).

[2] Significant decline with $p < 0.05$

[3] Significant change with $p < 0.05$

Olive-sided Flycatcher (*Contopus cooperi*) and American Robin (*Turdus migratorius*) were the two breeding species that had statistically significant declines within GOGA/PORE (Table 4.2.1). Cormier et al. (2011) found that Olive-sided Flycatcher was increasing on open space adjacent to the parks (Marin Municipal Water District) which contrasts with the GOGA/PORE decline. The California-wide BBS data, support the negative abundance trend found in the parks and show Olive-sided Flycatcher and American Robin species to be declining statewide (Sauer et al. 2014). The coastal California BBS also showed Olive-sided Flycatchers declining, but showed an increasing trend in American Robins (Sauer et al. 2014).

Warbling Vireo (*Vireo gilvus*) showed both positive and negative, although not significant, trends close to zero for GOGA/PORE and negative trends for both the California and coastal California BBS in Table 4.2.1 (Humple and Porzig 2012, Sauer et al. 2014). Another Warbling Vireo trend analysis, using mist-netting data from PORE/Palomarin, by Ballard et al. (2003) showed a significant decline for the previous time period, 1979–1999.

Swainson's Thrush (*Catharus ustulatus)* also showed the combination of both positive and negative trends close to zero for GOGA/PORE and California BBS (Table 4.2.1) although they were also not significant (Humple and Porzig 2012, Sauer et al. 2014). The coastal California BBS showed a significant decline (Sauer et al. 2014). Other published trend analyses, using mist-netting data from PORE/Palomarin, showed no significant trends from 1980–1994 (Johnson and Geupel 1996) and 1979–1999 (Ballard et al. 2003).

Song Sparrow (*Melospiza melodia*) (Table 4.2.1) showed a slight negative trend within GOGA/PORE which the Ballard et al. (2003) 1979–1999 PORE/Palomarin analysis corroborated although the trends were not significant. The California and Coastal California BBS also showed non-significant negative trends for this species (Sauer et al. 2014).

Fall and Winter Season Trends

In the Humple and Porzig (2012) report, GOGA/PORE Fall and Winter species trends were calculated as a capture rate using mist netting data from 2002–2011. There was no comparison reference for these trends outside of GOGA/PORE (e.g. California BBS data or Marin Municipal Water District). These capture rate trends will be compared to a previous analysis that was restricted to PORE and used the Palomarin mist netting dataset for the years 1979–1999 (Ballard et al. 2003). Note: trends based on fall mist netting are less-strongly correlated to local habitat quality than winter mist netting since the dynamics of migrant populations can be strongly influenced by local and regional weather and productivity of source populations of the migrants.

In the Fall season, Humple and Porzig (2012) found a significant positive capture rate trend for Wilson's Warbler although Ballard et al. (2003) found a contrasting and significant negative trend for Wilson's Warbler capture rates in the previous time period 1979–1999. Golden-crowned Sparrow (*Zonotrichia atricapilla*) had a significant negative trend for 2002–2011 (Humple and Porzig 2012). Ballard et al. (2003) also found a negative, although not significant, trend for Golden-crowned Sparrow in the previous time period (1979–1999).

In the winter season, Ruby-crowned Kinglet (*Regulus calendula*) had a significant negative capture rate trend in both time period analyses (Ballard et al. 2003, Humple and Porzig 2012).

The riparian species abundance trends for GOGA/PORE are a mix of declining, increasing or neutral in breeding, fall and wintering seasons. There is no clear pattern of riparian species trends with the current analysis available for review.

Stressors

Climate change, habitat degradation, predators, and invasive species are stressors that are well known to have direct impacts on landbird populations. This chapter will focus on the stressors of climate change, eucalyptus invasion, and cowbird parasitism because of the analyses and information available. The following discussion will include published studies using data from Point Blue surveys in both parks.

Climate change

Multiple published studies by Point Blue highlight the additional impact of climate change in combination with other stressors like habitat degradation and predation on landbird populations (Ballard et al. 2003, Macmynowski et al. 2007, Seavy et al. 2008, Gardali et al. 2012, Jongsomjit et al. 2013). The predicted effects of climate change on landbird populations differ depending on habitat type, life-history traits, or climate change model parameters (Seavy et al. 2008, Jongsomjit et al. 2013). Jongsomjit et al. (2013) compared the cumulative effects of climate change and development within California. Jongsomjit found that some habitat types are predicted to have less impact from climate change than land-use change to urban or intensive agriculture. GOGA lands potentially already have heavier impacts from the surrounding area development than PORE because of urban growth restrictions in western Marin County. Climate change affects migration timing (Macmynowski et al. 2007), avian body size (Goodman et al. 2012), and may cause species with limited juvenile dispersal to be at higher risk of extinction (Porzig et al. 2014). A predicted increase in annual precipitation in one climate change scenario may cause an increase for Song Sparrow reproductive success in Palomarin. The predicted increase in temperature, however, falls outside of known Song Sparrow reproductive parameters and may make this prediction unreliable. These temperature and precipitation changes will have different effects on juvenile and adult survival rates (Seavy et al. 2008, Dybala et al. 2013). Climate change effects on landbird populations is an ongoing priority for monitoring and analysis.

Invasive Eucalyptus *spp.*

Eucalyptus spp. are invasive trees that occur in wildland and urban areas throughout California. Ecological effects of eucalyptus include the alteration of fire regime, groundwater availability, and suppression of the native plant community (Cal-IPC 2015). Stralberg and Gardali (2007) analyzed point count data from GOGA/PORE documenting the landbird species diversity and richness in different habitats including eucalyptus-invaded plant communities. Using California Wildlife Habitat Relationship data vegetation types, Stralberg and Gardali (2007) created models to identify variables in each habitat type that support the greatest diversity and richness of landbirds. The study found percent eucalyptus to have an indeterminate correlation to species richness, fluctuating between positive and negative relationships in oak woodland and riparian habitats. Stralberg and Gardali

(2007) concluded that non-native eucalyptus likely has negative effects on breeding bird diversity although the results of the study were not consistent. Another GOGA/PORE study found that, in particular, juvenile Swainson's Thrush did not use eucalyptus when present in the habitat and was instead heavily dependent on the riparian areas of nesting adults, mixed-hardwood forest, and coastal scrub in its search for resources (White et al. 2005). The report by Flannery et al. (2001) showed eucalyptus habitat having fairly high bird indices compared with the other habitat types. This study also showed eucalyptus habitat to have the highest abundance of European Starlings. Although not an immediate priority, more peer-reviewed published research is needed on the effect of eucalyptus on landbird populations.

Brown-headed cowbird parasitism

A parasitic species, Brown-headed Cowbird (*Molothrus ater*), has been well studied both in GOGA/PORE and throughout its western range. In the PORE/Palomarin population trend analysis by Ballard et al. (2003), species with high cowbird parasitism rates had faster population declines than species with low cowbird parasitism rates. Gardali et al. (2000) hypothesized that factors such as the presence of the parasitic Brown-headed Cowbird may be the cause of the Warbling Vireo's low reproductive success. Although the study found that parasitized Vireo nests usually only rear cowbirds, Gardali concluded that the population decline is a result of the combined effects of parasitism, predator density, and variation of spring arrival dates (Gardali et al. 2000). A study by Michaud et al. (2004) found that 33% of Wilson's Warbler nests were parasitized by cowbirds although 74% failed due to nest predation. Cowbird parasitism was found to have little effect on the reproductive success of Song Sparrow individuals at Palomarin (Chase et al. 2005). Cowbird parasitism works in concert with other stressors like high levels of nest predation for many species (e.g. Gardali et al. 2000, Ballard et al. 2003, Chase et al. 2005) and merits continuing research at GOGA/PORE.

Level of confidence in assessment

The resource assessment in this chapter is limited to a literature review of pre-existing population trend information. The landbird focal resource assessment uses species population trends where available in published literature and reports to measure the condition of the resource. Due to the limited resources of the Inventory and Monitoring Program (Gardali et al. 2010), riparian habitat has been the primary focus for population trend modelling. There is medium confidence in the assessment due to the limited trend information for different habitats.

Gaps in understanding

Other habitats, besides riparian zones, have less survey effort overall in both GOGA and PORE and therefore have less trend analysis information available. Although oak woodland, scrubland, and grassland bird habitat is found to be less vulnerable to climate change (Gardali et al. 2012), these other vegetation types make up significant portions of both parks. Other landbird habitats have had similar impacts from habitat loss and degradation in California and their landbird populations could be included as a metric of ecological integrity for management decisions. Many studies (e.g. Seavy et al. 2008, Gardali et al. 2012, Jongsomjit 2013) point out that bird communities are threatened by multiple stressors that climate change will exacerbate over time.

The comprehensive landbird monitoring surveys of 1999–2000 included all breeding bird habitats within PORE and GOGA (Flannery et al. 2001) based on vegetation type. This extensive survey did not extend to properties below San Francisco or within San Mateo County. Habitats like Bishop Pine (PORE) and Coast Live Oak (GOGA/PORE) also had high levels of mean species diversity and richness when compared to riparian habitat (Red Alder and Willow) (Flannery et al. 2001).

If resources allow, future research could include monitoring and analysis for landbird populations in other habitats within the parks as well as extending to new areas within GOGA.

Condition Summary

The riparian species abundance trends for GOGA/PORE are a mix of declining, increasing or neutral in breeding, fall and wintering seasons. There is no clear pattern of riparian species trends with the current analysis available for review. The condition status of the landbird focal resource warrants moderate concern based on the above synthesis of riparian habitat assessments from Point Blue published and reported work. The overall trend in condition of the landbird resource is unchanging due to the mix of declining, increasing and neutral trends. The confidence in the assessment is medium due to the limited habitats with population trend models (Table 4.2.2).

Table 4.2.2. Condtion Summary for Breedind Landbird Diversity.

Indicators of Condition	Specific Measures	Condition Status	Rationale
Habitats analyzed	Number of habitats with trend analysis		Riparian habitat is the primary focus for species population models. No trends published for other habitats.
Population trends	Number of focal species with negative trends		Riparian species show a mix of declining, increasing and neutral trends
Overall Condition Status and Trend for Breeding Landbird Diversity			**The landbird resource for GOGA is in good condition and is unchanging based on an overview of riparian habitat species population trends. However, there is a low confidence in the assessment because of the limited number of habitats where trends are available.**

4.2.4. Information Sources

Literature Cited

Ballard, G., G.R. Geupel, N. Nur, and T. Gardali. 2003. Long-term declines and decadal patterns in population trends of songbirds in western North America, 1979–1999. *The Condor* 105:737–755.

California Invasive Plant Council (Cal-IPC). 2015. Assessment of Tasmanian blue gum (*Eucalyptus globulus*). http://www.cal-ipc.org/ip/inventory/pdf/Eucalyptus_globulus_PAF_2015March.pdf (accessed July 15, 2015).

Carignan, V., and M. Villard. 2002. Selecting indicator species to monitor ecological integrity: a review. *Environmental monitoring and assessment* 78:45–61.

Chase, M. K., and G. R. Geupel. 2005. The use of avian focal species for conservation planning in California. In Proceedings of the Third International Partners in Flight conference, CJ Ralph and TD Rich (eds.). USDA Forest Service Gen. Tech. Report PSW-GTR-191.

Chase, M.K., N. Nur, and G.R. Geupel. 2005. Effects of weather and population density on reproductive success and population dynamics in a Song Sparrow (*Melospiza melodia*) population: a long-term study. *The Auk* 122(2):571–592.

Cormier, R. L., N. E. Seavy, S. Jennings, and T. Gardali. 2011. Abundance patterns in landbirds in the Marin Municipal Water District over 15 years: 1996 to 2010. A report to the Marin Municipal Water District.

Dybala, K.E., J. M. Eadie, T. Gardali, N.E. Seavy, and M.P. Herzog. 2013. Projecting demographic responses to climate change: adult and juvenile survival respond differently to direct and indirect effects of weather in a passerine population. *Global Change Biology* 19:1584–1593.

Flannery, M.E., D.L. Humple, G. Ballard, and G.R. Geupel. 2001. Landbird Inventory of the National Parks of the San Francisco Bay Area: Final Report, December 2001. PRBO Report to the National Park Service #1004.

Gardali, T., Ballard, G., Nur, N., and Geupel, G. R. 2000. Demography of a Declining Population of Warbling Vireos in Coastal California. *The Condor* 102:601–609.

Gardali, T., D. Humple, M. Herzog, M. Koenen, D. Press, W. Merkle, and S. Allen. 2010. Riparian landbird monitoring protocol for Golden Gate National Recreation Area and Point Reyes National Seashore: version 4.4. Natural Resource Report NPS/SFAN/NRR—2010/207. National Park Service, Fort Collins, Colorado.

Gardali, T., Seavy, N. E., DiGaudio, R. T., and Comrack, L. A. 2012. A Climate Change Vulnerability Assessment of California's At-Risk Birds. *PLoS ONE*, *7*(3).

Goodman, R.E., G. Lebuhn, N.E. Seavy, T. Gardali, J.D. Bluso-Demers. 2012. Avian body size changes and climate change: warming or increasing variability? *Global Change Biology* 18: 63–73.

Humple, D. L., and Porzig, E. L. 2012. Riparian Landbird Monitoring in Golden Gate National Recreation Area and Point Reyes National Seashore: Analysis Report through winter 2011–12. PRBO Report to the National Park Service.

Johnson, M.D. and G.R. Geupel. 1996. The importance of productivity to the dynamics of a Swainson's Thrush population. The Condor 98:133–141.

Jongsomjit, D., Stralberg, D., Gardali, T., Salas, L., and Wiens, J. 2013. Between a rock and a hard place: the impacts of climate change and housing development on breeding birds in California. *Landscape Ecology*, *28*(2), 187–200.

MacMynowski, D.P., T.L. Root, G. Ballard, and G.R. Geupel. 2007. Changes in spring arrival of Nearctic-Neotropical migrants attributed to multiscalar climate. Global Change Biology 13: 1–13.

Michaud, J. C., T. Gardali, N. Nur, and D. J. Girman. 2004. Effects of nest predation and brood parasitism on population viability of Wilson's Warblers in coastal California. Wilson Bulletin 116:41–47.

National Park Service (NPS) 2014. Landbird Monitoring: GOGA and PORE Resource Brief. San Francisco Bay Area Network Inventory and Monitoring Program. http://science.nature.nps.gov/im/units/sfan/monitor/landbirds.cfm (accessed July 1, 2015).

Porzig, E.L., N.E. Seavy, T. Gardali, G.R. Geupel, M. Holyoak, and J.M. Eadie. 2014. Habitat suitability through time: using time series and habitat models to understand changes in bird density. *Ecosphere* 5(2):12.

Sauer, J. R., J. E. Hines, J. E. Fallon, K. L. Pardieck, D. J. Ziolkowski, Jr., and W. A. Link. 2014. The North American Breeding Bird Survey, Results and Analysis 1966–2013. Version 01.30.2015 USGS Patuxent Wildlife Research Center, Laurel, MD

Seavy, N.E., K.E., Dybala, and M.A. Snyder. 2008. Climate Models and Ornithology. *The Auk* 125: 1–10.

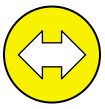
Siegel, R. B., R. L. Wilkerson, and M. Goldin Rose. 2010. Bird monitoring protocol for national parks in the Sierra Nevada Network. Natural Resource Report NPS/SIEN/NRR—2010/231. National Park Service, Fort Collins, Colorado.

Stralberg, D., and Gardali, T. 2007. Developing habitat-based landbird models as planning tools for the Golden Gate National Recreation Area and the Point Reyes National Seashore. Report to the Golden Gate National Parks Conservancy and the Golden Gate National Recreation Area. (No. PRBO Contribution #1551).

White, J. D., Gardali, T., Thompson, F. R., and Faaborg, J. 2005. Resource Selection by Juvenile Swainson's Thrushes During the Postfledging Period. The Condor, 107(2), 388–401.

4.3. Forests

Tree decline associated with the progression of sudden oak death warrants concern. The trend in forest biomass suggests the capacity for recovery. Confidence in the assessment is constrained by the paucity of site-specific data.



4.3.1. Why Focal Resource Was Assessed

Description

Golden Gate National Recreation Area (GOGA) manages 421 hectare of intact coast redwood forests in the San Francisco Bay Area. Two units, Muir Woods National Monument and the Phleger Estate, contain 92% of these redwood forests (Schirokauer et al. 2003[1]). Muir Woods represents one of the oldest (1908) examples of "saving the redwoods" by placing the trees in public ownership and the Phleger Estate one of the most recent (1995). Yet as Ruskin Hartley notes (2012), legal protection as a park is no longer sufficient to protect the redwoods in the era of global change.

Muir Woods National Monument is famous for its groves of ancient coast redwood trees (*Sequoia sempervirens*) that developed along the shores of Redwood Creek. In 2014, more than one million visitors toured this 225 hectare park. Since the National Park Service started counting in 1919 (https://irma.nps.gov/Stats/), 63 million people have come to see the "big trees." While coast redwoods are the most abundant tree species, covering 2/3 of the area, the Monument supports a mix of evergreen trees (Schirokauer et al. 2003) including the conifer, Douglas-fir (*Pseudotsuga menziesii*), and three common evergreen hardwoods: California bay laurel (*Umbellularia californica*), tanoak (*Notholithocarpus densiflorus*), and coast live oak (*Quercus agrifolia*). The Monument is located within the Redwood Creek Watershed (Fig. 4.3.1), a diverse 23 km^2 landscape in Marin County that spans from Mount Tamalpais to the north (top of the watershed, summit elevation 783 m) to the outflow of the creek at Muir Beach to the south. Most of the Redwood Creek Watershed is publicly owned and elements of the mixed evergreen forest (sensu Sawyer 2007) account for 45% of the vegetation (Fig. 4.3.2, Stillwater Sciences 2011). Thus, the redwood stands at the Monument are embedded within a large, contiguous expanse of intact forest that is protected by various forms of public ownership. The plant taxonomic reference follows Calflora (2016).

[1] The Phleger Estate parcel was not included in the initial Schirokauer et al. (2003) mapping effort but the subsequent vegetation map used the same methodology and plant community classification.

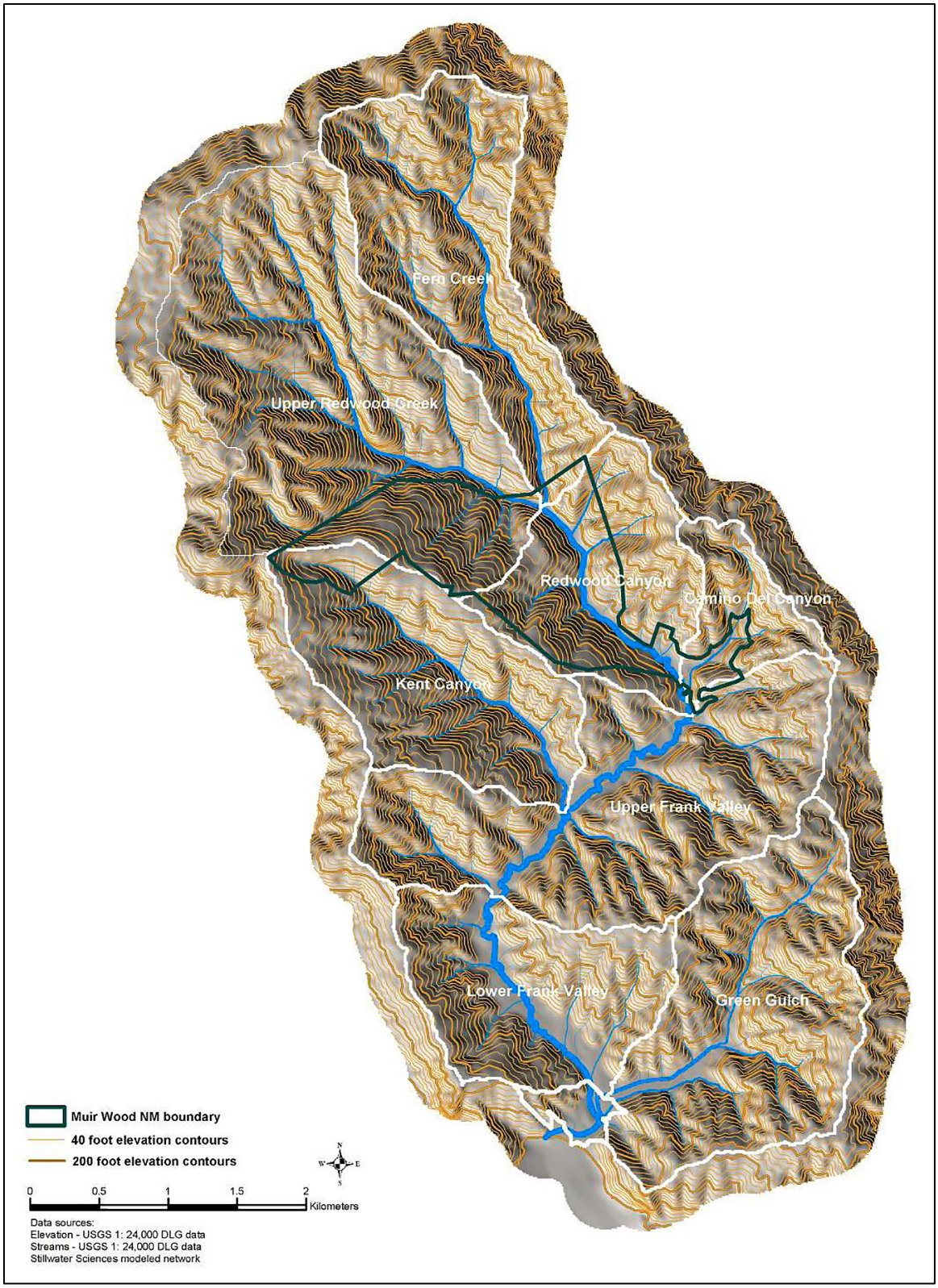


Figure 4.3.1. Shaded-relief topographic map of the Redwood Creek watershed. (Stillwater Sciences 2011).

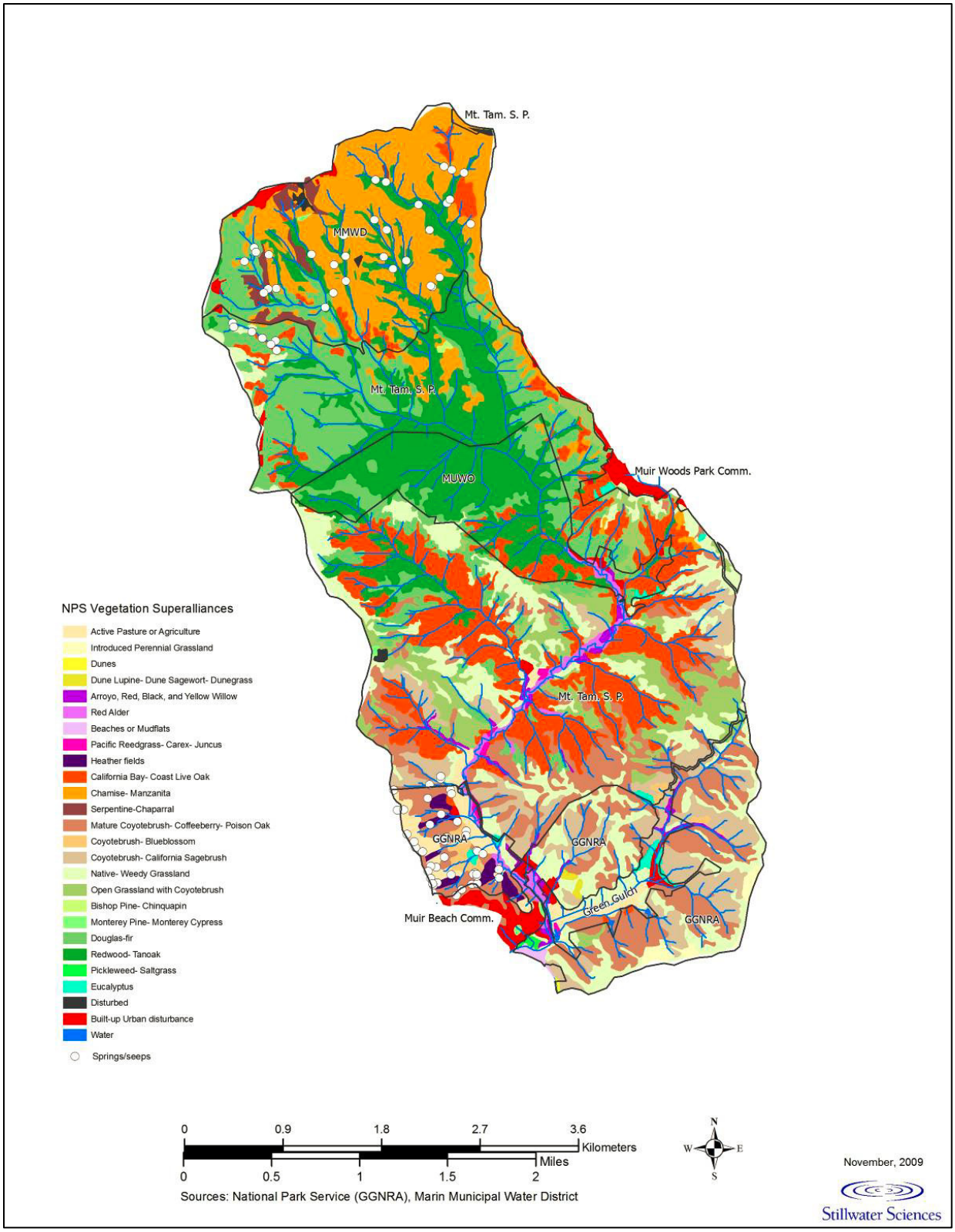


Figure 4.3.2. Vegetation cover types in Redwood Creek Watershed (Stillwater Sciences 2011).

The Phleger Estate, a 495 hectare forest in San Mateo County, was added to GOGA in 1995 (SMCHA 2010). The redwood-tanoak forest dominates in the stream valleys and lower slopes (52% by area). California bay-coast live oak forests cover the upper slopes and ridge top (37% by area). The Phleger Estate together with property owned by the San Francisco Public Utilities Commission (59 km^2) forms a large tract of protected lands (64 km^2 total). Like much of the coastal forests in the region and in contrast to the old-growth forests at Muir Woods, the forests on the Phleger Estate were extensively logged in the late 1800's and early 1900's (SMCHA 2010).

The forests at Muir Woods and the Phleger Estate supply essential structure and function to their ecosystems. The complex, multi-tiered canopy, characteristic of these forests (Ramage et al. 2010, Van Pelt et al. 2016), provides critical wildlife habitat. For example, the cavities that develop from fire scars and other injuries in large, old redwood trees provide roosting sites for locally rare species like Townsend's big-eared bats (*Corynorhinus townsendii,* Mazurek 2004). Muir Woods, in particular, is a refuge not only for old-growth redwoods (Jacobs and McBride 1985) but also for threatened and endangered animals (NPCA 2011) like the northern spotted owl (*Strix occidentalis*) and coho salmon (*Oncorhynchus kisutch*). The coastal conifer forests are among the most productive forests in the world (Busing and Fujimori 2005, Sillett et al. 2015). This flux of energy supports the base of the food chain and ensures close biotic regulation of water and nutrient cycles (Whittaker 1975). Collectively the forest in GOGA currently store 76 Gg of carbon in the aboveground live vegetation (Battles et al. 2014). This carbon represents 99% of the total aboveground carbon stored in vegetation. It is a source of nutrient capital and a contribution to climate change mitigation. Degradation of these forests would clearly pose a risk to the resource condition of GOGA.

Primary risks to the forest include climate change, an altered fire regime, and the spread of exotic pathogens (NPCA 2011, Hartley 2012). Fire is a critical component of the coast redwood disturbance regime (Ramage et al. 2010) but its role in these coastal forests is complex (Lorimer et al. 2009). However there is no doubt that the long-term policy of fire suppression has extended the current fire-free interval from the pattern of frequent, low-intensity burns that existed under Native American management prior to European settlement (Jacobs and McBride 1985, Brown et al. 1999). In 1995, the presence of exotic pathogen, *Phytophthora ramorum* and causal agent of Sudden Oak Death (SOD), was confirmed in Muir Woods. It has resulted in the widespread mortality of tanoak (Swiecki and Bernhardt. 2006).

This assessment will first consider the status of the entire forest community at Muir Woods and the Phleger Estate and then focus on the Douglas-fir/Coast redwood community (Fig. 4.3.3). Forest types were defined using the "community" designation from the National Park Service vegetation map (Schirokauer et al. 2003). This class is based on vegetative associations that share dominant species and other floristic, physiognomic, and ecological properties. In this sense, it is similar to the mesocluster defined by the US National Vegetation Classification System. However the community designation is specifically designed for vegetation management purposes – an important consideration for this effort. The key difference with the purely ecological association is that the community combines Douglas-fir stands with redwood stands in one class, Douglas-fir/Coast Redwood (190 hectares at Muir Woods; 226 hectares at the Phleger Estate).

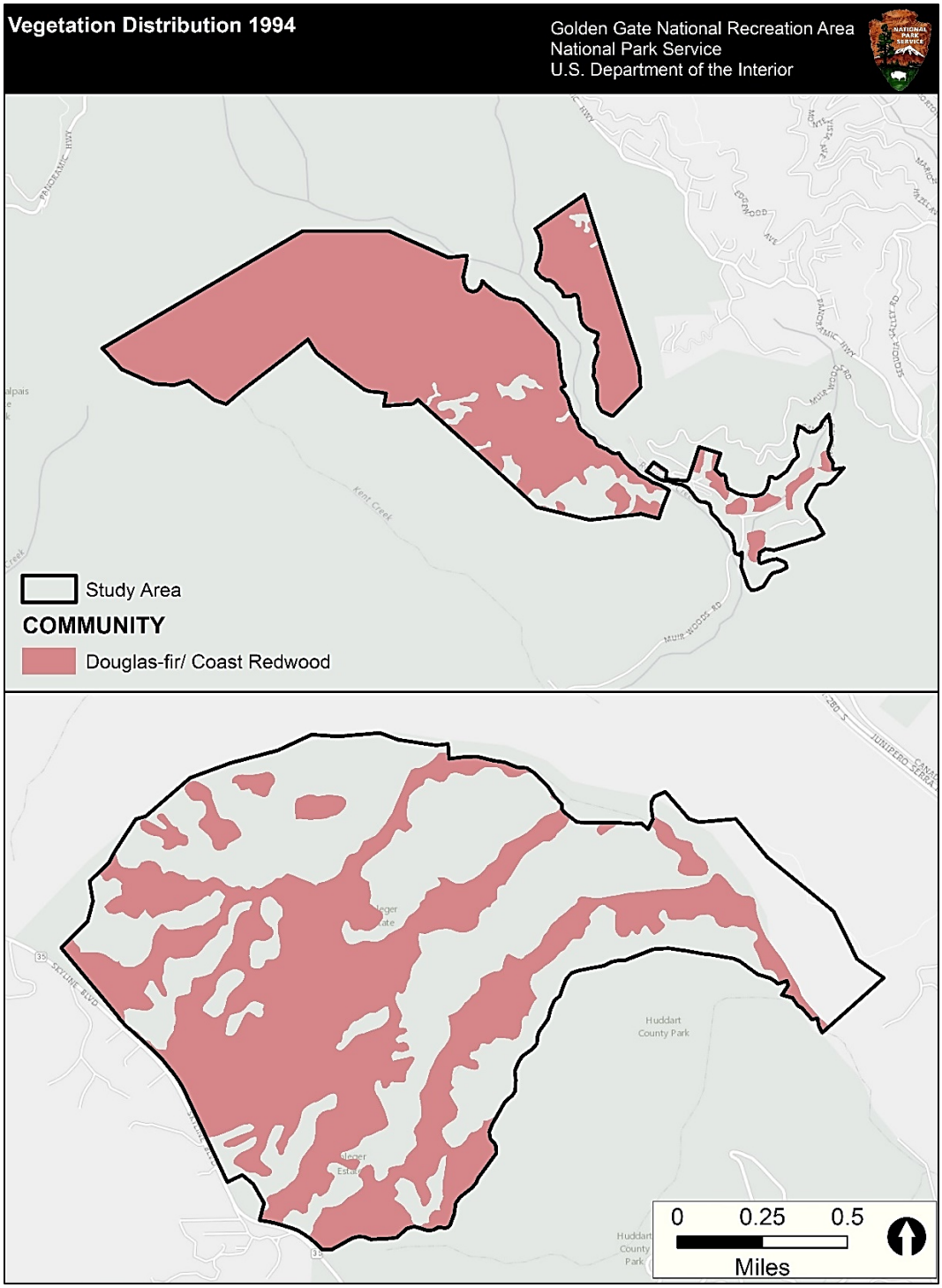


Figure 4.3.3. Distribution of Douglas-fir/Coast redwood communities at Muir Woods, GOGA (upper panel) and the Phleger Estate, GOGA (lower panel) (Schirokauer et al. 2003).

Critical questions

The concept of ecological integrity has proven to be a useful framework to assess the condition of protected ecosystems (Parrish et al. 2003, Tierney et al. 2009). In broad terms, ecological integrity

can be defined as the capability of the ecosystem to maintain the composition and structure of the biological community; the productive capacity of the ecosystem; and the ability to recover from stress and disturbance. Given this definition, it is clear that integrity shares an intellectual history with ideas expressed in terms of ecosystem health, ecological sustainability, and resilience (Rapport et al. 1998). The distinguishing feature of integrity is its explicit focus on evaluating management decisions and conservation efforts.

Recently Battles et al. (2013) evaluated the structure, composition, and function of forests at Sequoia and Kings Canyon National Parks in terms of ecological integrity. This work provides a template for the condition assessment of the redwood forests in GOGA. Thus the critical questions focus on addressing the key components of integrity as identified in Tierney et al. (2009):

- What is the current trend (2001–2010) in forest biomass accumulation?
- What is the impact of projected changes in climate on the distribution of the Douglas-fir/Coast Redwood Forest?
- What is the impact of the altered fire regime on the Douglas-fir/Coast Redwood Forest?
- What is the impact of exotic forest pathogens on the Douglas-fir/Coast Redwood Forest?
- What is the potential for the impact of these perturbations to compound (sensu Metz et al. 2013)?

4.3.2. How Focal Resource Was Assessed

Measures

Biomass accumulation provides a valuable synoptic perspective on ecosystem function (Whittaker 1975). It represents a measure of both the productivity of the primary producers as well as the pool of "organic capital" available to fuel heterotrophic processes (DeAngelis et al. 1981). This report focused on estimating the biomass stored in the aboveground live vegetation (AGL). While it is not the only pool of biomass in the ecosystem, live vegetation constitutes a large, dynamic pool that can be measured relatively accurately. Moreover in forests, it is directly linked to tree demography and carbon cycling (Fahey et al. 2005, van Doorn et al. 2011). Decreases in AGL over time can indicate a decline in the ecological integrity of the forests (Tierney et al. 2009).

Models of vegetation distribution based on the projected changes in climate (i.e., climate envelope models) provide insights into the future ecologies of natural systems that cannot be observed directly (Lenihan et al. 2008, Stralberg et al. 2009). Thus despite their limitations, they are a valuable aspect of a multi-faceted vulnerability assessment (Hameed et al. 2013). At the least, these projections quantify the mismatch between potential future climates and the current temperature and precipitation regimes of the extant species.

The suppression of fire at GOGA can lead to the build-up of fuels and thus change the behavior of wildfires. To the extent that this behavior does not match the natural fire regime, it represents a threat to the integrity of the forests (Donato et al. 2009, Tierney et al. 2009). Thus wildfire hazard is an important measure of the status of the forest resource.

The spread of exotic pathogens is an obvious threat to the forest (Liebhold et al. 1995). Their distribution and abundance are key determinants of vital rates such as tree growth and survival. Decreases in tree growth and survival are clear indicators of declining ecological integrity (Tierney et al. 2009).

Data Sources and Methods

Trends in biomass accumulation were quantified at Muir Woods and the Phleger Estate from 2001 to 2010 using an approach designed to track greenhouse gas fluxes for the wildlands of California that meets standards set by the Intergovernmental Panel on Climate Change and the California Air Resources Board (Battles et al. 2014). This approach uses the United States Geological Survey's Landscape Fire and Resource Management Planning Tool (Landfire) as its remote sensing framework. For spatial units defined by vegetation type, vegetation cover, and vegetation height as determined by Landfire (900 m^2 in area), Battles et al. (2014) calculated biomass densities from public data sources including the United States Forest Services' Forest Inventory and Analysis (FIA) Program. Change in biomass through time can be estimated from changes in vegetation type, cover, and/or height as tracked by Landfire. Gonzalez et al. (2015) successfully applied the methodology to measure changes in aboveground carbon stock in California. However they noted several limitations. Uncertainty in carbon pool estimates depended on the spatial scale. For PORE, the standard deviation in the 2010 pool estimate of 910 GgC was ± 29%. Also due to limitations in the Landfire classification scheme, the method tended to underestimate growth by about 6% in tall, closed canopy forests. Finally as recently documented by Lutz et al. (2017), the core predictions used by FIA tend not to include examples from the larger specimens of a species thereby creating a bias in the sample that likely underestimates the contribution of the largest trees. On the other hand, Gonzalez et al. (2015) noted that their method was an excellent means to monitor losses of biomass given the ability of Landfire to detect decreases in canopy cover and height.

Projections of future vegetation distributions developed by Stralberg et al. (2009) and Ackerly et al. (2015) were used to quantify the mismatch between potential future climates and the existing climate regimes of the extant redwood forests at Muir Woods and the Phleger Estate. The two projects take a similar general approach to projecting change in that they model the distribution of major vegetation types (not species) in response to climate. However they vary in scope and statistical framework. Stralberg et al. (2009) project vegetation change across California based on the output from two global circulation models and one emission scenario. They rely on a non-parametric, machine learning approach to classify vegetation types to climate regimes. In contrast, Ackerly et al. (2015) limit their analysis to the San Francisco Bay area but consider 54 separate climate scenarios. Moreover Ackerly et al (2015) rely on parametric multinomial regression model to quantity the relationship between climate and vegetation distribution.

For the Stralberg et al. (2009) analysis, results for Muir Woods and the Phleger Estate were obtained from the interactive website maintained by the Environmental Change Network (ECN 2015). These projections consider results from two global circulation models assuming a medium-high emissions scenario. This scenario, denoted A2 (Cayan et al. 2012), assumes a fragmented and heterogeneous

world where populations continue to grow and economic development continues although unevenly resulting in high but not the highest greenhouse gas emissions.

To obtain specific predictions for GOGA from the Ackerly et al. (2015) results, the baseline climate was estimated for central location at both sites. The baseline climate was defined from the 30-yr normals (1980–2010) reported by the PRISM Climate Group (http://www.prism.oregonstate.edu/explorer/). Predicted change in forest vegetation types was calculated as a function of changes in mean annual temperature using the equations provided in Table S5 in Ackerly et al. (2015). For simplicity, the total annual precipitation was kept constant. This assumption of constancy is warranted given the variability (high) and relative magnitude (low) in the expected changes in precipitation in northern California (Ackerly et al. 2015).

As part of its fire management plan (GGNRA 2005), GOGA developed a wildland fire hazard model. Potential fire behavior was used to determine the degree of hazard based on the topography and fuels under extreme weather conditions. To quantify the impact of the altered fire regime, the distribution of forests was compared to the areas of high hazard.

Results in the peer-reviewed literature, much of it based on the repeated measure of field plots located in or near (e.g., Marin County) Muir Woods, provided the primary means to assess the impact of *P. ramorum* on the Douglas-fir/Coast redwood forest. The threats posed by interacting perturbations were evaluated from a literature review.

Reference Conditions/Values

Two reference conditions were developed to evaluate the trends in biomass accumulation: a theoretically based standard and a regional standard. For the old-growth forest at Muir Woods, biomass accumulation is expected to be relatively constant with only temporary shifts away from a baseline maximum (Turner 2010). At Phleger Estate with second-growth forests that developed following logging the expectation is different. Given the vegetation dynamics of the mixed evergreen forest and the longevity of the canopy dominants (Hunter and Parker 1993, Hunter 1997), ecosystem theory (sensu Bormann and Likens 1979) predicts that this century-old forest should be adding biomass albeit slowly in the absence of exogenous factors (i.e., stressors). For a more pragmatic perspective, biomass trends for coastal forests in the region were used as a regional reference condition. The region was defined as the tree-dominated landscapes in Marin, San Francisco, and San Mateo counties. The expectation was that while forests throughout the region may be exposed to the same stressors, forests protected at GOGA should retain biomass at a higher rate than in the region as a whole.

The reference condition regarding the impact of climate change was simply the maintenance of the status quo (defined by the existing NPS vegetation map) with regard to range of the existing forest types. For the altered fire regime, a hazard condition of moderate was assumed to be the baseline condition. For exotic pathogens, the reference condition was the composition and structure of the forest in absence of the pathogen.

4.3.3. Condition Assessment

Condition and Trend (with Stressors included)

What is the current trend (2001–2010) in forest biomass accumulation?

Between 2001 and 2010, aboveground live biomass (AGL) at Muir Woods was virtually unchanged from 262 Mg/ha in 2001 to 265 Mg/ha in 2010, a rate of increase of 0.2%/yr. The same pattern was observed at the Phleger Estate; AGL was maintained at 223 Mg/ha (Fig. 4.3.4). At both sites, there was also no loss of forest cover. In contrast, AGL declined regionally at the rate of 0.9%/yr (Fig. 4.3.5). A change in forest cover, rather than AGL density, drove the trend. While average AGL density remained steady at 136 Mg/ha, the tree-dominated landscape declined from 5,213 km^2 to 4,824 km^2 (7%). The large uncertainty associated with the Landfire-based estimator of biomass change for small parcels (Battles et al. 2014) precludes an analysis of change by forest type.

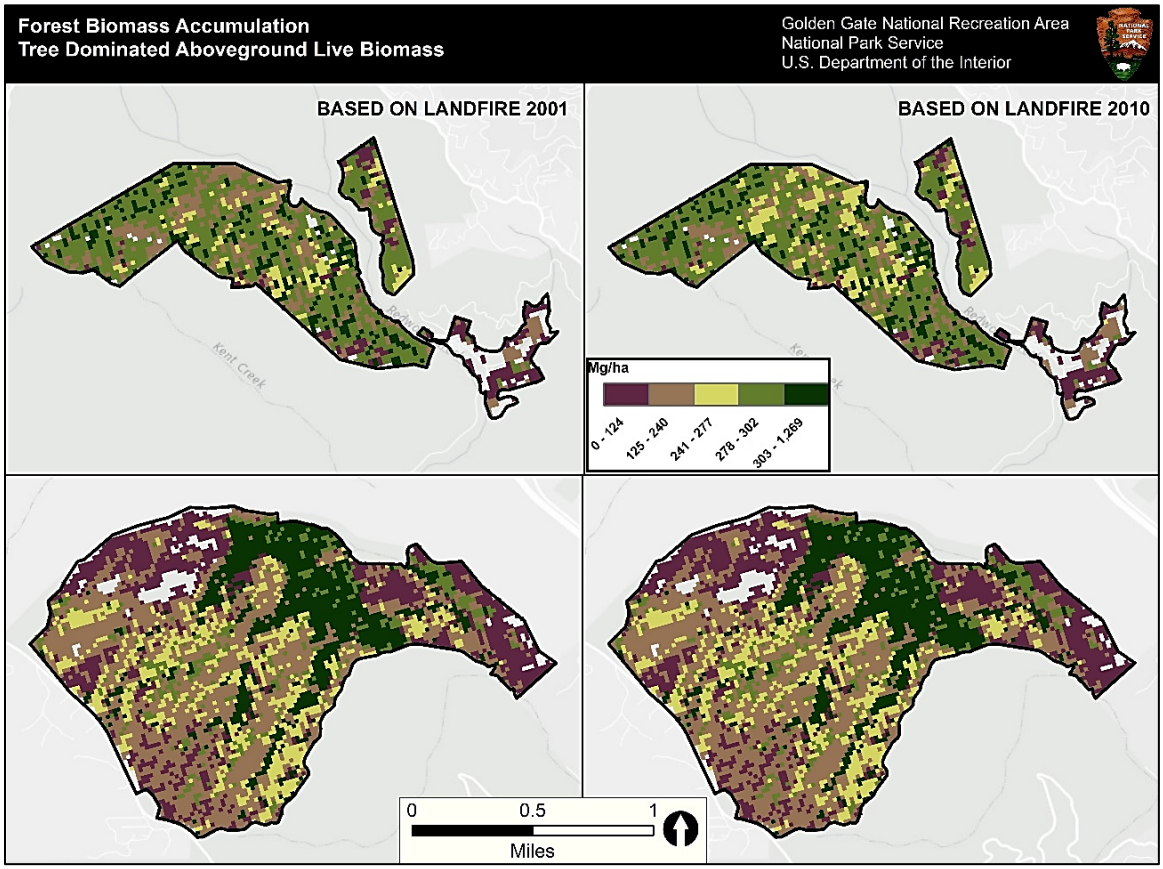


Figure 4.3.4. Changes in the aboveground live biomass in the tree-dominated landscape of Muir Woods, GOGA (upper panels) and the Phleger Estate, GOGA (lower panels) between 2001 and 2010 (Landfire program, https://www.landfire.gov/; Battles et al. 2014).

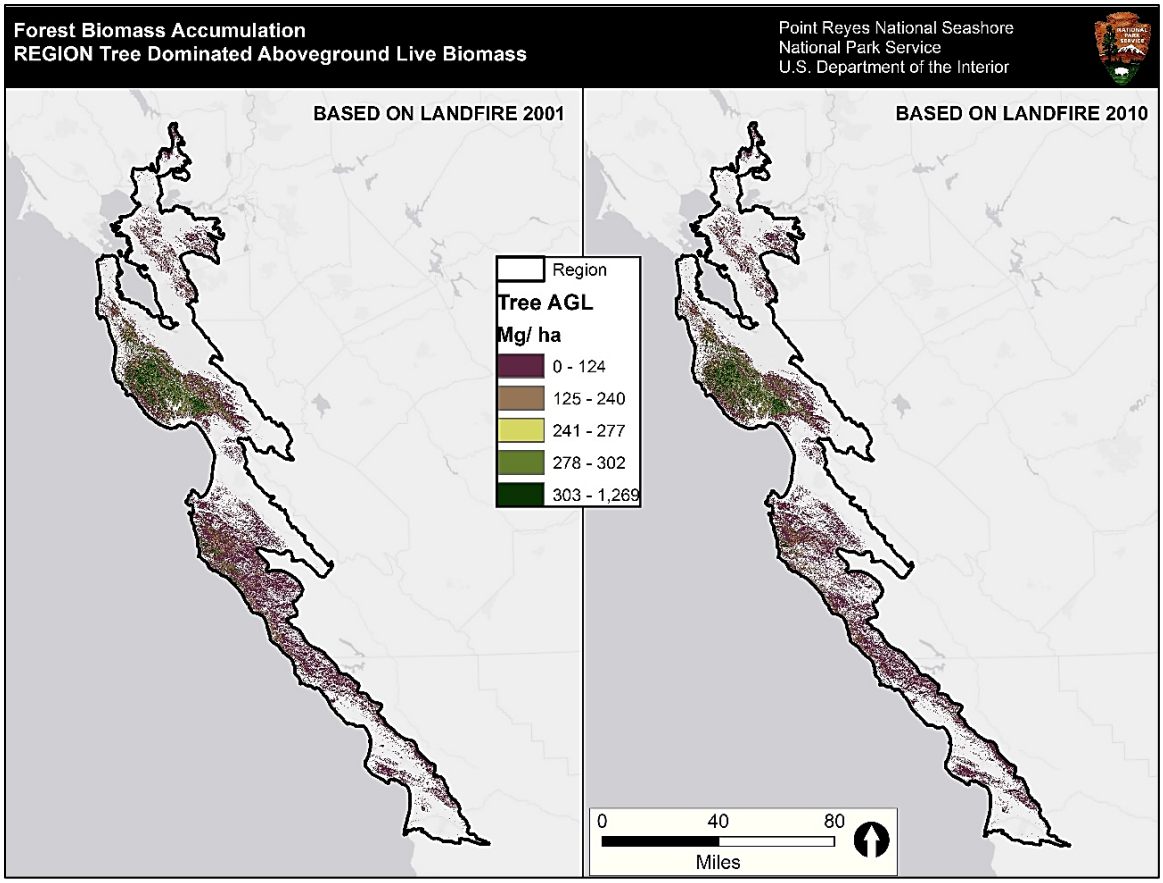


Figure 4.3.5. Changes in the aboveground live biomass stored in the tree-dominated landscape of the region (Marin, San Francisco, and San Mateo counties) between 2001 and 2010 (Landfire program, https://www.landfire.gov/; Battles et al. 2014).

These results support the conclusion that the forests at Muir Woods and the Phleger Estate have sustained their biomass capital. While the stationarity of AGL at Muir Woods matches expectations, the second-growth forests at the Phleger Estate do not appear to be accumulating biomass at the rate predicted by theory. However, both sites are clearly outpacing the regional forest.

What is the impact of projected changes in climate on the distribution of the Douglas-fir/Coast Redwood Forest?

Based on the projections obtained from the ECN interactive vegetation map (ECN 2015), climate change will cause a dramatic contraction of the Douglas-fir/Coast Redwood forests at Muir Woods and the Phleger Estate. In fact, results from two different simulations of future climate predict that no climate niches will be present in 2100 that support Douglas-fir/Coast Redwood forests.

Results from Ackerly et al. (2015) also suggest that by the end of the century, given the expected warming (Figs 4.3.6 and 4.3.7, top panels), there will be very little climatically suitable habitat for Redwood Forests at either site (Fig. 4.3.8). Although the decline is sooner and notably steeper with increasing temperature at the Phleger Estates, there is limited climatically suitable redwood habitat left at either site given the expected temperature in 2100. Douglas-fir Forests also suffer a net decline

after an initial increase with moderate warming but the extent of the loss is much less than the Redwood Type (Fig. 4.3.8). Again the sensitivity to the warming was stronger at the Phleger Estates than Muir Woods, a sensitivity due to the fact that it is already warmer and drier at the Phleger Estates than Muir Woods (1.8 °C warmer in mean annual temperature and 130 mm less annual precipitation, based on 30-yr normals from 1981–2010).

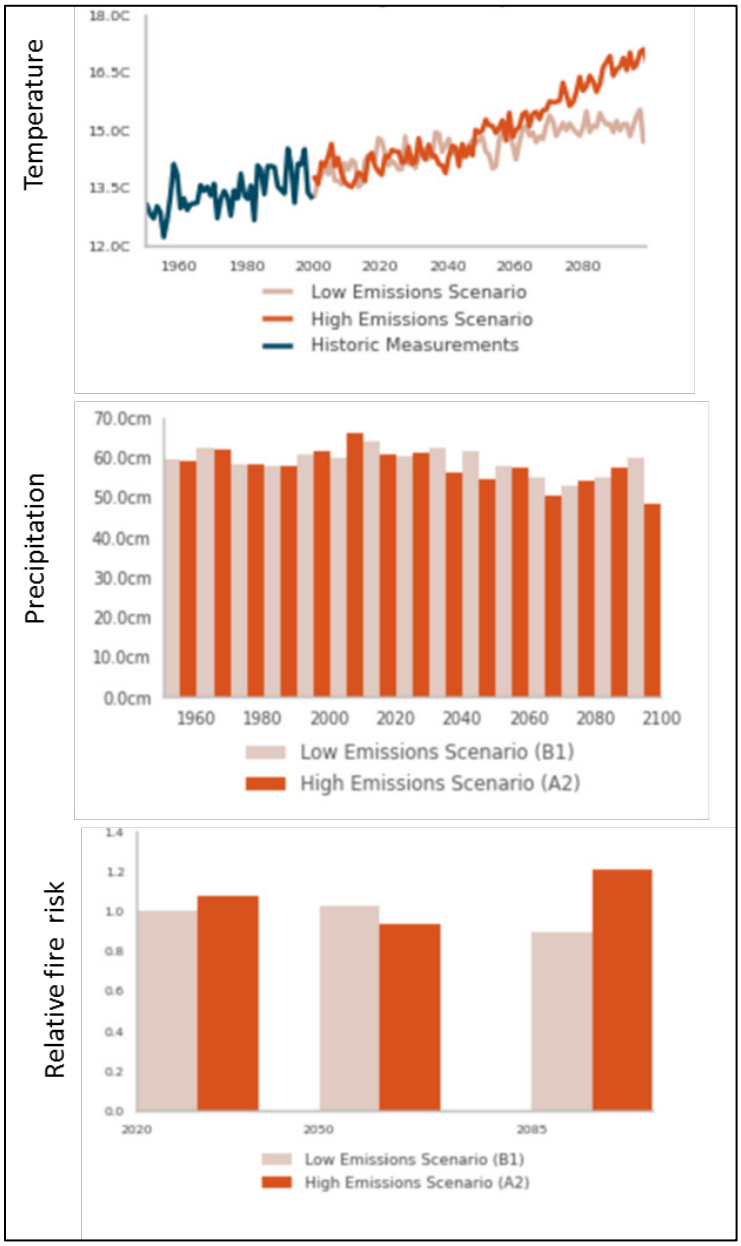


Figure 4.3.6. Potential interactions between climate change and future wildfire risk for Muir Woods, GOGA. Projections for Cal-adapt (http://cal-adapt.org/) for Mill Valley Area. Upper panel is the predicted average annual mean air temperature from four global circulation models under a low and high emission scenarios. Middle panel is the predicted average annual precipitation from four global circulation models under a low and high emission scenarios. Lower panel is the relative increase in fire risked associated with projected climate change.

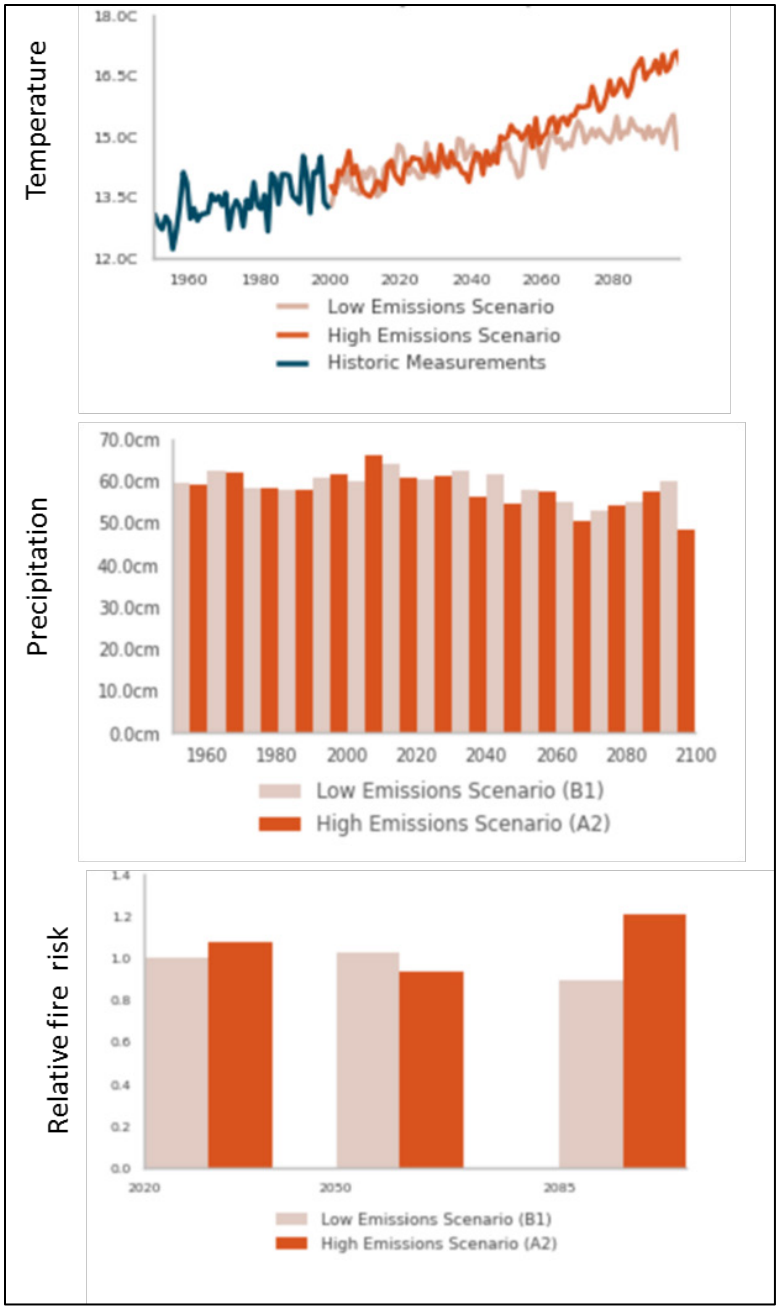


Figure 4.3.7. Potential interactions between climate change and future wildfire risk for Phleger Estate, GOGA. Projections for Cal-adapt (http://cal-adapt.org/) for Moss Beach Area. Upper panel is the predicted average annual mean air temperature from four global circulation models under a low and high emission scenarios. Middle panel is the predicted average annual precipitation from four global circulation models under a low and high emission scenarios. Lower panel is the relative increase in fire risked associated with projected climate change.

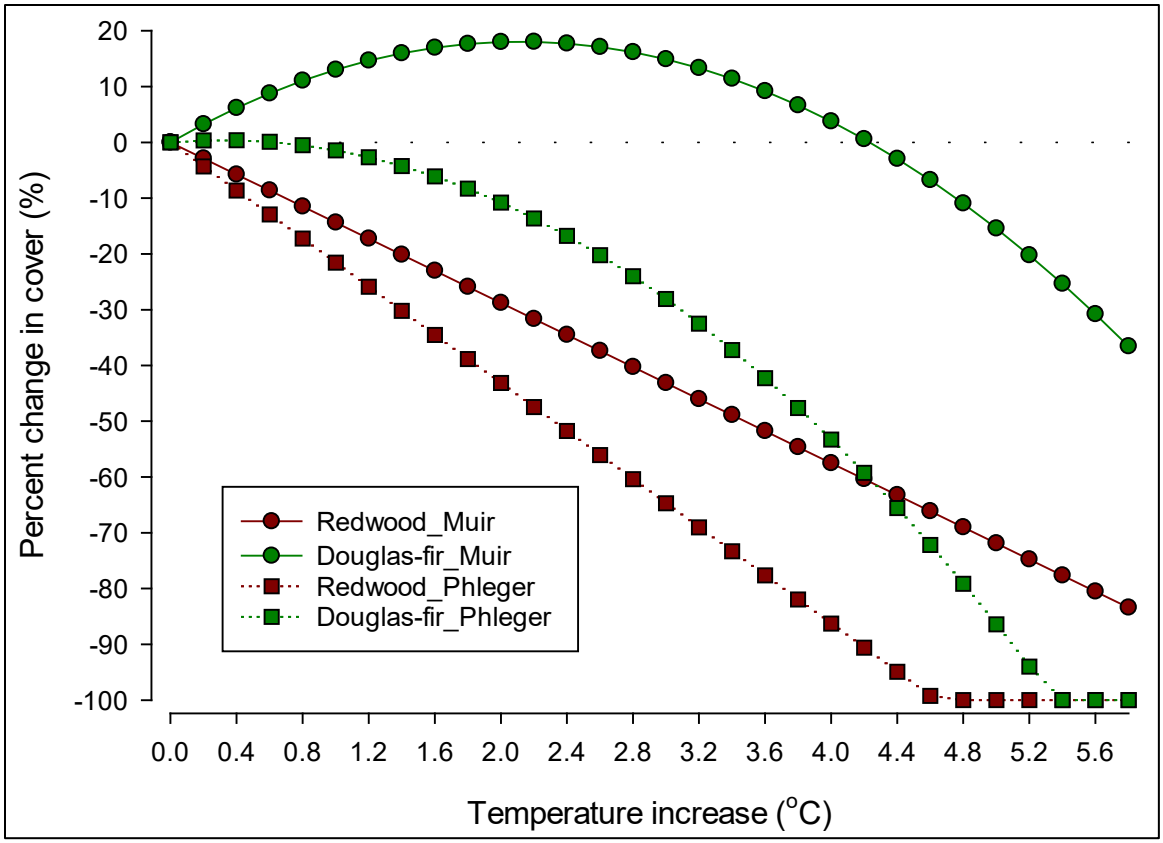


Figure 4.3.8. Projections of percent change in vegetation cover associated with increases in mean annual temperature for the forest vegetation types at Muir Woods and Phleger Estates. The baseline conditions were calculated for a pixel (800 m) near the center of Muir Woods (37.8890 °N; 122.5827 °W; elevation = 190 m). The interpolated 30-yr mean for annual temperature was 13.5°C. For these projections, annual precipitation was held constant at the 30-yr mean of 1070 mm. The baseline conditions were calculated for a pixel (800 m) near the center of the Phleger Estates (37.4475 °N; 122.3130 °W; elevation = 366 m). The interpolated 30-yr mean for annual temperature was 15.3°C. For these projections, annual precipitation was held constant at the 30-yr mean of 940 mm. Results projected for the Redwood Forest and Douglas-fir Forest classifications defined by Ackerly et al. (2015).

As Hameed et al. (2013) note, the transformations predicted by these vegetation models will not occur by the end of the century. These models ignore a host of ecological and meteorological realities. The dynamics of these forests play out over centuries and forest migrations do not necessarily track climate change (Zhu et al., 2012). For example, Sillett et al. (2015) documented steady increases in wood production for redwoods trees during the last century despite a warming climate. In addition, the distribution and structure of these forests are strongly linked to key aspects of the coastal climate (Barbour et al. 2014), namely cloud cover and fog (Fischer et al. 2009, Johnstone and Dawson 2010, Carbone et al. 2013), but the coastal climate is notoriously difficult to predict (Fernandez et al. 2015). Nevertheless, results from these models outline a stark reality supported by near-term observations (Johnstone and Dawson 2010, Baguskas et al. 2014); the expected future climate is unlikely to be favorable to coast redwoods as well as Douglas-fir.

What is the impact of the altered fire regime on the Douglas-fir/Coast Redwood Forest?

The hazard posed by wildfires to the forests at Muir Woods (Fig. 4.3.9) spans the range from moderate (hazard score ≤ 1) in the western extent to very high (hazard score =3) on the eastern edge of the property. On average, the majority of the Douglas-fir/Coast Redwood Forest is exposed to high or very high hazard. At the Phleger Estate, most of the forest is in high or very high hazard (Fig. 4.3.10). The current extent of the fire hazard is a direct result of alteration to the natural fire regime (Jacobs and McBride 1985). Effective fire suppression has resulted in the accumulation of fuels in these forests.

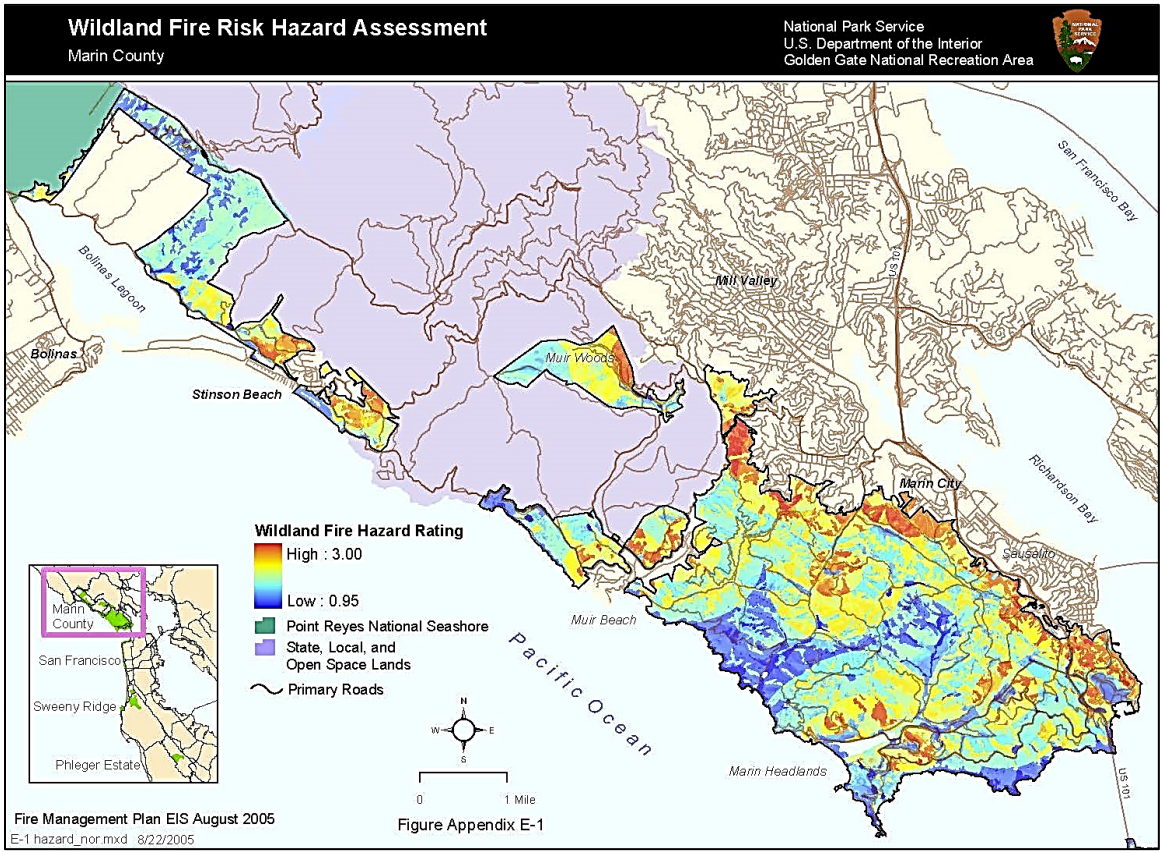


Figure 4.3.9. Wildand Hazard Map for Muir Woods from Appendix E in GGNRA 2005 (NPS).

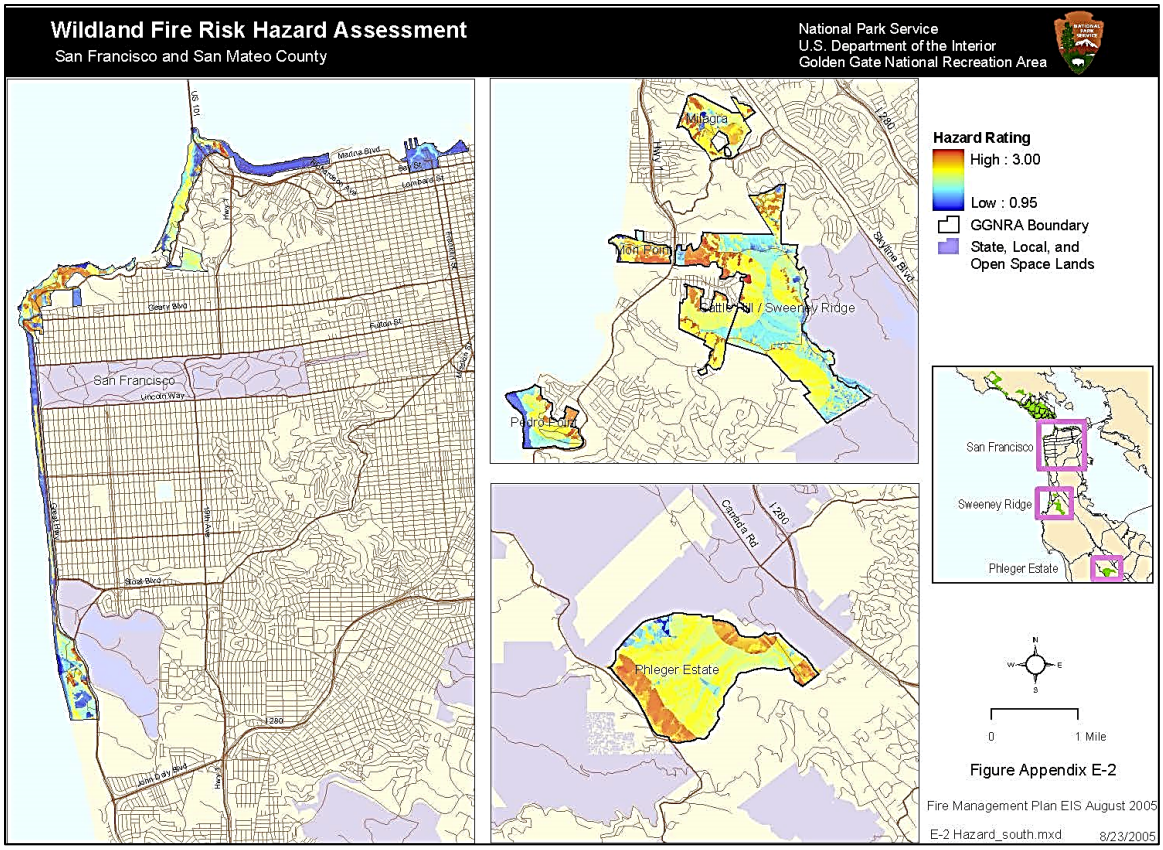


Figure 4.3.10. Wildand Hazard Map for the Phleger Estate from Appendix E in GGNRA 2005 (NPS).

The behavior of fires in high and very high hazard areas are expected to burn hot under fire weather conditions (GGNRA 2005). However, the predicted fire behavior is very sensitive to the representation of surface fuels in the fire models (Hall and Burke 2006). The existing suite of fuel types may not adequately characterize surface fuel loads in these coastal forests (S. Stephens, personal communication 2014) and the choice between two competing types can dramatically shift predicted fire behavior in the redwood forest (A. Forrestel, personal communication 2014). In addition, the effect of fire in the Douglas-fir/Coast Redwood forest continues to be debated. The natural fire regime remains obscured by a long history of human ignitions that predate European settlement (Brown et al. 1999). While it is clear that these forests did not develop with a high intensity fire regime (Hunter and Parker 1993, Lorimer et al. 2009), the results of even a hot fire in these forests would likely not result in complete removal of the canopy (Ramage et al. 2010, A. Forrestel, personal communication). In summary, the potential for hazardous fire behavior exists at both Muir Woods and the Phleger Estate, but the effects on the Douglas-fir/Coast redwood forest may not be as severe as predicted by the current fire models.

The goal of fire management plan at GOGA continues to be to prevent fires and reduce fuels (GGNRA 2005). Success in this regard would limit the consequence of the altered fire regime for the forests. To date, fire suppression has been effectively deployed. Thus the threat to the forest resource depends on the probability of a fire overcoming management efforts to contain it.

What is the impact of exotic forest pathogens on the Douglas-fir/Coast Redwood Forest?

The progression of *P. ramorum* disease in the Douglas-fir/Coast Redwood Forest at Muir Woods has resulted in the sustained and steep decline of the most susceptible species, tanoak (Swiecki and Bernhardt. 2006). Tanoak is a major canopy constituent of Douglas-fir/Coast Redwood association (Ramage et al. 2012) and typically accounts for 20% of the total tree basal area in this forest type (Hunter1997). Swiecki and Bernhardt (2006) monitored disease progression in a plot network that included sites in Muir Woods. They reported a steady increase in the disease both in terms of new infections and declining health for tanoak. For example, the rate of new infections in tanoak was more than 5%/yr between 2000 and 2004. Over the same time period, infected trees died at an annual rate of 8.2%/yr (Swiecki and Bernhardt 2006). Comparable rates of disease progression were reported for similar forests in nearby sites including the Marin Municipal Water District (Ramage et al. 2011) and Point Reyes National Seashore (Ramage et al. 2012, Forrestel et al. 2015). Hayden et al. (2011) found limited population-level resistance to the disease and among tanoak populations in the region. These results suggest that individual stands in invaded landscapes are unlikely to escape the disease (Cobb et al. 2013). For the Douglas-fir/Coast Redwood Forest (Forrestel et al. 2015), it seems that recovery of forest structure lost to the disease is relatively slow. At the same time, the losses are restricted to the susceptible species. Thus, while *P. ramorum* is re-organizing species composition, shifting trophic structure, and at least temporarily reducing canopy cover, it seems unlikely to catalyze a regime shift (sensu Folke et al. 2004).

There is no documented occurrence of *P. ramorum* infected trees in the Phleger Estate (Oakmapper 2015). However there are multiple reports of infected trees just southeast of the property. Although *P. ramorum* dispersal is predominantly local, the close proximity of propagules (< 1km) makes the spread of the disease to the Phleger Estate a likely occurrence in the near future (Meentemeyer et al. 2011). Moreover resource managers have observed dead and dying tanoak with symptoms of sudden oak death (A. Forrestel, personal communication 2014).

What is the potential for the impact of these perturbations to compound?

Recently Metz et al. (2013) documented compounding perturbations between sudden oak death and wildfire in a coast redwood forest. During the Basin Fire in 2008 in Monterey County (the current southern extent of *P. ramorum*), redwood trees in stands with sudden oak death suffered 200% higher fire-related mortality than in healthy stands. Metz et al. (2013) attributed this significant interaction to hotter fires in diseased stands due the presence of higher surface fuel loads. The build-up of surface fuels in coastal forests as a consequence of disease-related tanoak mortality is a region-wide phenomenon (Valachovic et al. 2011). No measurements are available for Muir Woods but at PORE, Forrestel et al. (2015) measured significant increases in “diseased fuel load” in both Douglas-fir and coast redwood dominated stands. Based on fire behavior models, the increased fuel loads were sufficient to increase wildfire intensity and the probability of tree mortality in infected stands (Forrestel et al. 2015).

Metz et al. (2013) also noted the potential for a warming climate to further exacerbate the disease-fire interaction. At Muir Woods, air temperatures have been rising since 1980 and the warming is

projected to continue. By the end of the century, annual average air temperature is expected to rise from 1.7 to 2.9°C (Fig. 4.3.6).

The synergy among this combination of stressors does pose a threat to the ecological integrity of the forest at Muir Woods. However the high diseased fuel loads will decline with time. Inputs will cease as all the susceptible tanoak die and the deadwood will decompose. The exact rate will depend on the particulars of disease progression, tree mortality, and deadwood decomposition, but based on field-parameterized models from Cobb et al. (2013), it seems that the window of elevated fuel loads is about 20 years. Moreover, the projected increase in wildfire risk is less than 20% through 2050 (Fig. 4.3.6). Thus the critical question regarding the fate of the forest resource is the probability of a wildfire occurring while fuel loads are elevated.

The climate projections and future fire risk are similar for the Phleger Estate (Fig. 4.3.7). However as noted above, the extent of *P. ramorum* infection has not been as carefully documented which precludes the evaluation of interacting stressors.

Level of confidence in assessment

The assessments of biomass accumulation and exotic disease progression are grounded in site-specific, data-driven, research for Muir Woods whereas the evaluations of climate change, the altered fire regime, and compound perturbations rely more on projections and models. The ranking of confidence in these elements reflect the source of the information with results based on data judged to be more reliable than models. Collectively, these results have a low level of confidence given the lack of information needed to estimate uncertainty. For example, the monitoring plots set-up to track the progression of sudden oak death in and around Muir Woods (Swiecki and Bernhardt 2006) focus on tracking the fate of 12 individual trees in small plots (0.02 ha). While they are the best data used in this report, it is stretch to infer conditions in a forest type that spans 190 hectares from a sample that totals 0.24 ha. For Phleger Estate, there was no site specific, plot inventory data available.

Gaps in understanding

The value of a forest monitoring network that is measured repeatedly over time cannot be overstated. While the gold standard is a tagged-tree inventory of fixed radius plots in sufficient density to capture the variation in composition and structure over the entire landscape, there are less expensive strategies to monitor the condition of forest resources. For example, McPherson et al. (2010) have used plotless sampling techniques to good advantage in their effort to monitor sudden oak death in coast live oak forests.

The same plot network (or subset) could also serve as the means to assess surface fuel loads and distribution. As noted above, the performance of the fire models depend on the adequate characterization of the surface fuels. Thus, direct measures are essential, particularly when the goal is to assess fire hazard across the landscape and over time (Collins et al. 2013). Given the integral role fire plays in the dynamics of Mediterranean ecosystems, a better understanding of the potential fire effects is essential.

Invasive plants clearly represent a threat to the ecological integrity of forests (Tierney et al. 2009). However there was not sufficient information available to assess the current extent of invasive plants in the redwood forests at either site. The State of the Parks report for Muir Woods (NPCA 2011) notes the concern over *Ehrharta erecta* (Lam.), erect veldtgrass. The California Invasive Plant Council ranks the potential impact of *E. erecta* on native ecosystems as moderate (Cal-IPC 2016). It is a C3 perennial grass native to South Africa. It is most commonly found in disturbed areas and can spread rapidly (Cal-IPC 2016). *E. erecta* has been observed in the understory of Douglas-fir/Redwood forests at Muir Woods and the Park is working to limit its spread (NPCA 2011). There is at least one case (near Sky Camp at Point Reyes National Seashore) where *E. erecta* has completely taken over the understory of a Douglas-fir dominated stand (A. Forrestel, personal communication 2014). The existing invasive plant monitoring system at GOGA should consider expanding efforts to track spread invasive plants in forested areas with particular attention focused on locations that have been recently disturbed.

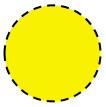
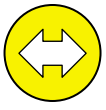
The detailed vegetation maps for Muir Woods and the Phleger Estate are precise and accurate (Schirokauer et al. 2003). They are absolutely indispensable for management and research. However the map for Muir Woods is more than two decades old and needs to be updated, on a regular basis if possible. All indications suggest that an era of accelerated ecological dynamics is at hand. Charting the subsequent shifts in the vegetation will require a dynamic rather than static approach. Strategies that rely on remote sensing and machine learning may be able to track key changes in vegetation at a precision sufficient to quantify range shifts while also greatly reducing the expense associated with more traditional approaches to vegetation mapping (Kennedy et al. 2010, Su et al. 2015). A promising example at Muir Woods is the use of light detection and ranging (LiDAR) along with hyperspectral data to conduct a tree inventory (Ballanti et al. 2015).

Climate change clearly has the potential to transform the coast redwood forests in GOGA. Species like coast redwood are dependent on the unique climatic conditions that occur near the coast (Barbour et al. 2014). Yet the aspects of climate that critically matter, namely fog drip and cloud cover (Carroll et al. 2014), are difficult to simulate reliably. Fernandez et al. (2015) used extremes in the historical climate record to find analogous conditions to the projected future climate scenarios. They demonstrated the value of their approach by examining changes in the near-term (next 20 years) suitability of the habitat for coast redwood forests. Similar to the results from Stralberg et al. (2009) and Ackerly et al. (2015), they found that climatically suitable habitat for redwood would contract in the San Francisco Bay Area. Redwood forests at Muir Woods and Phleger Estates were among the most sensitive to warming across the entire range of the species (Figure 7 in Fernandez et al. 2015). However preliminary results from a redwood tree ring chronology from Muir Woods (Carroll 2015) shows that redwood growth had less sensitivity to air temperature than to measures of moisture availability (e.g., Palmer Drought Severity Index, soil moisture availability, spring precipitation). Clearly, understanding the future climate in sufficient detail is both a critical gap in knowledge and a research priority.

Condition Summary

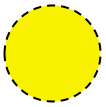
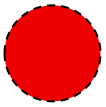
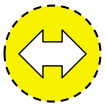
The ecological integrity of forests is an integrative measure that considers the structure, composition and function of the forest (Tierney et al. 2009). At Muir Woods, the progression of *P. ramorum* in the Douglas-fir/Coast Redwood Forest is having a widespread impact via the increased mortality of susceptible tree species. The decline in tanoak due to the presence of a "priority 1" pathogen (sensu Tierney et al. 2009) warrant significant concern. The expected changes in the climate, the altered fire regime, and their interaction with the disease pose potential yet unrealized threats to the condition of the forests. However the fact that the forest sustained its biomass capital despite the suite of stressors attests to the functional capacity for recovery. Clearly decreases in growth in *P. ramorum* infected stands were offset by gains elsewhere. In terms of the functioning of the forest as whole, the biomass trend suggest maintenance of the status quo. The primary conclusions of a forest resource holding its own despite substantial cause for concern are well-grounded in empiricism but Muir Woods lacks the comprehensive site-specific data needed to assign high confidence to this assessment (Table 4.3.1).

Table 4.3.1. Resource Condition Summary for Muir Woods.

Indicators of Condition	**Specific Measures**	**Condition Status**	**Rationale**
Biomass accumulation	Aboveground live biomass (AGL) accumulation (theoretical expectation)		Small increase in forest biomass from 2001 to 2010
	AGL accumulation (regional comparison)		Biomass trends improving relative to regional forests where AGL declined from 2001–2010
Future forest distributions under climate change	Predictive vegetation models		Climate niche suitable for conifer-dominated communities declines sharply by 2100
Risk of catastrophic fire	Fire hazard model		Most of the coastal forest classified as high or very high hazard but current impacts are effectively mitigated by fire management
Exotic disease progression	Tree mortality and growth as measured in field plots		Susceptible species continue to die but community wide collapse unlikely
Potential for compounding perturbations	Fuel load and future fire risk		Transient risk of more severe fire behavior associated with pathogen mortality
Overall Condition Status and Trend for Forest: Muir Woods			–

The likely but undocumented presence of *P. ramorum* at the Phleger Estate would help explain the lack of biomass accumulation in these second growth forests. In terms of the altered fire regime and climate change, the Phleger Estate likely shares the same risks as Muir Woods, but there is a notable lack of specific information for this forest. Thus the condition summary is even less certain (Table 4.3.2). Considering the trajectory of sudden oak death once it is established in a susceptible population, the potential for forest decline in the near-future is high.

Table 4.3.2. Resource Condition Summary for Phleger Estate.

Indicators of Condition	**Specific Measures**	**Condition Status**	**Rationale**
Biomass accumulation	Aboveground live biomass (AGL) accumulation (theoretical expectation)		No increase in forest biomass from 2001 to 2010 despite theoretical expectations.
	AGL accumulation (regional comparison)		Biomass trends improving relative to regional forests where AGL declined from 2001–2010
Future forest distributions under climate change	Predictive vegetation models		Climate niche suitable for conifer-dominated communities declines sharply by 2100
Risk of catastrophic fire	Fire hazard model		Most of the coastal forest classified as high or very high hazard but current impacts are effectively mitigated by fire management
Exotic disease progression	Tree mortality and growth as measured in field plots		No documented presence of P. ramorum but presence likely
Potential for compounding perturbations	Fuel load and future fire risk		No increase in disease-associated fire hazard given limited impact of the pathogen
Overall Condition Status and Trend for Forest: Phleger Estate			–

4.3.4. Information Sources

Sources of Expertise

- Alison Forrestel, Vegetation Ecologist, Golden Gate National Recreation Area
- Stephen Skartvedt, GIS Specialist, Golden Gate National Recreation Area
- David S. Saah, Associate Professor, University of San Francisco

Literature Cited

Ackerly, D.D**,** W.K. Cornwell, S.B Weiss, L.E. Flint and A.L. Flint. 2015. A geographic mosaic of climate change impacts on terrestrial vegetation: which areas are most at risk? PLoS ONE 10:e0130629.

Baguskas, S. A., S. H. Peterson, B. Bookhagen, and C. J. Still. 2014. Evaluating spatial patterns of drought-induced tree mortality in a coastal California pine forest. Forest Ecology and Management 315:43–53.

Ballanti, J., E. Hines, and B. Kruse. 2015. Tree inventory using remote sensing at Muir Woods and Kent Canyon. http://www.sfnps.org/download_product/5014/0 (accessed May 10, 2016).

Battles, J.J., P. Gonzalez, T. Robards, B.M. Collins, and D.S. Saah. 2014. Final Report: California Forest and Rangeland Greenhouse Gas Inventory Development. California Air Resources Board Agreement 10-778. http://www.arb.ca.gov/research/apr/past/10-778.pdf.

Battles, J.J., D. S. Saah, T. Robards; S. Cousins, R. A. York and D. Larson. 2013. A natural resource condition assessment for Sequoia and Kings Canyon National Parks: Appendix 12 – Intact forests. Natural Resource Report. NPS/SEKI/NRR—2013/665.12. National Park Service. Fort Collins, Colorado. Published Report-2195699.

Barbour, M., J. Loidi, G. Garcia-Baquero, R. Meyer, S. Springs, and V. Whitworth. 2014. The composition and physiognomy of forest types are strongly linked to distance inland along the northern California coast. Phytocoenologia 44:165–173.

Bormann, F. H., and G. E. Likens. 1979. Pattern and Process of a Forested System. Springer-Verlag, New York.

Brown, P. M., M. W. Kaye, and D. Buckley. 1999. Fire history in Douglas-fir and coast redwood forests at Point Reyes National Seashore, California. Northwest Science 73:205–216.

Busing, R. T., and T. Fujimori. 2005. Biomass, production and woody detritus in an old coast redwood (*Sequoia sempervirens*) forest. Plant Ecology 177:177–188.

Cal-IPC. 2016. California Invasive Plant Council. http://www.cal-ipc.org/ip/management/plant_profiles/Ehrharta_erecta.php) (accessed April 20, 2016)

Carbone, M. S., A. Park Williams, A. R. Ambrose, C. M. Boot, E. S. Bradley, T. E. Dawson, S. M. Schaeffer, J. P. Schimel, and C. J. Still. 2013. Cloud shading and fog drip influence the metabolism of a coastal pine ecosystem. Global Change Biology 19:484–497.

Carroll, A.L., S.C. Sillett and R.D. Kramer, 2014. Millennium-scale crossdating and inter-annual climate sensitivities of standing California redwoods. PloS one, 9(7), p.e102545.

Carroll, A.L. 2015. Preliminary dendrochronology at Muir Woods National Monument. http://www.sfnps.org/download_product/5098/0 (accessed May 18, 2016)

Calflora. 2016. Berkeley, California: The Calflora Database. Available: http://www.calflora.org/ (accessed Dec 12, 2015).

Cayan, D., M. Tyree, D. Pierce and T. Das. 2012. Climate change and sea level rise scenarios for California vulnerability and adaptation assessment. California Energy Commission. Publication number: CEC- 500-2012-008.

Cobb, R. C., D. M. Rizzo, K. J. Hayden, M. Garbelotto, J. A. Filipe, C. A. Gilligan, W. W. Dillon, R. K. Meentemeyer, Y. S. Valachovic, and E. Goheen. 2013. Biodiversity conservation in the face of dramatic forest disease: an integrated conservation strategy for tanoak (*Notholithocarpus densiflorus*) threatened by sudden oak death. Madroño 60:151–164.

Collins, B.M., H.A. Kramer, K. Menning, C. Dillingham, D. Saah, P.A. Stine and S.L. Stephens. 2013. Modeling hazardous fire potential within a completed fuel treatment network in the northern Sierra Nevada. Forest Ecology and Management 310:156–166.

DeAngelis, D.L., R.H. Gardner, and H.H. Shugart. 1981 Productivity of forest ecosystems studied during the IBP: the woodland dataset. In: Dynamic properties of forest ecosystems (ed. by D.E.Reichle), pp. 567–672. Cambridge University Press, Cambridge.

Donato, D. C., J. B. Fontaine, W. D. Robinson, J. B. Kauffman, and B. E. Law. 2009. Vegetation response to a short interval between high-severity wildfires in a mixed-evergreen forest. Journal of Ecology 97:142–154.

ECN. 2015. California Landscape Conservation Cooperative. Environmental Change Network. Interactive map modeling bird distribution response to climate change. http://data.prbo.org/apps/ecn/ (accessed Dec 29, 2015).

Fahey, T.J, T.G. Siccama, C.T. Driscoll, G.E. Likens, J. Campbell, C.E. Johnson, J.J. Battles, J.D. Aber, J.J. Cole, M.C. Fisk, P.M. Groffman, S.P. Hamburg, R.T. Holmes, P.A. Schwarz, and R.D. Yanai. 2005. The biogeochemistry of carbon at Hubbard Brook. Biogeochemistry 75:109–176.

Fernández, M., H. H. Hamilton, and L. M. Kueppers. 2015. Back to the future: using historical climate variation to project near-term shifts in habitat suitable for coast redwood. Global Change Biology 21:4141–4152.

Fischer, D. T., C. J. Still, and A. P. Williams. 2009. Significance of summer fog and overcast for drought stress and ecological functioning of coastal California endemic plant species. Journal of Biogeography 36:783–799.

Folke, C., S. Carpenter, B. Walker, M. Scheffer, T. Elmqvist, L. Gunderson, and C. Holling. 2004. Regime shifts, resilience, and biodiversity in ecosystem management. Annual Review of Ecology, Evolution, and Systematics 35:557–581.

Forrestel, A. B., B. S. Ramage, T. Moody, M. A. Moritz, and S. L. Stephens. 2015. Disease, fuels and potential fire behavior: Impacts of Sudden Oak Death in two coastal California forest types. Forest Ecology and Management 348:23–30.

GGNRA. 2005. The Golden Gate National Recreation Area. Fire Management Plan. Final EIS. https://parkplanning.nps.gov/document.cfm?parkID=303&projectID=46704&documentID=53624.

Gonzalez, P., J. J. Battles, B. M. Collins, T. Robards, and D. S. Saah. 2015. Aboveground live carbon stock changes of California wildland ecosystems, 2001–2010. Forest Ecology and Management 348:68–77.

Hall, S.A. and I.C. Burke. 2006. Considerations for characterizing fuels as inputs for fire behavior models. Forest Ecology and Management 227:102–114.

Hameed, S. O., K. A. Holzer, A. N. Doerr, J. H. Baty, and M. W. Schwartz. 2013. The value of a multi-faceted climate change vulnerability assessment to managing protected lands: Lessons from a case study in Point Reyes National Seashore. Journal of environmental management 121:37–47.

Hartley, R.K. 2012. Redwood forest conservation: Where do we go from here? Pages 3–10 *in* Standiford, R.B., T.J. Weller, D.D. Piirto, and J.D. Stuart (Editors). Proceedings of the Coast Redwood Forests in a Changing California: A Symposium for Scientists and Managers. US Forest Service PSW-GTR-238.

Hayden, K. J., A. Nettel, R. S. Dodd, and M. Garbelotto. 2011. Will all the trees fall? Variable resistance to an introduced forest disease in a highly susceptible host. Forest Ecology and Management 261:1781–1791.

Hunter, J., and V. Parker. 1993. The disturbance regime of an old-growth forest in coastal California. Journal of Vegetation Science 4:19–24.

Hunter, J. C. 1997. Fourteen years of change in two old-growth *Pseudotsuga-Lithocarpus* forests in northern California. Journal of the Torrey Botanical Society 124:273–279.

Jacobs, D. F., D. W. Cole, and J. R. McBride. 1985. Fire history and perpetuation of natural coast redwood ecosystems. Journal of Forestry 83:494–497.

Johnstone, J. A., and T. E. Dawson. 2010. Climatic context and ecological implications of summer fog decline in the coast redwood region. Proceedings of the National Academy of Sciences of the United States of America 107:4533–4538

Kennedy, R. E., Z. Yang, and W. B. Cohen. 2010. Detecting trends in forest disturbance and recovery using yearly Landsat time series: 1. LandTrendr – Temporal segmentation algorithms. Remote Sensing of Environment 114:2897–2910.

Lenihan, J. M., D. Bachelet, R. P. Neilson, and R. Drapek. 2008. Response of vegetation distribution, ecosystem productivity, and fire to climate change scenarios for California. Climatic Change 87:215–230.

Liebhold, A. M., W. L. MacDonald, D. Bergdahl, and V. C. Mastro. 1995. Invasion by exotic forest pests: a threat to forest ecosystems. Forest Science 41:a0001-z0001.

Lorimer, C. G., D. J. Porter, M. A. Madej, J. D. Stuart, S. D. Veirs, S. P. Norman, K. L. O'Hara, and W. J. Libby. 2009. Presettlement and modern disturbance regimes in coast redwood forests: implications for the conservation of old-growth stands. Forest Ecology and Management 258:1038–1054.

Lutz, J. A., J. R. Matchett, L. W. Tarnay, D. F. Smith, K. M. Becker, T. J. Furniss, and M. L. Brooks. 2017. Fire and the distribution and uncertainty of carbon sequestered as aboveground tree biomass in Yosemite and Sequoia & Kings Canyon National Parks. Land 6:10.

McPherson, B. A., S. R. Mori, D. L. Wood, M. Kelly, A. J. Storer, P. Svihra, and R. B. Standiford. 2010. Responses of oaks and tanoaks to the sudden oak death pathogen after 8y of monitoring in two coastal California forests. Forest Ecology and Management 259:2248–2255.

Meentemeyer, R. K., N. J. Cunniffe, A. R. Cook, J. A. Filipe, R. D. Hunter, D. M. Rizzo, and C. A. Gilligan. 2011. Epidemiological modeling of invasion in heterogeneous landscapes: spread of sudden oak death in California (1990–2030). Ecosphere 2:art17.

Metz, M. R., J. M. Varner, K. M. Frangioso, R. K. Meentemeyer, and D. M. Rizzo. 2013. Unexpected redwood mortality from synergies between wildfire and an emerging infectious disease. Ecology 94:2152–2159.

Mazurek, M.J., 2004. A maternity roost of Townsend's Big-eared Bats (Corynorhinus townsendii) in coast redwood basal hollows in northwestern California. Northwestern Naturalist 85:60–62.

NPCA. 2011. Muir Woods National Monument: A resource assessment. National Parks Conservation Association, State of the Parks. Available at www.npca.org/stateoftheparks.

NPS. 2014. Golden Gate National Recreation Area Muir Woods National Monument. Final General Management Plan/Environmental Impact Statement. National Park Service. http://parkplanning.nps.gov/projectHome.cfm?projectId=15075

Oakmapper. 2015. Monitoring sudden oak death. www.oakmapper.org (accessed December 10, 2015).

Parrish, J.D., D.P. Braun, and R.S. Unnasch. 2003. Are we conserving what we say we are? Measuring ecological integrity within protected areas. BioScience 53: 851–60.

Ramage, B. S., K. L. O'Hara, and B. T. Caldwell. 2010. The role of fire in the competitive dynamics of coast redwood forests. Ecosphere 1.

Ramage, B. S., K. L. O'Hara, and A. B. Forrestel. 2011. Forest transformation resulting from an exotic pathogen: regeneration and tanoak mortality in coast redwood stands affected by sudden oak death. Canadian Journal of Forest Research 41:763–772.

Ramage, B. S., A. B. Forrestel, M. A. Moritz, and K. L. O'Hara. 2012. Sudden oak death disease progression across two forest types and spatial scales. Journal of Vegetation Science 23:151–163.

Rapport, D.J., R. Costanza, and A.J. McMichael. 1998. Assessing ecosystem health. Trends in Ecology and Evolution 13: 397–402.

Sawyer, J.O., 2007. Forests of northwestern California. In: Barbour, M.B., Keeler-Wolf, T., Schoeherr, A.A. (Eds.), Terrestrial Vegetation of California. 3rd edition. University of California Press, Berkeley, CA, USA, pp. 253–295.

Schirokauer, D., T. Keeler-Wolf, J. Menke, and P. van der Leeden. 2003. Point Reyes National Seashore, Golden Gate National Recreation Area, and surrounding wildlands plant community classification and mapping project final report. National Park Service, Point Reyes Station, California, USA.

Sillett, S. C., R. Van Pelt, A. L. Carroll, R. D. Kramer, A. R. Ambrose, and D. Trask. 2015. How do tree structure and old age affect growth potential of California redwoods? Ecological Monographs 85:181–212.

SMCHA. 2010. San Mateo County Historical Association. Historic Resource Study for Golden Gate National Recreation Area in San Mateo County. Part V. http://www.nps.gov/goga/learn/historyculture/upload/San-Mateo-HRS-Part-V-Phleger-Estate.pdf.

Stillwater Sciences. 2011. Final report: Redwood Creek Watershed Assessment. Prepared for Golden Gate National Recreation Area. Berkeley, CA.

Su, Y, Q. Guo, D. L. Fry, B. M. Collins, N.M. Kelly, J. P. Flanagan , and J. J. Battles. 2015. A vegetation mapping strategy for conifer forests by combining airborne lidar data and aerial imagery. Canadian Journal of Remote Sensing 42:1–15.

Stralberg, D., D. Jongsomjit, C. A. Howell, M. A. Snyder, J. D. Alexander, J. A. Wiens, and T. L. Root. 2009. Re-shuffling of species with climate disruption: a no-analog future for California birds. PloS one 4:e6825.

Swiecki, T. J. and E. Bernhardt. 2006. Disease risk factors and disease progress in coast live oak and tanoak affected by *Phytophthora ramorum* canker (sudden oak death). In: Frankel, Susan J.; Shea, Patrick J.; and Haverty, Michael I., tech. coords. Proceedings of the sudden oak death second science symposium: the state of our knowledge. USDA Gen. Tech. Rep. PSW-GTR-196.

Tierney, G. L., D. Faber-Langendoen, B. R. Mitchell, W. G. Shriver, and J. P. Gibbs. 2009. Monitoring and evaluating the ecological integrity of forest ecosystems. Frontiers in Ecology and the Environment 7:308–316.

Valachovic, Y. S., C. A. Lee, H. Scanlon, J. M. Varner, R. Glebocki, B. D. Graham, and D. M. Rizzo. 2011. Sudden oak death-caused changes to surface fuel loading and potential fire behavior in Douglas-fir-tanoak forests. Forest Ecology and Management 261:1973–1986.

van Doorn, N. S., J.J. Battles, T.J. Fahey, T.G. Siccama, and P.A. Schwarz. 2011. Links between biomass and tree demography in a northern hardwood forest: A decade of stability and change in Hubbard Brook Valley, New Hampshire. Canadian Journal of Forest Research 41: 1369–1379.

Van Pelt, R., S. C. Sillett, W. A. Kruse, J. A. Freund, and R. D. Kramer. 2016. Emergent crowns and light-use complementarity lead to global maximum biomass and leaf area in Sequoia sempervirens forests. Forest Ecology and Management 375:279–308.

Whittaker, R. H. 1975. Communities and ecosystems. 2nd edition. Macmillan Publishing, New York.

Zhu, K., C. W. Woodall, and J. S. Clark. 2012. Failure to migrate: lack of tree range expansion in response to climate change. Global Change Biology 18:1042–1052.

4.4. Invasive Plants

The number of invasive plant species and the extent of area invaded are high and continue to increase. Confidence in existing data is limited by the non-systematic temporal and spatial coverage of past sampling efforts.



4.4.1. Why Focal Resource Was Assessed

Description

The current rate of invasive species introductions is unprecedented, and the dramatic impacts of invasive plant species on community and ecosystem function have been well documented (Vitousek and Walker 1989, D'Antonio and Vitousek 1992, Gordon 1998, Mack et al. 2000). Invasive species have been directly linked to the replacement of dominant native species (Tilman 1999), the loss of rare species (King 1985), changes in ecosystem structure, alteration of nutrient cycles and soil chemistry (Ehrenfeld 2003), shifts in community productivity (Vitousek 1990), reduced agricultural productivity, and changes in water availability (D'Antonio and Mahall 1991). Often the damage caused by these species to natural resources is irreparable and our understanding of the consequences incomplete.



Golden Gate National Parks Conservancy employee gathers data on an invasive *Cotoneaster* shrub. NPS Photo.

The National Park Service defines non-native plants as plant species that occur in a given location as a result of direct, indirect, deliberate, or accidental actions by humans. Invasive plants are non-native plants that have been introduced to new areas beyond their native ranges, adversely affect these habitats and bioregions, and have aggressive characteristics. Their effects can be economic, environmental, and/or ecological. For the National Park Service, the consequences of these invasions

present a significant challenge to the management of the agency's natural resources "unimpaired for the enjoyment of future generations." National Parks, like other land management organizations, are inundated by new non-native species arriving through predictable (*e.g.*, road, trail, and riparian corridors), sudden (*e.g.*, long-distance dispersal through cargo containers and air freight), and unexpected anthropogenic pathways (*e.g.*, weed seeds in restoration planting mixes). Non-native plants claim an estimated 4,600 acres of public lands each year in the United States (Asher and Harmon 1995), significantly altering local flora. Invasive plants infest an estimated 2.6 million of the 83 million acres managed by the NPS (Welch et al. 2014).

Given the extraordinary biodiversity of the San Francisco Bay Area and urban development pressures, GOGA serves as crucial habitat for many native species. Invasive plants threaten many of these rare species. For example, in GOGA, 25 species of exotic plants have been noted as directly threatening rare plant populations (NPS 2004). GOGA is an unusual unit in the NPS in that it has many disjunct properties and a high ratio of urban interface along a lengthy and fragmented boundary. Many GOGA lands also have a long history of military and ranching use prior to their inclusion in the NPS. Because of these and other potential human activity vectors for the spread of invasive plants, GOGA has a great interest in understanding how invasive plants occur on the landscape. Further introductions and rates of invasion may be reduced by identifying natural and human invasion pathways and prioritizing the species and areas most in need of management.

To assess invasive plants in GOGA, we analyzed available datasets and reports to address the following critical questions:

- Which invasive plants are present in the park and what are their distributions?
- What are the most heavily invaded areas in GOGA?
- What has been the rate of spread of high priority invasive plant species since initial mapping was completed in 1987?
- How many new invasive species (i.e., formerly unknown in the park) are detected in GOGA each year?
- How does survey effort impact the number of invasive species detected per subwatershed each year?

4.4.2. How Focal Resource Was Assessed

Measures

Several metrics were selected to assess the extent of exotic plant invasion and the potential for future introductions/spread of invasive plants in each management zone: the number of invasive species present, the rate of spread of high priority plant species, the extent of area invaded, and the number of new introductions per year. We used these metrics together to generate an overall assessment of invasive plant species in GOGA.

Data Sources

Parkwide Data Surveys of invasive, non-native plants were initiated at GOGA in 1987. These surveys were conducted by qualified botanists who hand-mapped species infestation sizes and

distributions using USGS quad maps. In 1995 GOGA began collecting invasive plant species data on the Presidio and in Gerbode Valley using GPS equipment (Thomas 1987). Most of this survey work was conducted by AmeriCorps interns or volunteers. Between 1996 and 1998 survey and monitoring efforts were continued for specific species. However, these surveys were not always well-planned and were inconsistently implemented. Different park programs and projects used a variety of mapping protocols based upon their variable needs and available resources. As a result, GOGA has a wealth of invasives information but it is highly disjointed. Inconsistencies in data availability and methodology limit the usefulness of much of this data. The analysis portion of the invasives condition assessment is focused only on Marin County lands. This is because San Francisco and San Mateo lands either lack sufficient baseline data or are small, fragmented parcels where a landscape scale analysis would not be meaningful.

Several datasets were included in this analysis. In addition to the hand mapped 1987 data described above, we used a compilation of datasets primarily collected from 2006–2014. Important internal data sources included: vegetation managers provided data from areas planned for weed treatment during the 2015 calendar year, invasive plant treatment and assessment data from Geoweed, data provided by GGNPC Projects and Park Stewardship teams, and historical data on the NPS GIS server. In a few cases, data collected prior to 2006 was included in this dataset if it was determined that these data reflect current species distributions on the ground and that these data were not captured in any more recent mapping effort. This assessment also relied on data collected as part of the SFAN (San Francisco Bay Area Network) Early Detection of Invasive Species program. Below, we briefly describe this database. A complete description of the sampling methods, scheduling, data management, and data collection is provided in the Early Detection protocol (Williams et al. 2009).

Early Detection Data

Exotic species were prioritized for monitoring and treatment based on current knowledge and rankings of invasive plant distribution in the GGNRA (using the work performed database) beginning in 2008 (see Williams 2009 for details). This included summing recognized invasiveness and stratifying by feasibility of control based on categories of actual or estimated infested acreage in the park. Based on best available knowledge, species priority levels were ranked higher for invasive species believed to alter ecosystems and for species that endangered rare plants in SFAN parks. Next, based on best available knowledge, species were ranked by ease of control independent of number of acres infested. All points were summed for the overall invasiveness score, then sorted according to feasibility of control based on number of acres infested with that species, cost for removal, politics, and access. Species lists were updated annually for the following field season.

Data was collected at the sub-watershed level. GOGA manages all or part of 30 watersheds and 118 subwatersheds. The list of priority areas where monitoring would take place was generated in 2008, the year prior to full-protocol implementation. This was done by ranking subwatersheds using their number and degree of current infestations, risk of further infestations, and priority of natural resources present. Thirty-eight of the subwatersheds in GOGA were deemed at high risk of invasion and harm to significant biological resources. Within GOGA, all roads and trails in high-priority subwatersheds are visited annually. In addition, one-fifth of all other subwatersheds are surveyed

annually, noting presence and absence of priority exotic species. Using this system, a complete survey of GOGA trails and roads is completed every five years.

Searches for invasive plants were conducted by teams of one to four individuals along trails and roads within the parks. The official search area used for recording both positive (plant occurrence) and negative data (areas where target plants were not found) was restricted to 5 meters on either side of the route. Along the survey route observers recorded location and associated biological information (phenology, habitat, distribution) of priority target plant populations that were encountered. The level of detail for data collection was dictated by the ranking of the plant on the priority list and the extent of the infestation (Williams 2009). Data collection ranged from simple (presence/absence) for low-priority species to complex (digital point and polygon data, as well as associated phenological and habitat data) for high-priority species. Control survey data was not collected. This data was collected in tandem with ongoing park invasive plant management programs.

Methods

To assess the status of invasive plants by management zone we ranked four metrics: the number of invasive species present, the rate of spread of high priority plant species, the extent of area invaded, and the number of new introductions per year. We used these metrics together to generate an assessment of potential invasive plant impacts in each management zone and an overall assessment of invasive plant species in GOGA. For these analyses, the initial 1987 surveys are used as baseline data and levels of current infestation are determined from compilation of the datasets described above collected primarily from 2006 to 2014. Management zones were rated as green (low concern), yellow (moderate concern), or red (high concern). The number of invasive plant species present in each management zone was ranked as follows: green for no invasive species, yellow for 1 to 5 invasive species, and red for more than 5 invasive species. The rate of spread, from 1987 to present, of high priority plant species was rated green for less than 10 acres, yellow for 10 to 25 acres, and red for more than 25 acres. The extent of area invaded was ranked green for less than 5%, yellow for between 5% and 10%, and red for greater than 10%. The number of new introductions per year, as recorded in the early detection data, was rated green for no new invasive species, yellow for 1 to 3 new invasive species, and red for more than 3 new invasive species. We adopted the suggested aggregation rule set used in State of the Park reporting in which the overall assessment of the condition for a resource is based on a combination of the status of multiple indicators. The individual metrics were ranked by technical experts and then averaged by management zone. To determine the combined condition, each red symbol is assigned zero points, each yellow symbol is assigned 50 points, and each green symbol 100 points. Open circles are omitted from the calculation. Once the average is calculated, the following scale is applied to determine the resulting condition score: 0–33 red, 34–66 yellow, and 67–100 green.

Reference Conditions/Values

The distribution and abundance of invasive plants in GOGA was assessed by comparison to historic conditions. The selected reference condition was pre-European settlement or no invasive plants.

4.4.3. Condition Assessment

Condition and Trend

Which invasive plants are present in the park and what are their distributions?

The GOGA Vegetation Management Program is actively managing more than 140 different invasive plant species. There are 17 invasive plant species that were identified as the focus for the distribution and rate of spread analyses because they are both high management priorities and have sufficient data available to warrant analysis (Table 4.4.1). The I&M Early Detection program monitors 174 invasive plant species in GOGA. This list is updated annually in order to reflect early detection priorities. In 2014, the list of priority invasive species in GOGA included 123 species (Appendix 4.4.1) with 62 of these species considered highly invasive.

Table 4.4.1 Focal invasive plant species for this analysis. These species are both high management priorities and have sufficient data available.

Species	**Common Name**
Acacia sp.	Acacia
Ageratina adenophora	Thoroughwort, Eupatorium
Arctotheca prostrata	Cape weed
Cortaderia sp.	Pampas grass, Jubata grass
Cotoneaster sp.	Cotoneaster
Cupressus macrocarpa,	Monterey cypress
Cytisus scoparius	Scotch broom
Cytisus striatus	Portugese broom, striated broom
Delairea odorata	Cape ivy
Ehrharta erecta	Ehrharta, veldt grass
Eucalyptus globulus	Eucalyptus
Festuca arundinacea	Tall fescue
Genista monspessulana	French broom
Helichrysum petiolare	Helichrysum, Licorice plant
Leucanthemum vulgare	Ox-eye daisy
Phalaris aquatica	Harding grass
Pinus radiata	Monterey pine

Invasive plant species have been documented on more than 25% of the acres in GOGA. Figures 4.4.1, 4.4.2, and 4.4.3 show the wide distribution of invasive plants in the three regions of the park: Marin County, San Francisco, and San Mateo County. Note that these maps likely underestimate the total area invaded because not all park lands have been surveyed and, therefore, the areas not mapped as invaded may have no invasive plants present or may have not been surveyed. We did not have presence-absence data available to definitively indicate the areas with no invasive plant species present.

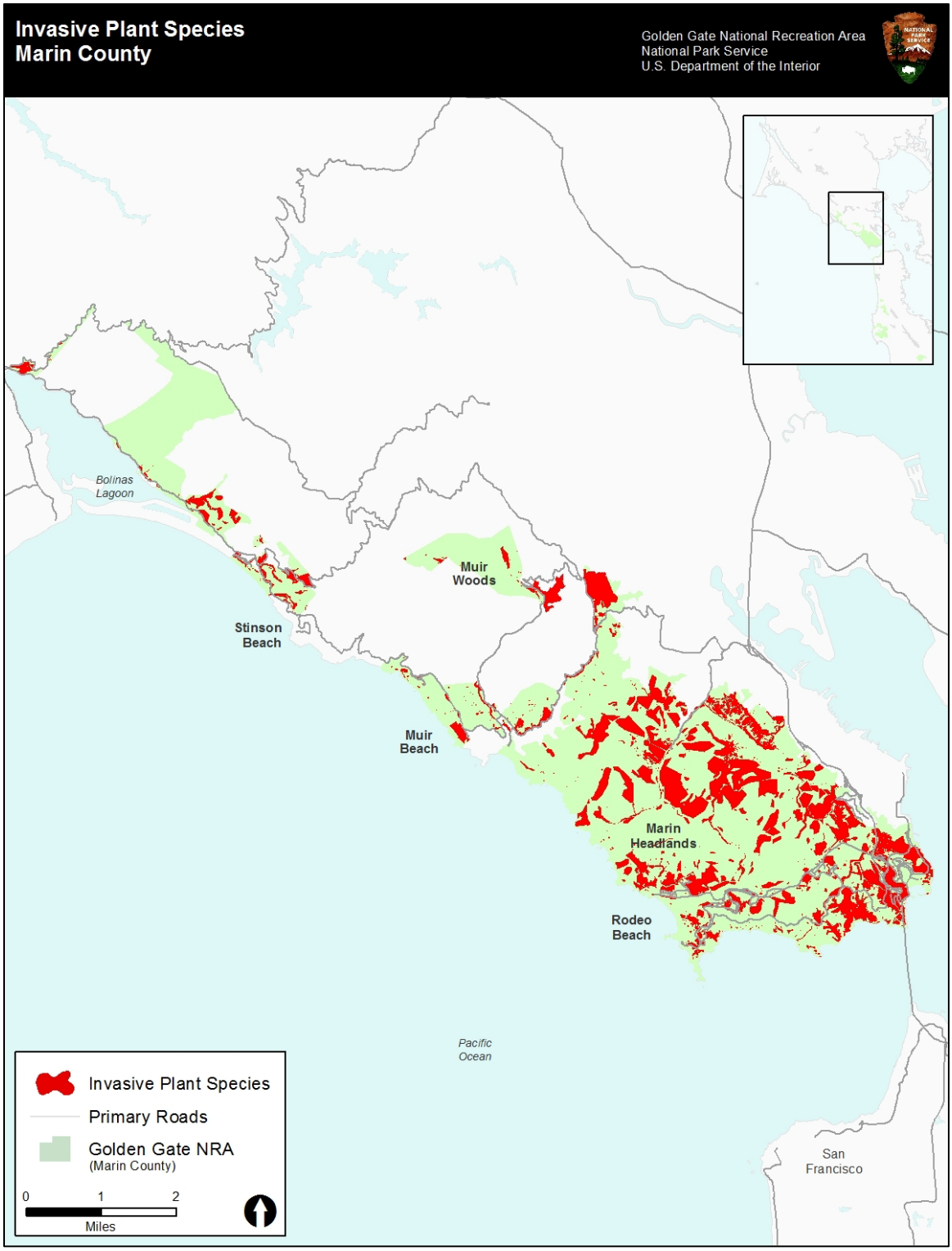


Figure 4.4.1. Overview of invasive plant species locations mapped in GOGA managed lands in Marin County. Note that, because not all park lands have been surveyed, the areas not labeled as invaded on this map are not necessarily free of invasive plants (NPS).

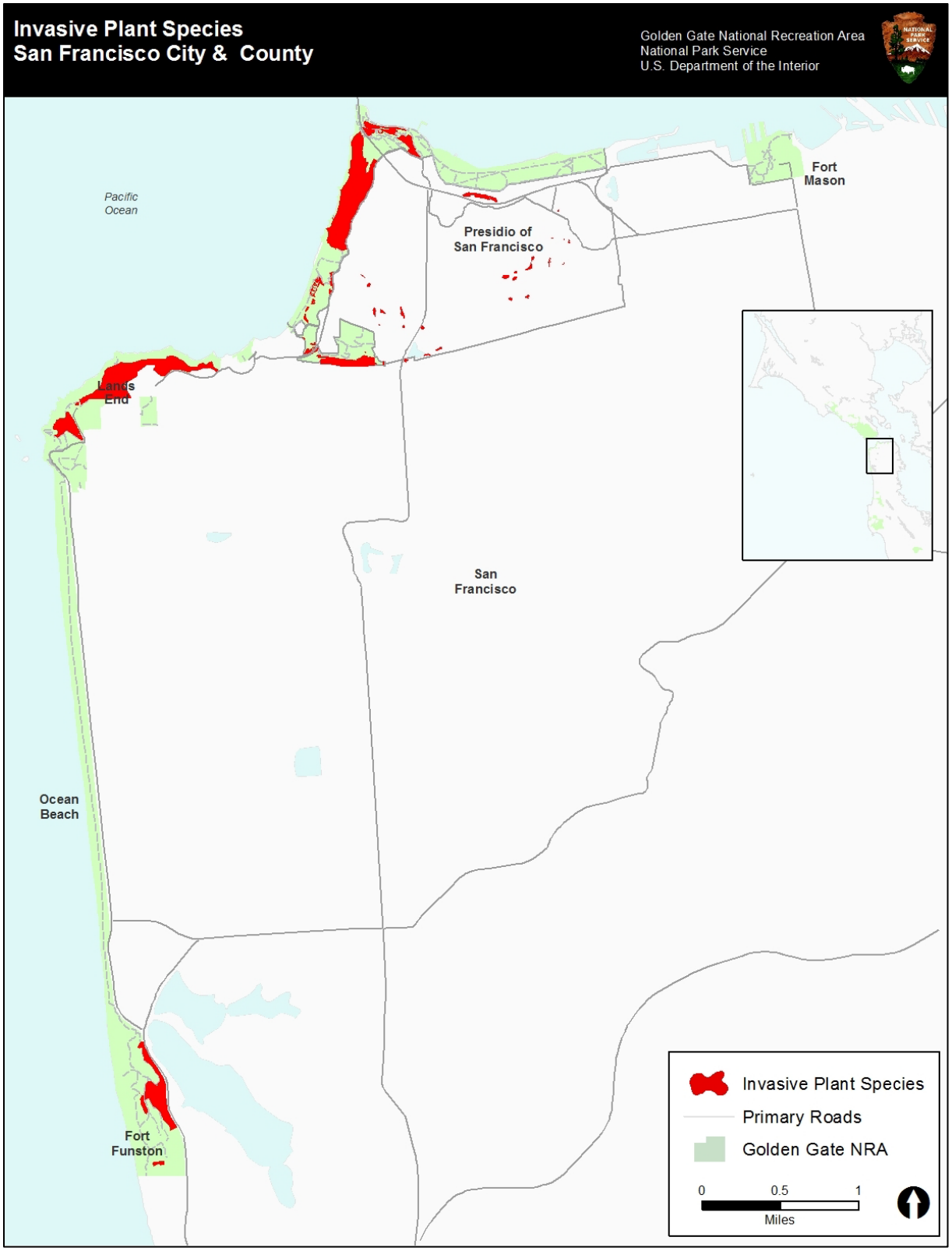


Figure 4.4.2. Overview of invasive plant species locations mapped in GOGA lands in San Francisco. Note that, because not all park lands have been surveyed, the areas not labeled as invaded on this map are not necessarily free of invasive plants (NPS).

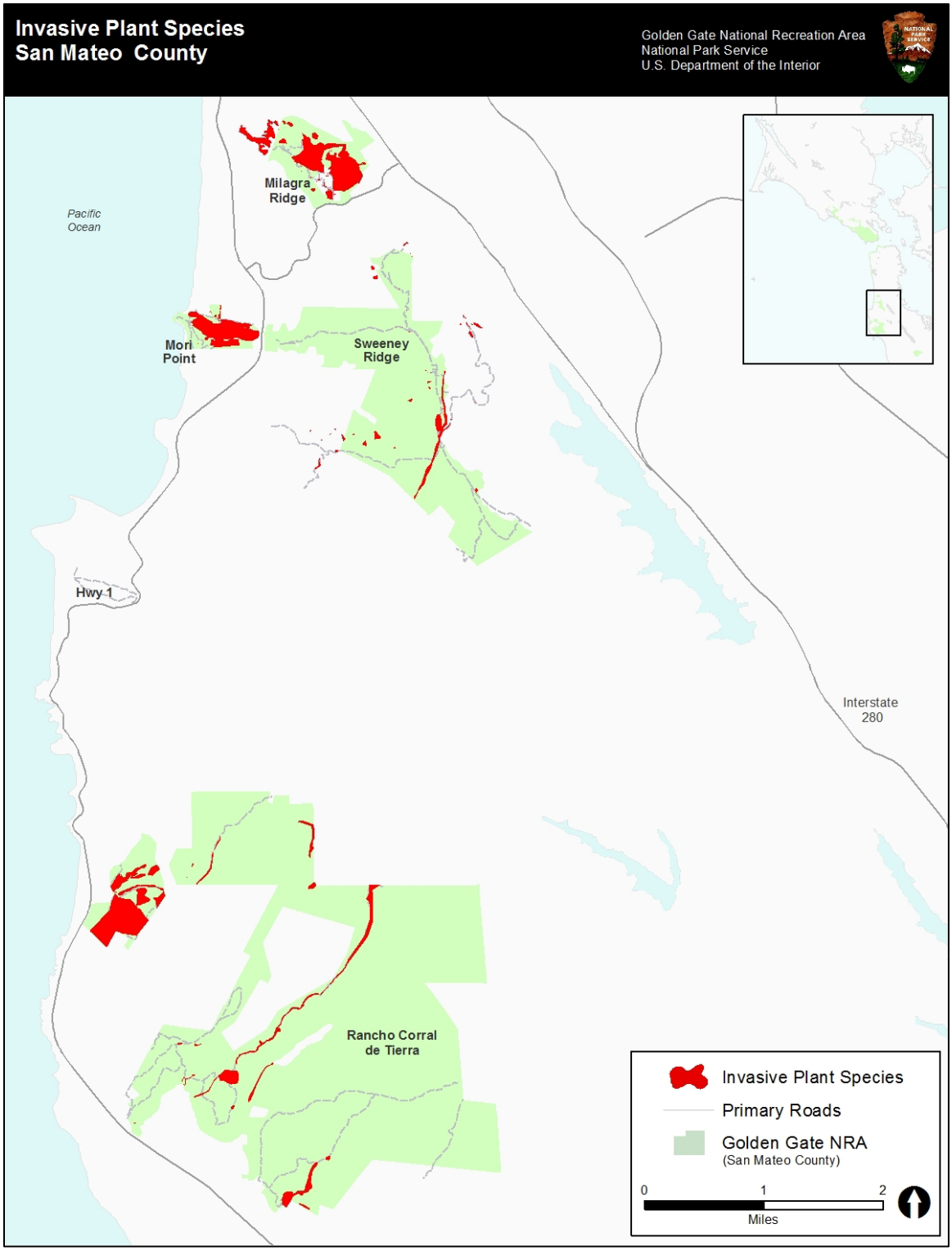


Figure 4.4.3. Overview of invasive plant species locations mapped in GOGA lands in San Mateo County. Note that, because not all park lands have been surveyed, the areas not labeled as invaded on this map are not necessarily free of invasive plants (NPS).

Figures 4.4.4 through 4.4.21 illustrate the distribution of the focal invasive plant species included in this analysis using the most recent mapping data. From this analysis, the most widely distributed of the high priority species include *Ageratina adenophora* and *Genista monspessulana* which have been documented in relatively large areas and with populations dispersed throughout the park.

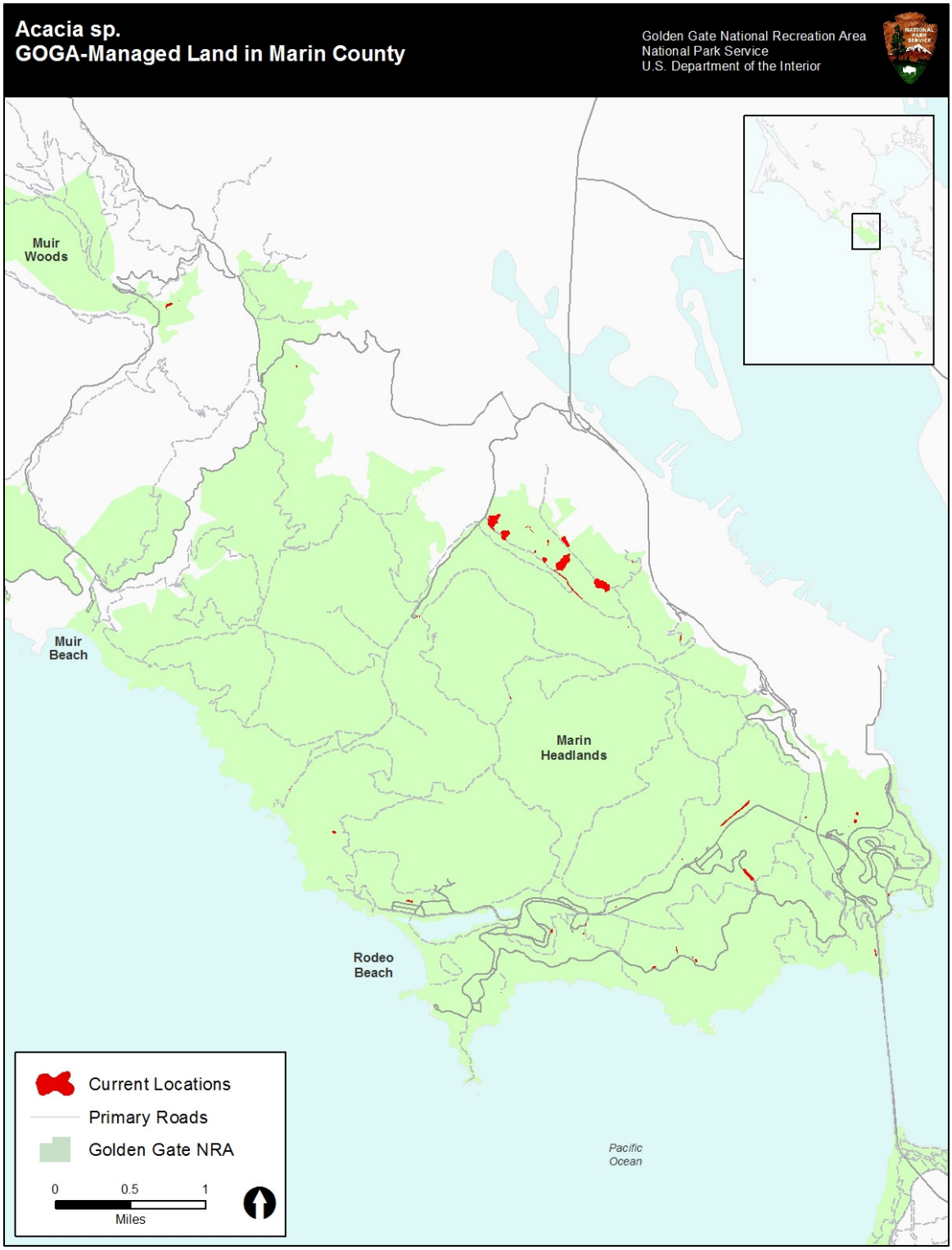


Figure 4.4.4a. Recorded distribution of *Acacia* spp. in southern GOGA managed lands in Marin County (NPS).



Figure 4.4.4b. Recorded distribution of *Acacia* spp. in northwestern GOGA managed lands in Marin County. Due to the small size of recorded *Acacia* spp. patches in this region, *Acacia* spp. distribution is displayed as points in this map. Each point represents an area 0.5 acres or smaller (NPS).

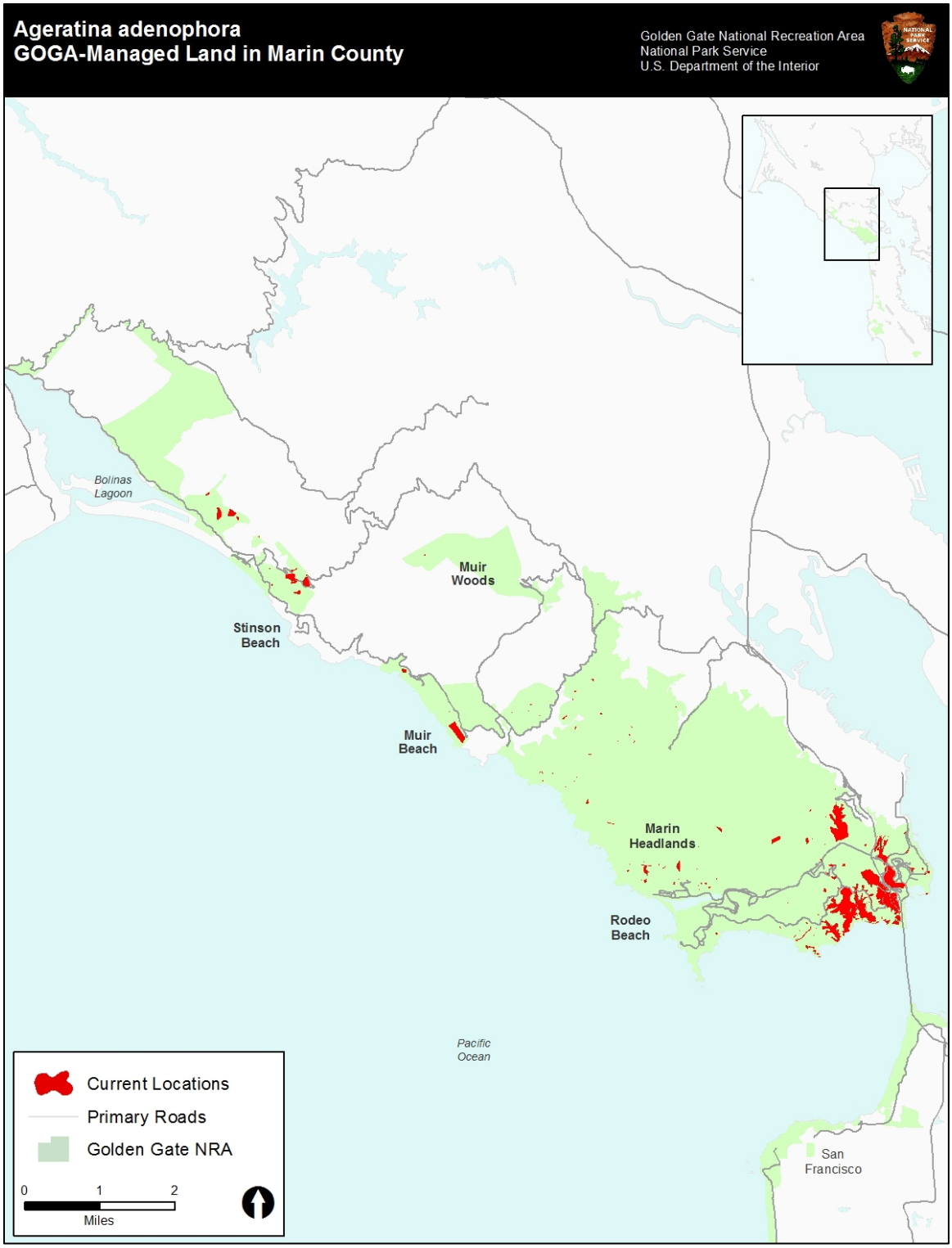


Figure 4.4.5. Recorded distribution of *Ageratina adenophora* in GOGA managed lands in Marin County (NPS).

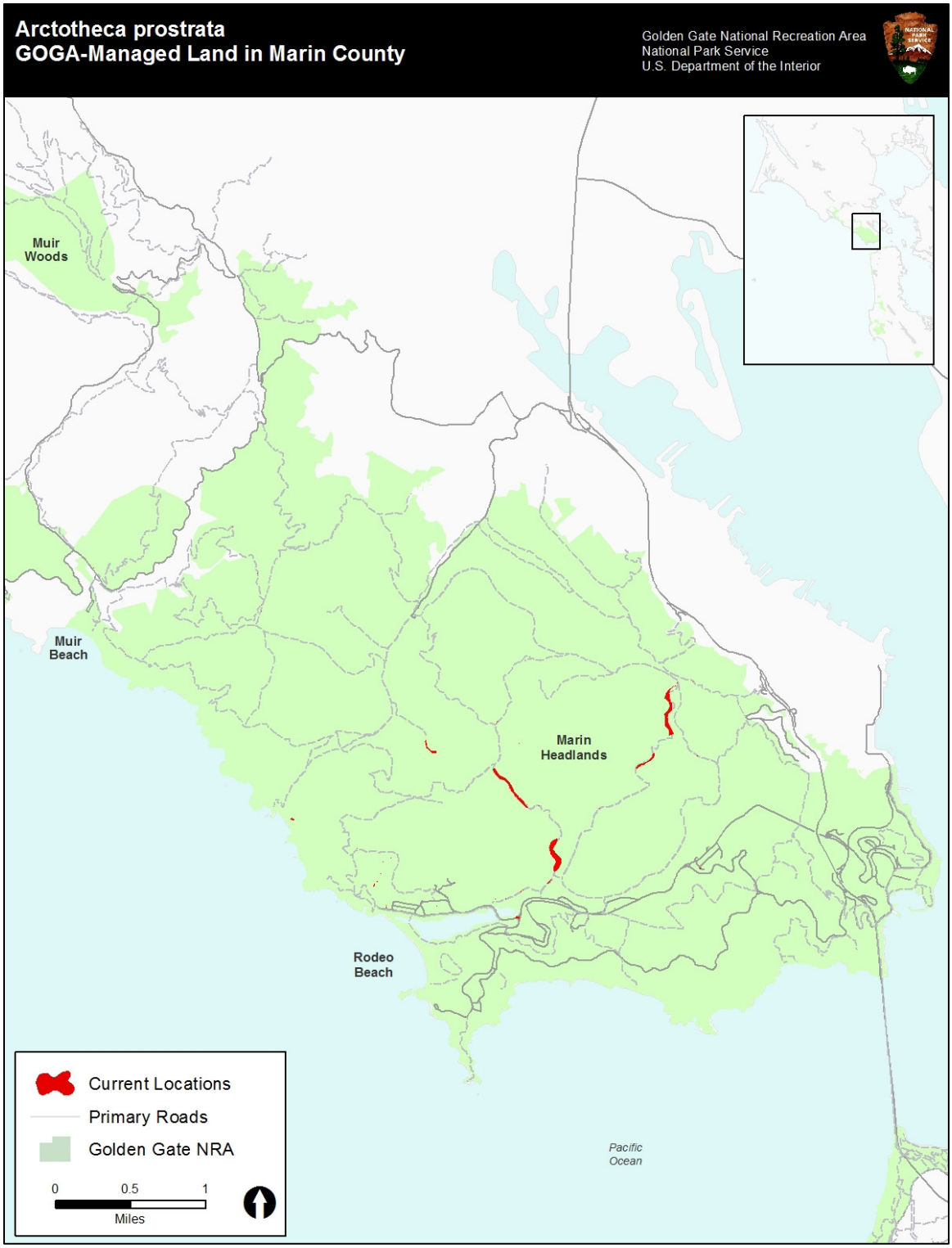


Figure 4.4.6. Recorded distribution of *Arctotheca prostrata* in GOGA managed lands in Marin County (NPS).

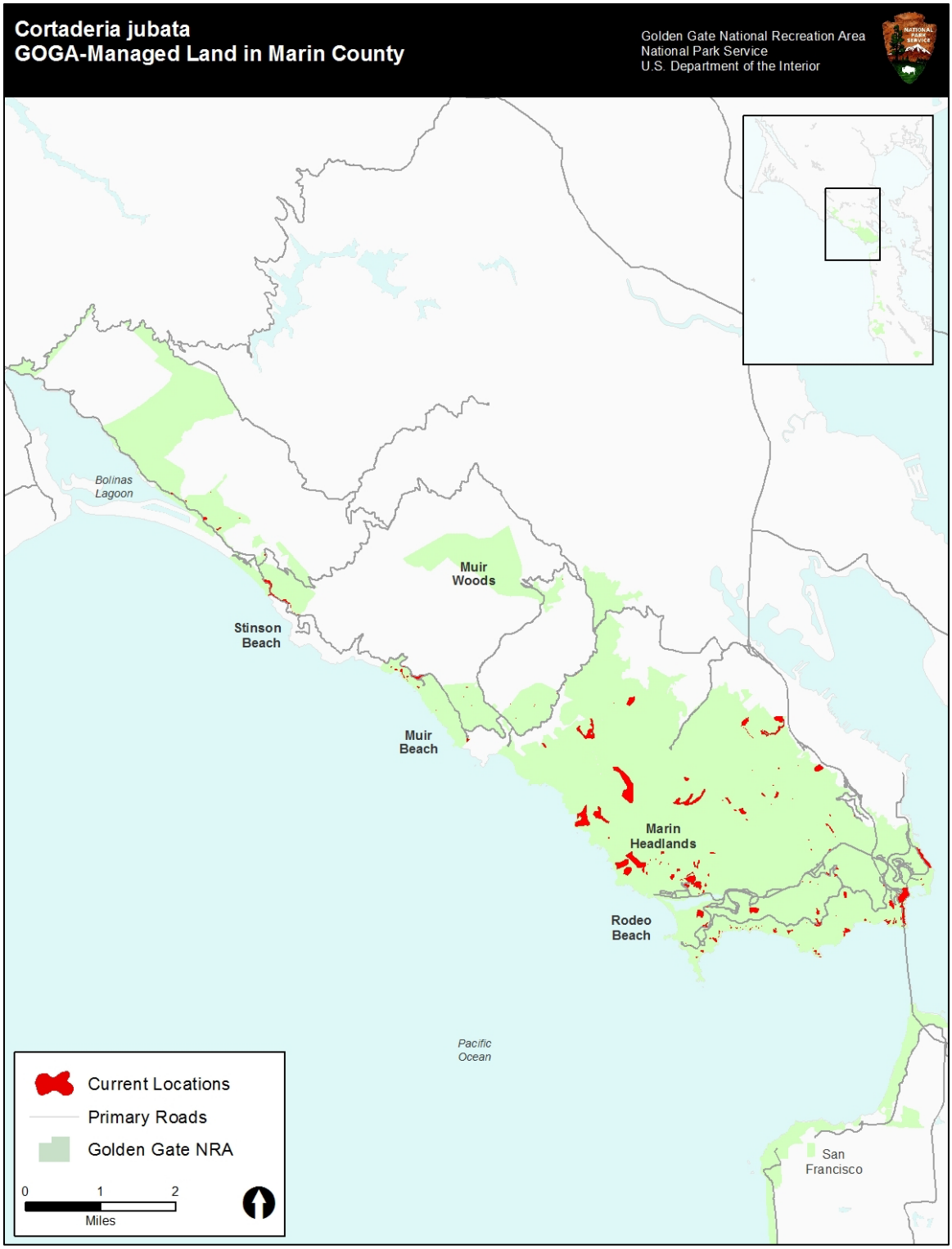


Figure 4.4.7. Recorded distribution of *Cortaderia jubata* in GOGA managed lands in Marin County (NPS).

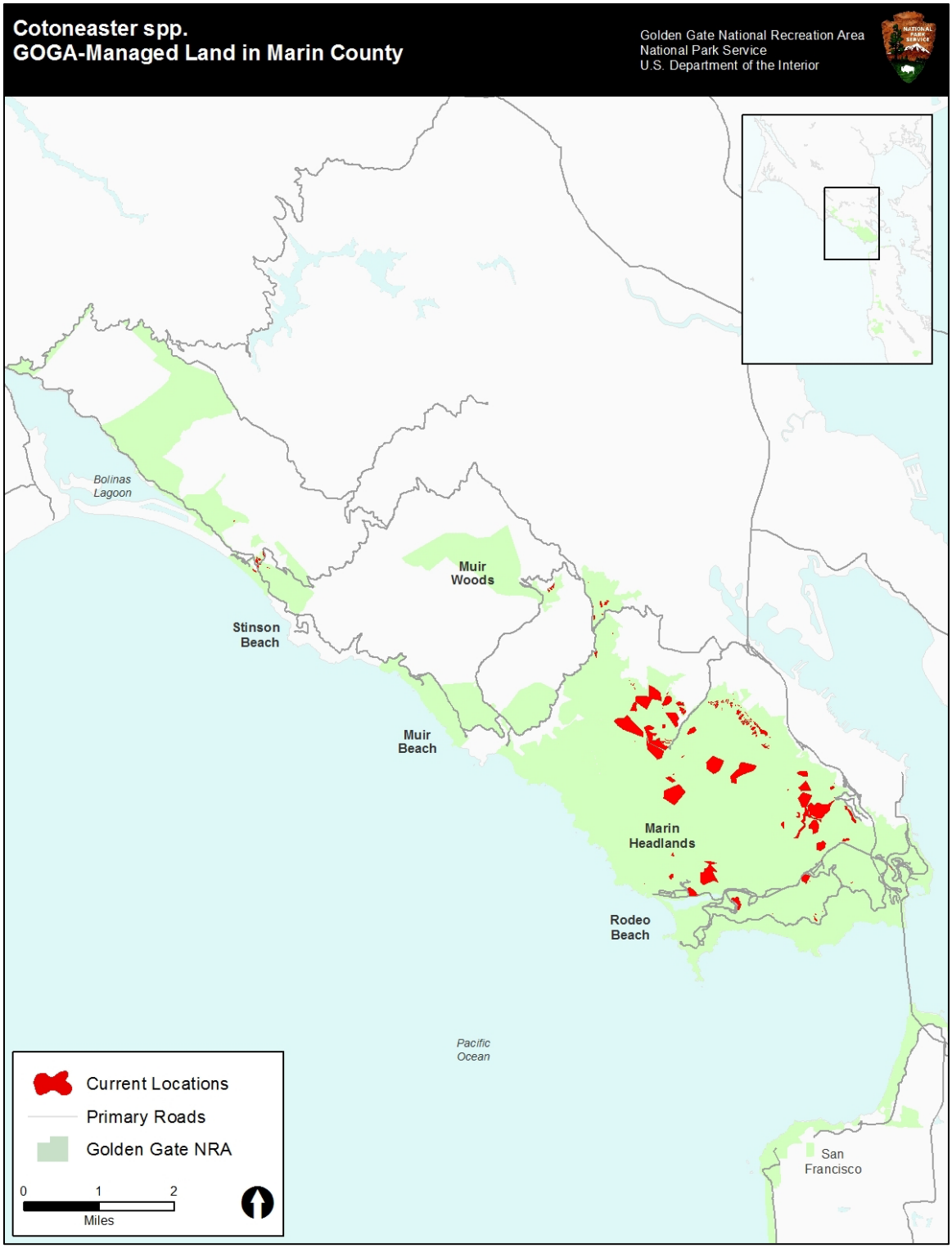


Figure 4.4.8. Recorded distribution of *Cotoneaster* spp. in GOGA managed lands in Marin County (NPS).

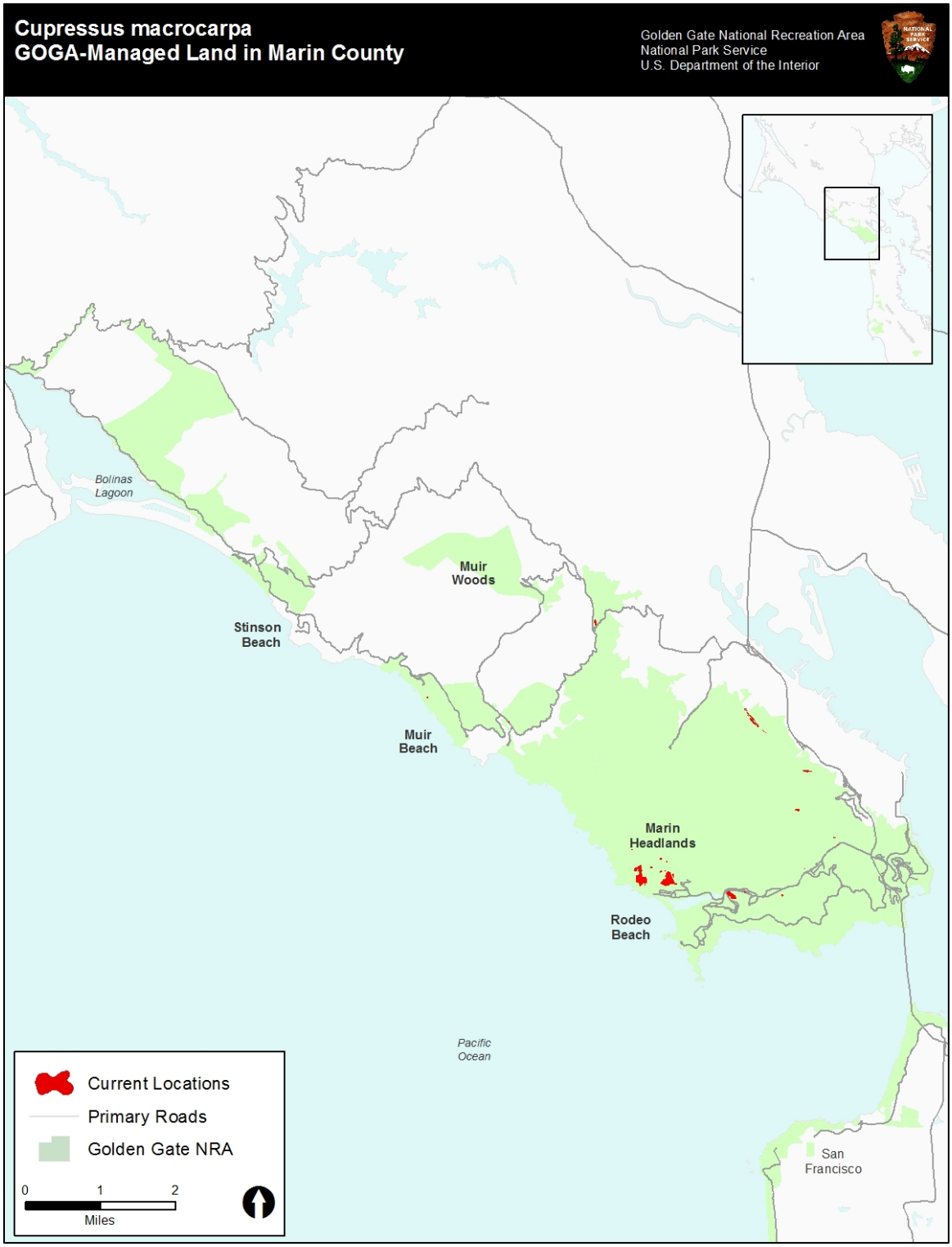


Figure 4.4.9. Recorded distribution of *Cupressus macrocarpa* in GOGA managed lands in Marin County (NPS).

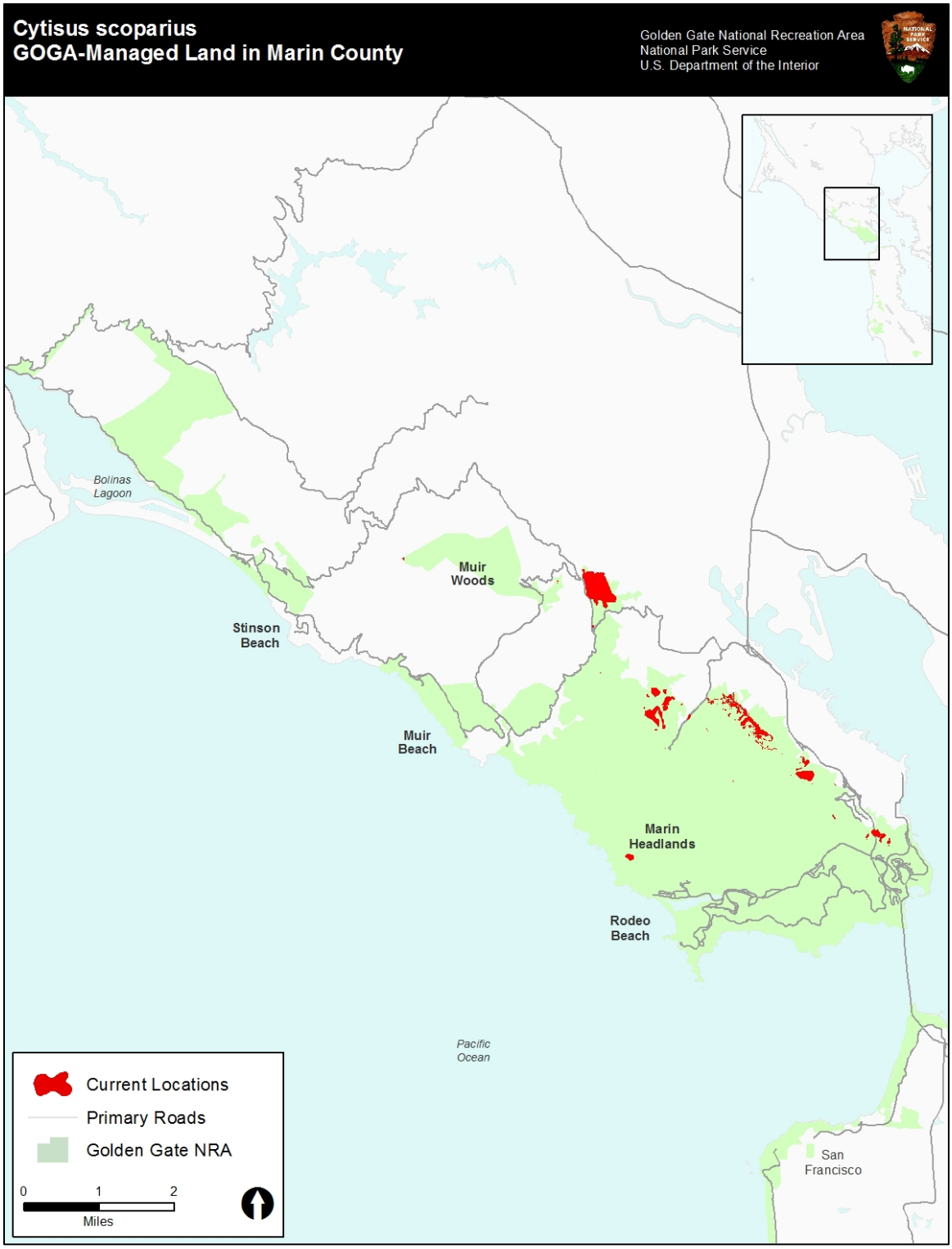


Figure 4.4.10. Recorded distribution of *Cytisus scoparius* in GOGA managed lands in Marin County (NPS).

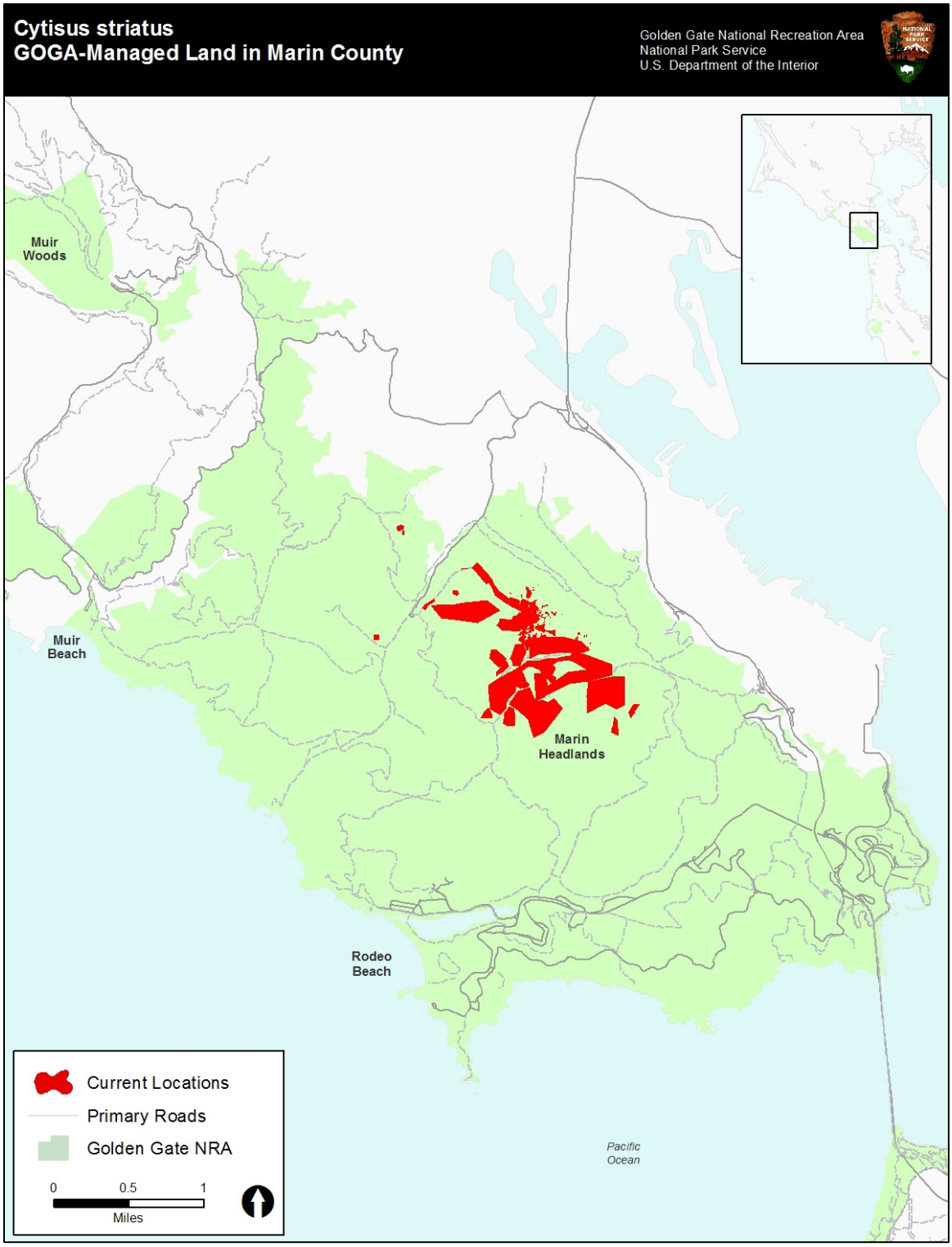


Figure 4.4.11. Recorded distribution of *Cytisus striatus* in GOGA managed lands in Marin County (NPS).

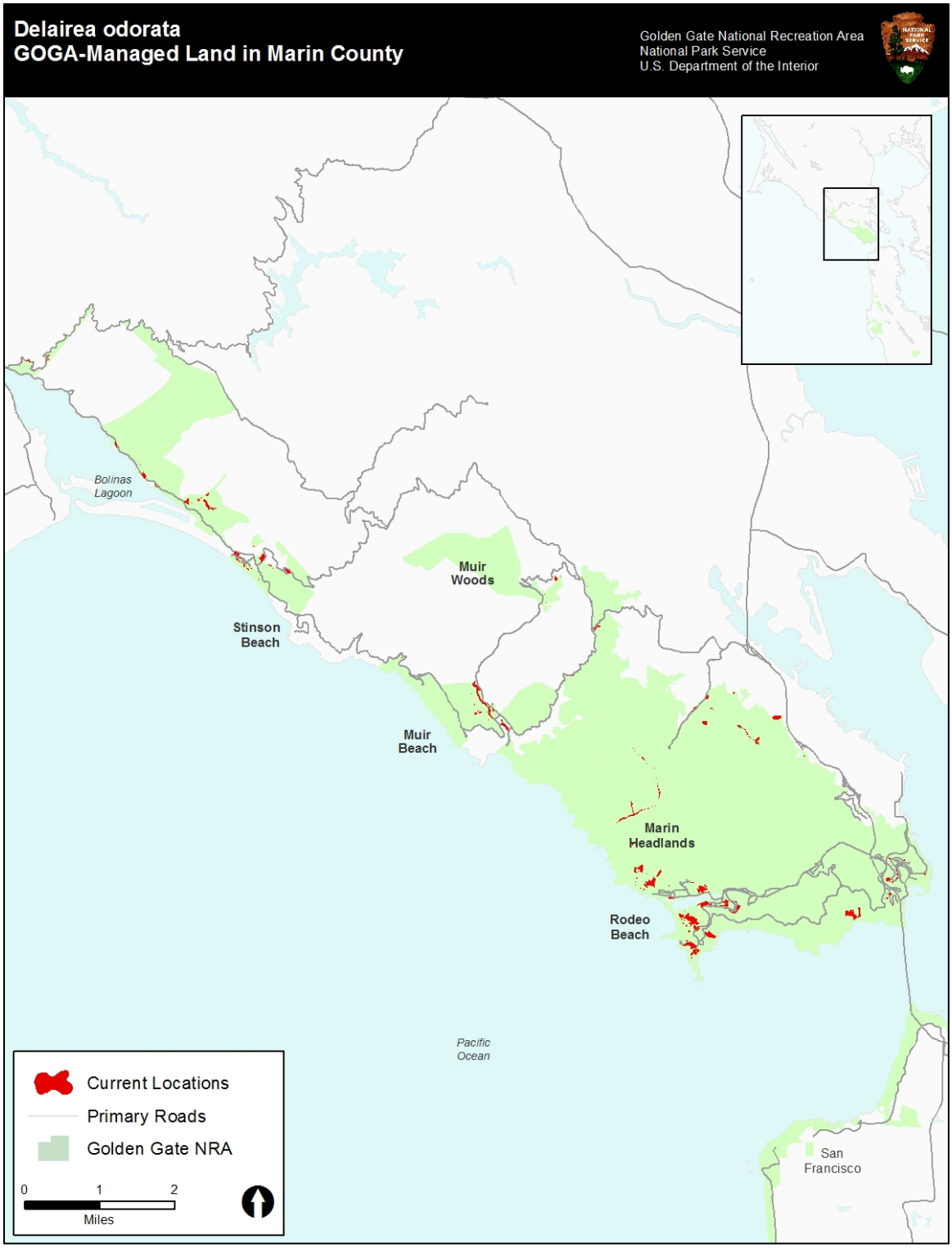


Figure 4.4.12. Recorded distribution of *Delairea odorata* in GOGA managed lands in Marin County (NPS).

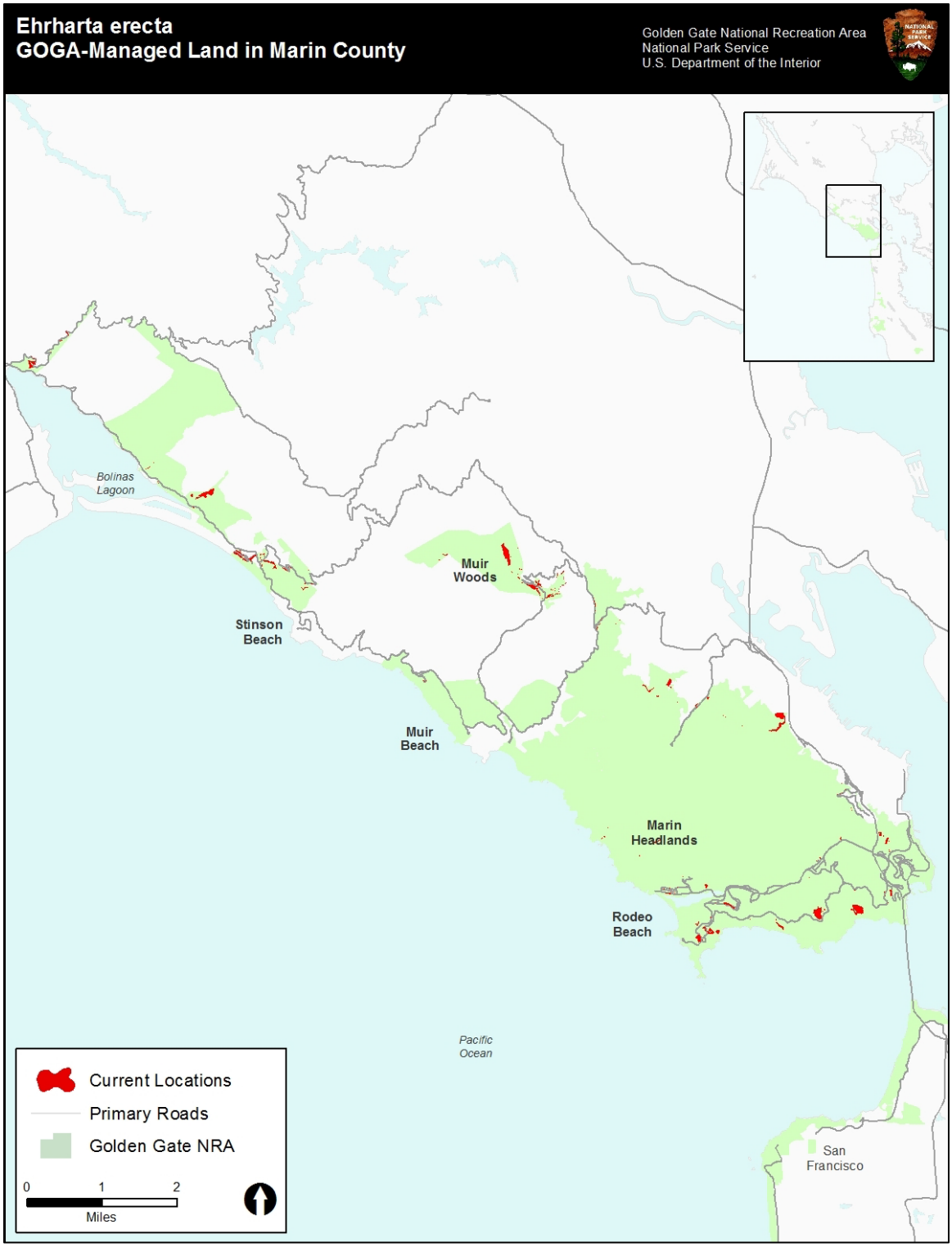


Figure 4.4.13. Recorded distribution of *Ehrharta erecta* in GOGA managed lands in Marin County (NPS).

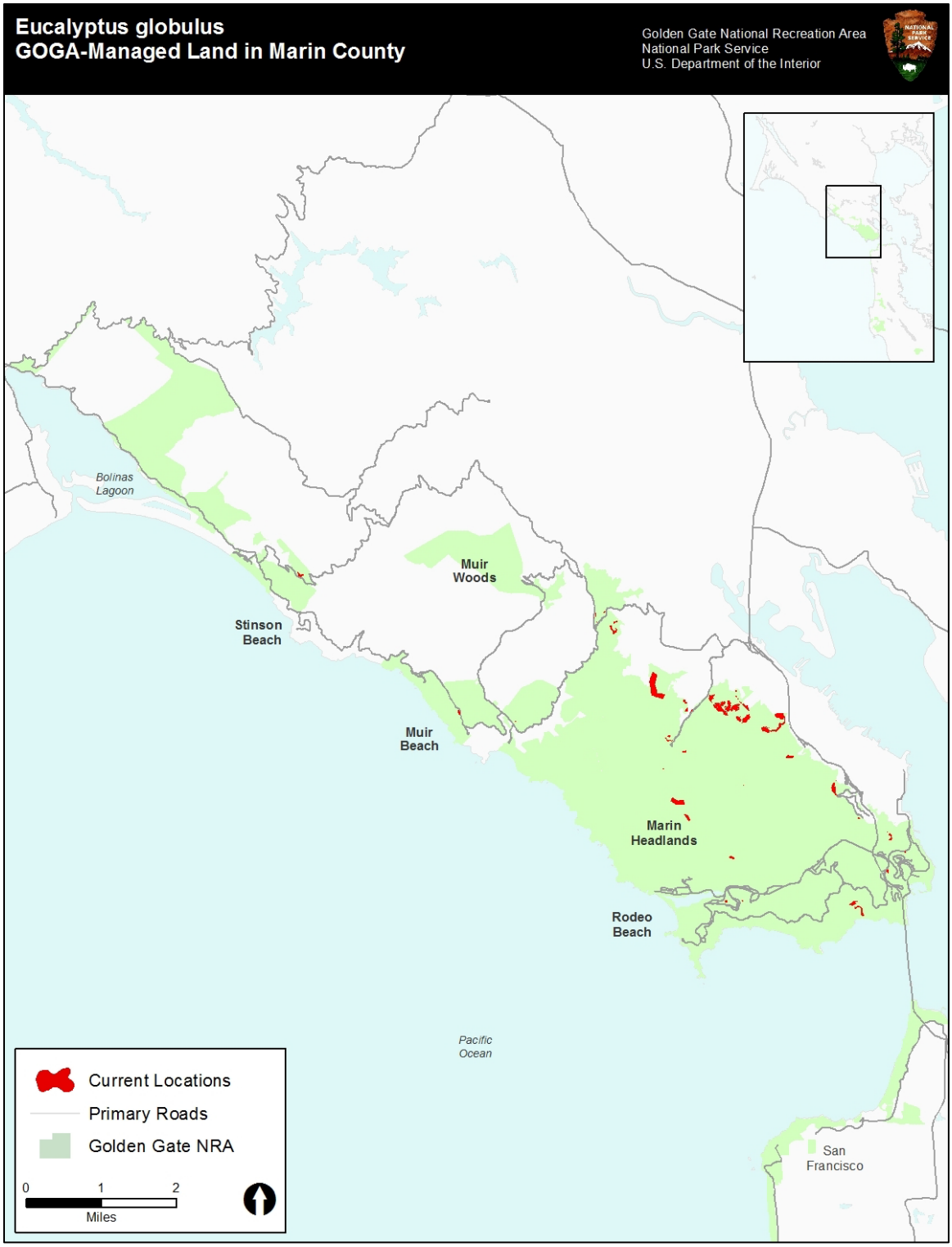


Figure 4.4.14. Recorded distribution of *Eucalyptus globulus* in GOGA managed lands in Marin County (NPS).

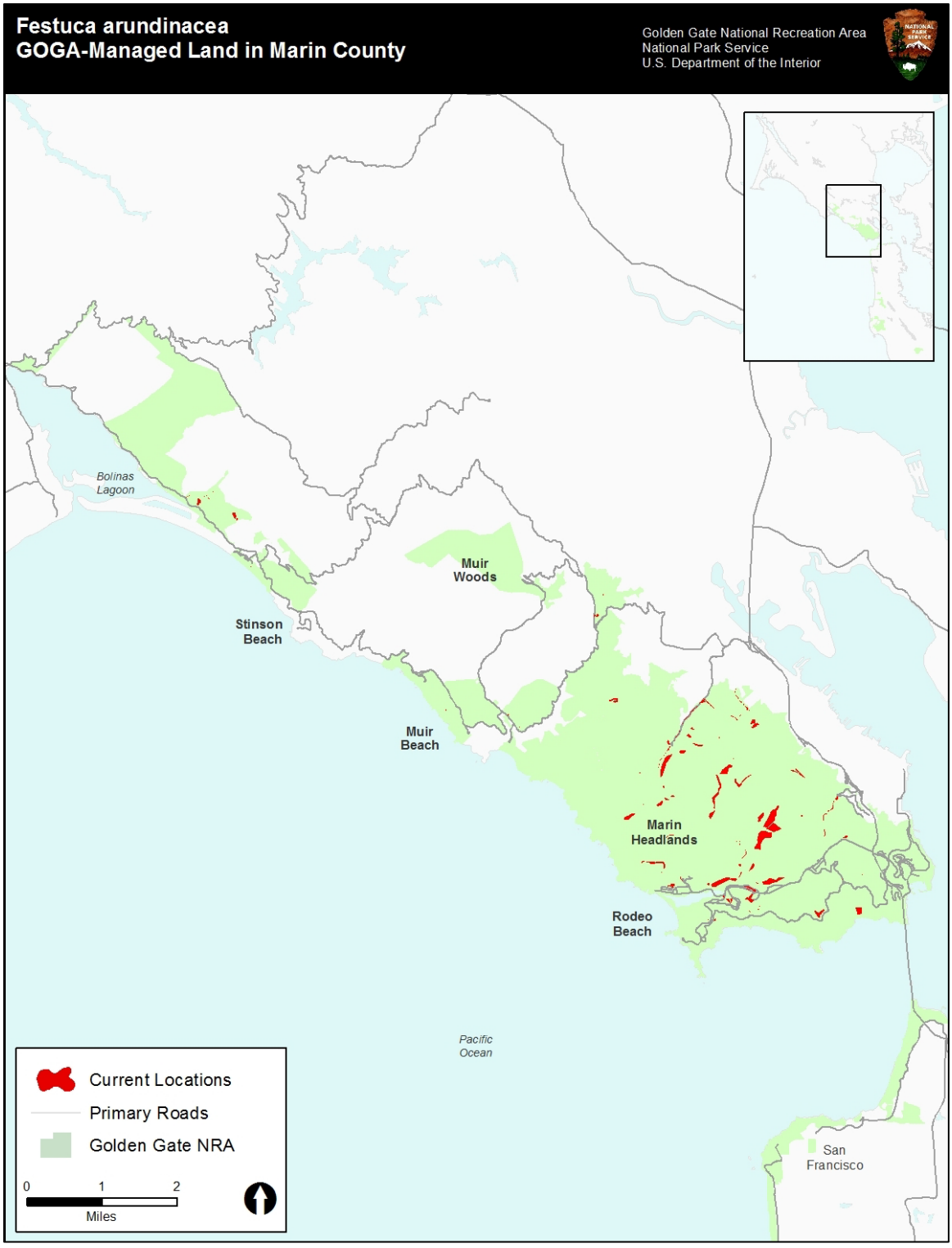


Figure 4.4.15. Recorded distribution of *Festuca arundinacea* in GOGA managed lands in Marin County (NPS).

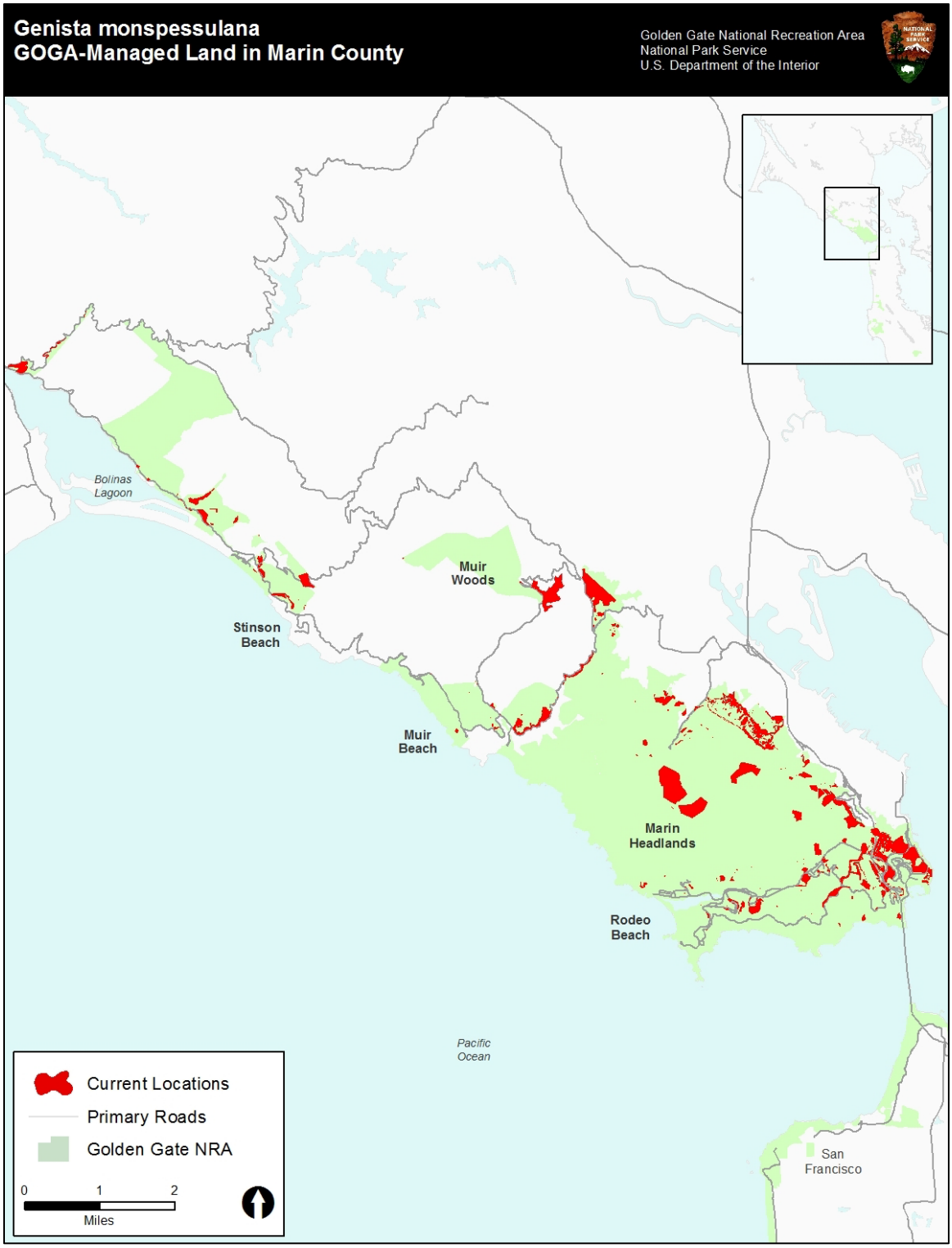


Figure 4.4.16. Recorded distribution of *Genista monspessulana* in GOGA managed lands in Marin County (NPS).

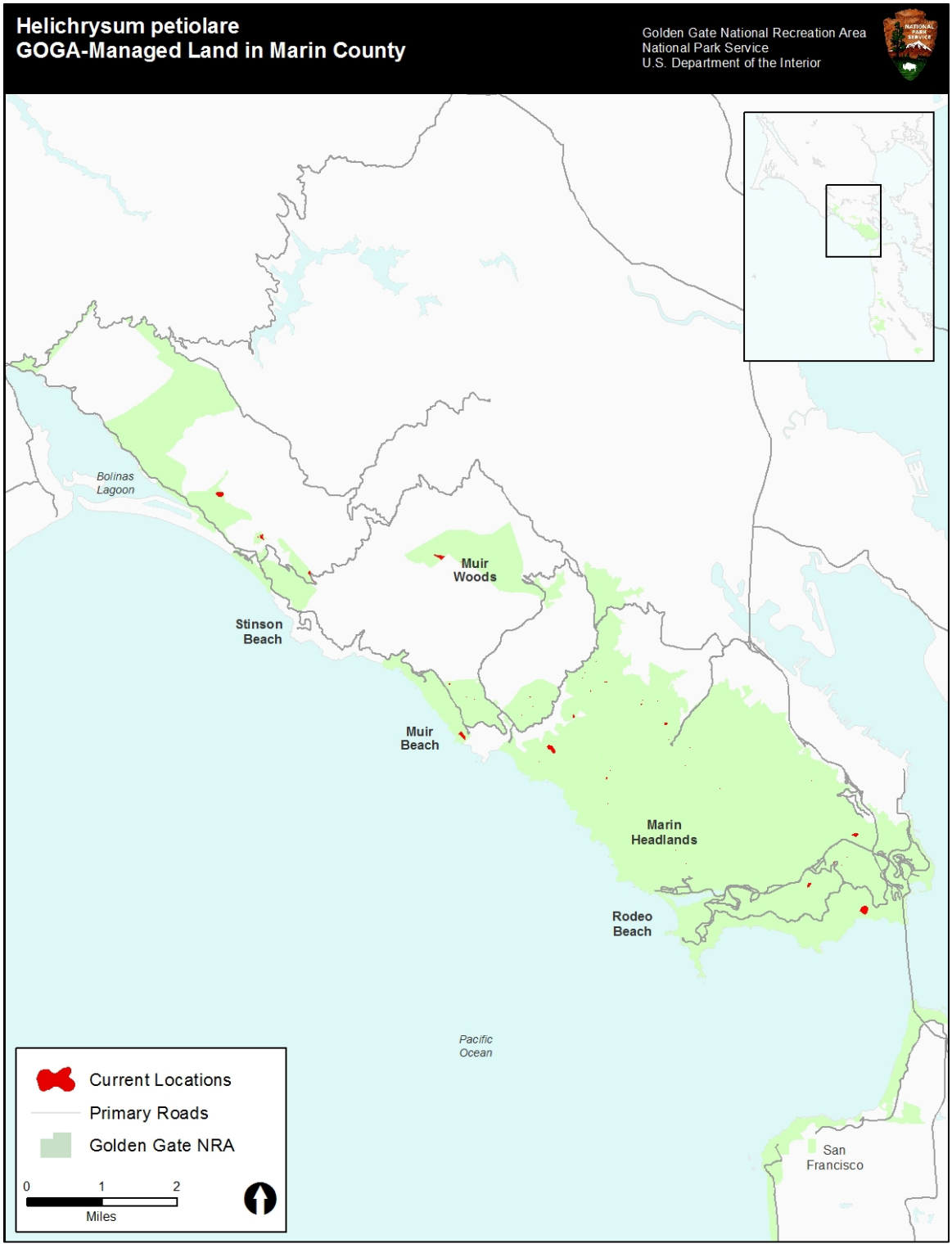


Figure 4.4.17. Recorded distribution of *Helichrysum petiolare* in GOGA managed lands in Marin County (NPS).

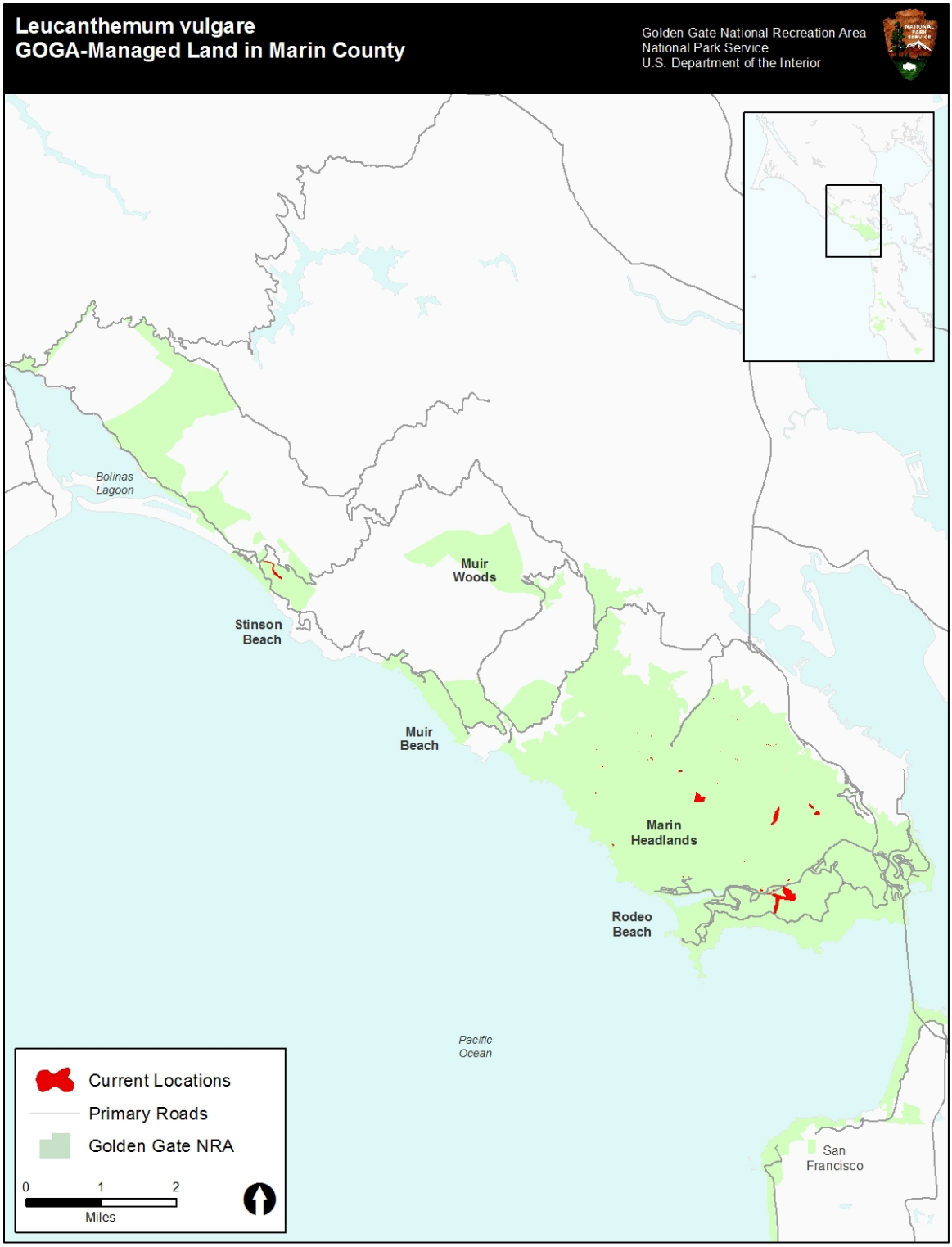


Figure 4.4.18. Recorded distribution of *Leucanthemum vulgare* in GOGA managed lands in Marin County (NPS).

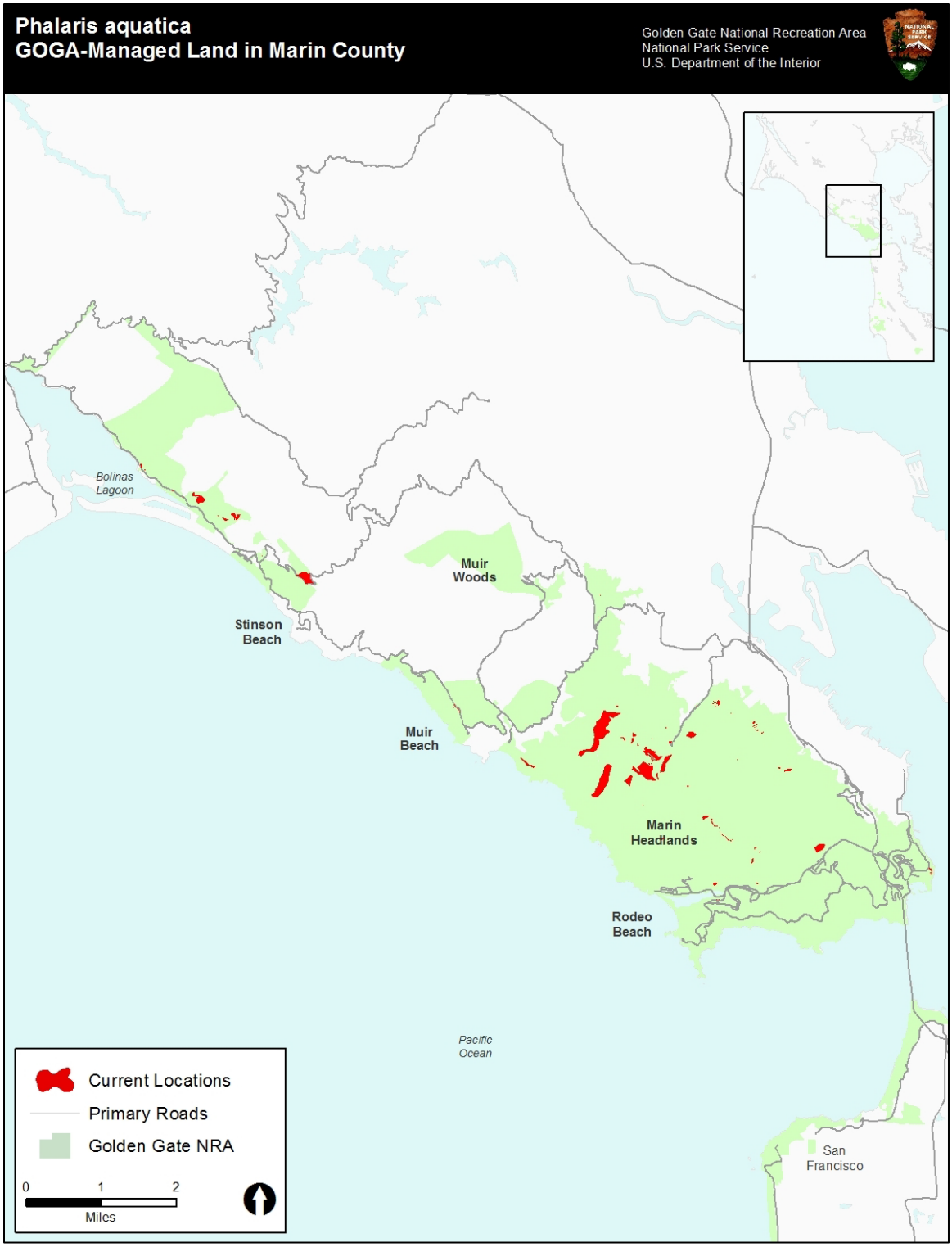


Figure 4.4.19. Recorded distribution of *Phalaris aquatica* in GOGA managed lands in Marin County (NPS).

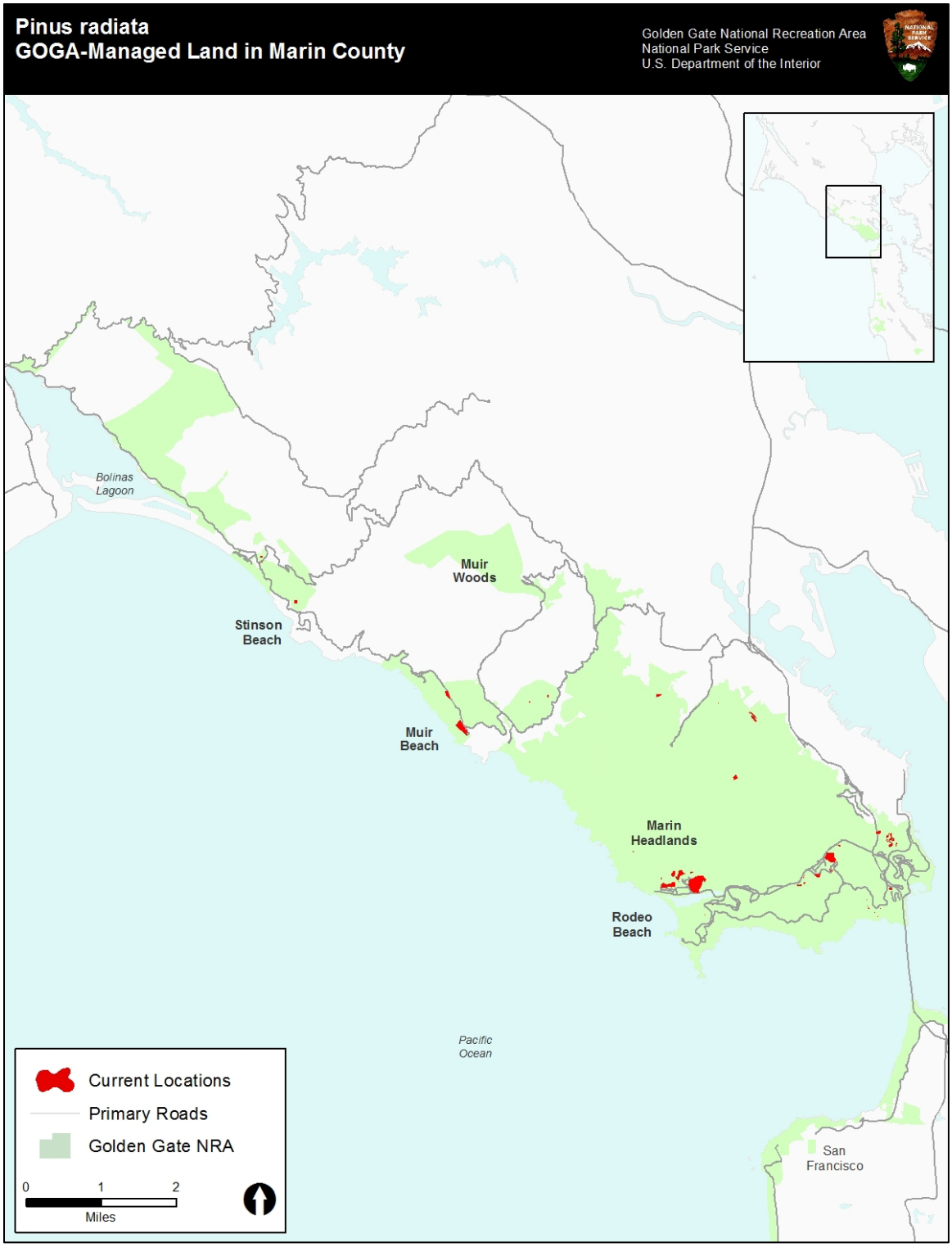


Figure 4.4.20. Recorded distribution of *Pinus radiata* in GOGA managed lands in Marin County (NPS).

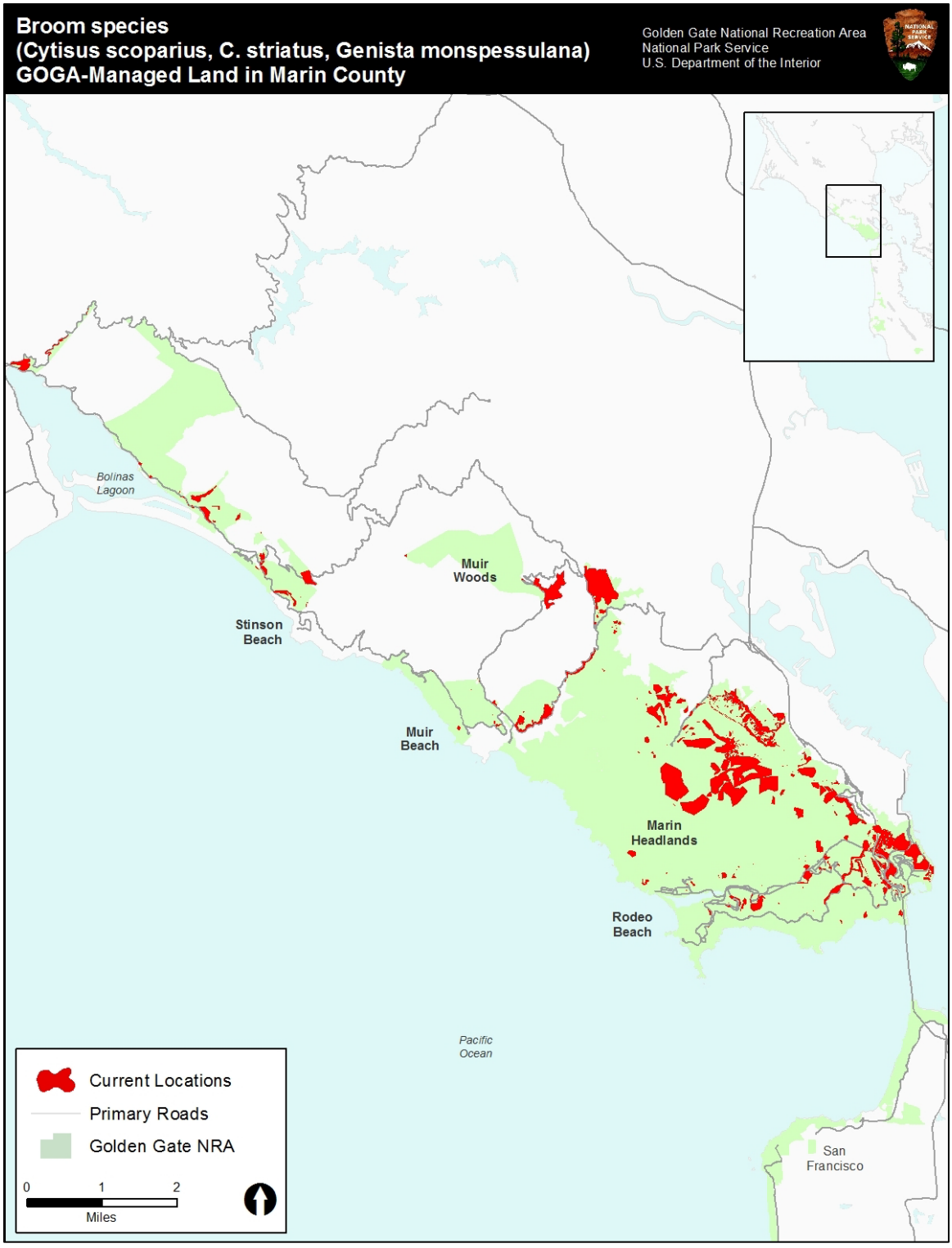


Figure 4.4.21. Recorded distribution of broom species *Cytisus scoparius*, *Cytisus striatus*, and *Genista monspessulana* in GOGA managed lands in Marin County (NPS).

What are the most heavily invaded areas in GOGA?

While many of the acres surveyed in GOGA have just one of the 17 focal invasive species mapped, some contain as many as 15 of these species (Figure 4.4.22). This analysis indicates higher numbers of invasive species concentrated around Oakwood Valley and in smaller areas near Fort Baker and Kirby Cove. The data also suggest a greater level of invasion near roads and trails. However, given currently available data, it is difficult to determine whether this pattern is due to higher invasion near roads and trails or if it simply reflects the higher number of surveys in these areas. The overlay analysis displayed in Figure 4.4.22 likely underestimates the number of invasive species currently in GOGA as many of these areas have not been surveyed recently and may have been invaded by additional species since the last survey.

Of the eight management zones, the Natural Zone had the largest number of invasive species and total amount of invaded land area with 45 invasive plant species documented in over 5,200 acres. However, the Natural Zone is also the largest zone in GOGA. When the total land area in each zone is taken into account, the Park Operations Zone had the highest relative number of invasive species with 6 species recorded in 32 acres and the Evolved Cultural Landscape Zone had the greatest percentage of invaded land area with invasive plants present in at least 70% of the acres in this zone. These numbers represent minimum values because not all areas have been surveyed. In addition, the accuracy of comparisons among zones is reduced because the percentage of land area surveyed in each zone varied significantly.

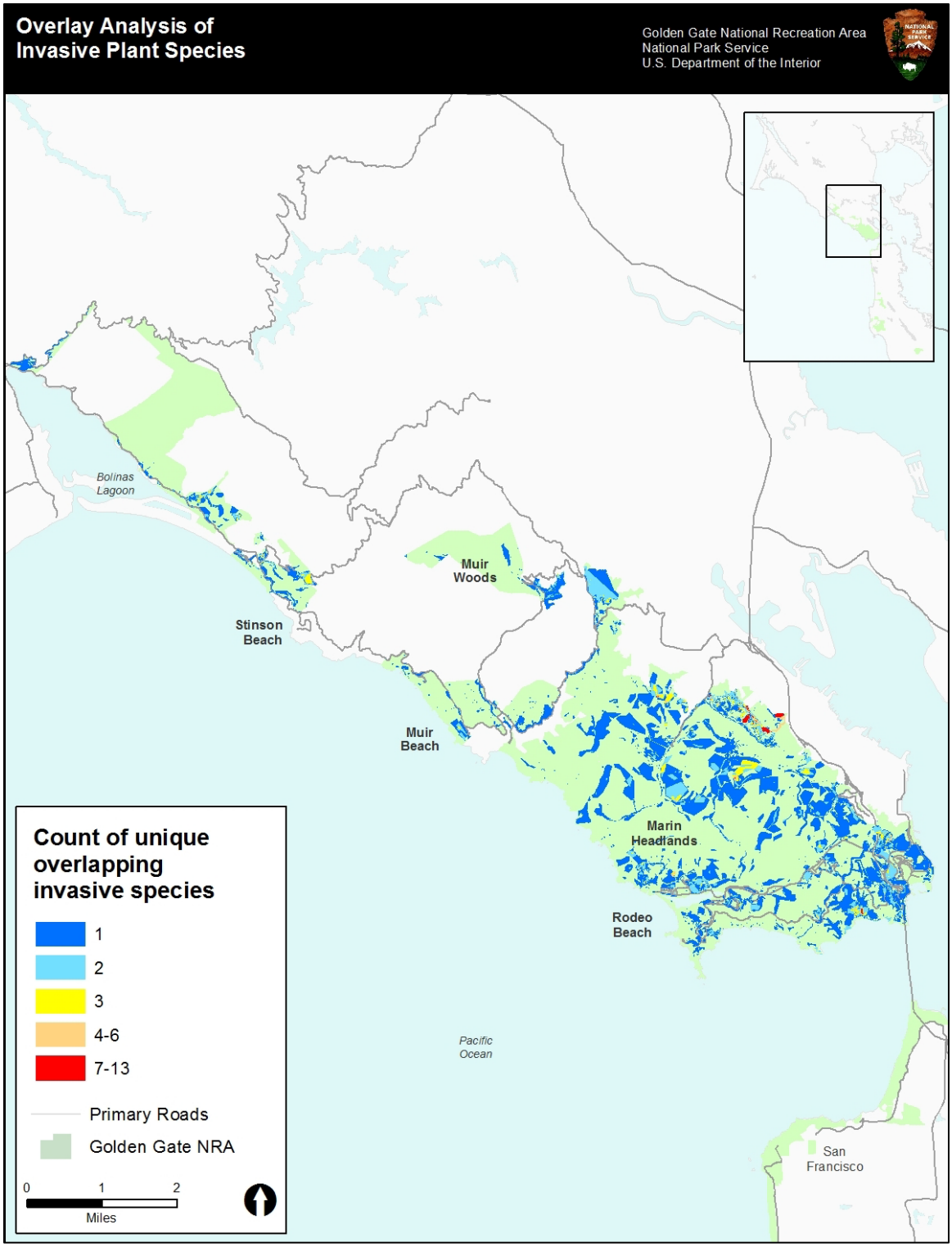


Figure 4.4.22. Overlay analysis of invasive plant species in GOGA managed lands in Marin County (NPS).

What has been the rate of spread of high priority invasive plant species since initial mapping was completed in 1987?

Baseline mapping for many focal invasive plant species in GOGA was completed in 1987. The following maps display the area invaded in 1987 and the area recorded as invaded in subsequent surveys on GOGA managed land in Marin County (Figures 4.4.23 through 4.4.32). Maps are included for all focal invasive plant species for which 1987 data was available (10 of 17 species).

The documented distribution of focal invasive plants in 1987 was relatively low for most species. Only *Cytisus scoparias* (157 acres) and *Eucalyptus globulus* (128 acres) were recorded as present in more than 50 acres in 1987. The recorded expansion in the area invaded since these initial surveys also varied significantly by species. Cotoneaster sp. had the largest recorded increase in distribution in GOGA with 382 acres recorded as invaded between 1987 and 2014. *Ageratina adenophora* also experienced a large increase in the measured area of invasion with 349 acres recorded as invaded between 1987 and 2014. The lowest recorded rate of spread was observed for *Arctotheca prostrata* (13.5 acres) and *Cupressus macrocarpa* (15 acres). Again, these changes in the distribution of each species are only approximations and our confidence in these estimates is reduced because current distributions are not fully mapped. In addition, percent cover is not available for the historical mapping and for only a portion of the current mapping, so changes reflect only gross acres. Further, these rates of spread do not reflect the fact that most of the priority populations have undergone management and continue to be managed annually.

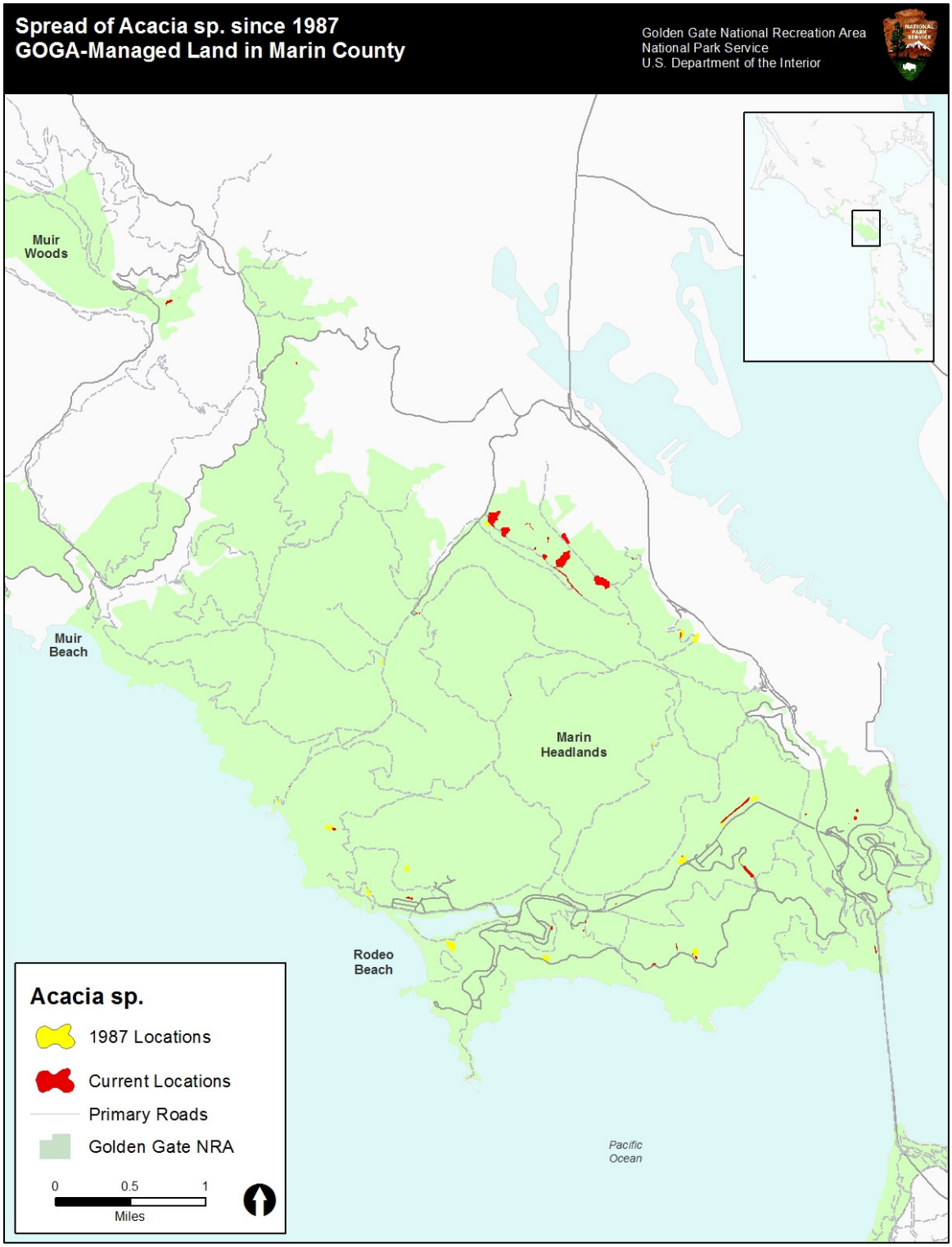


Figure 4.4.23. Areas in which *Acacia* sp. presence was documented in 1987 and in subsequent surveys in GOGA managed lands in Marin County. The area of recorded occurrence increased by 18.6 acres since 1987 (NPS).

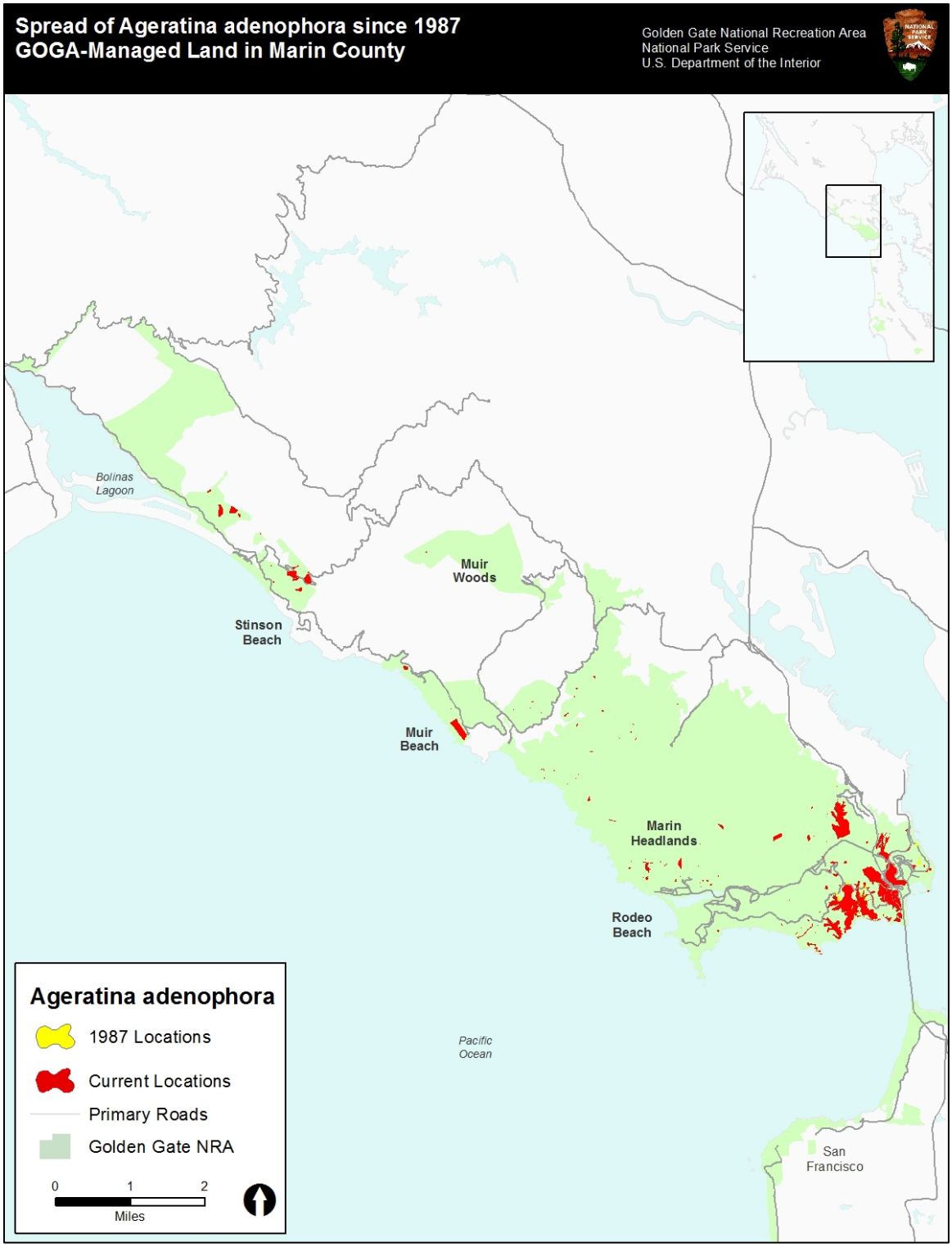


Figure 4.4.24. Areas in which *Ageratina adenophora* presence was documented in 1987 and in subsequent surveys in GOGA managed lands in Marin County. The area of recorded occurrence increased by 519.8 acres since 1987 (NPS).

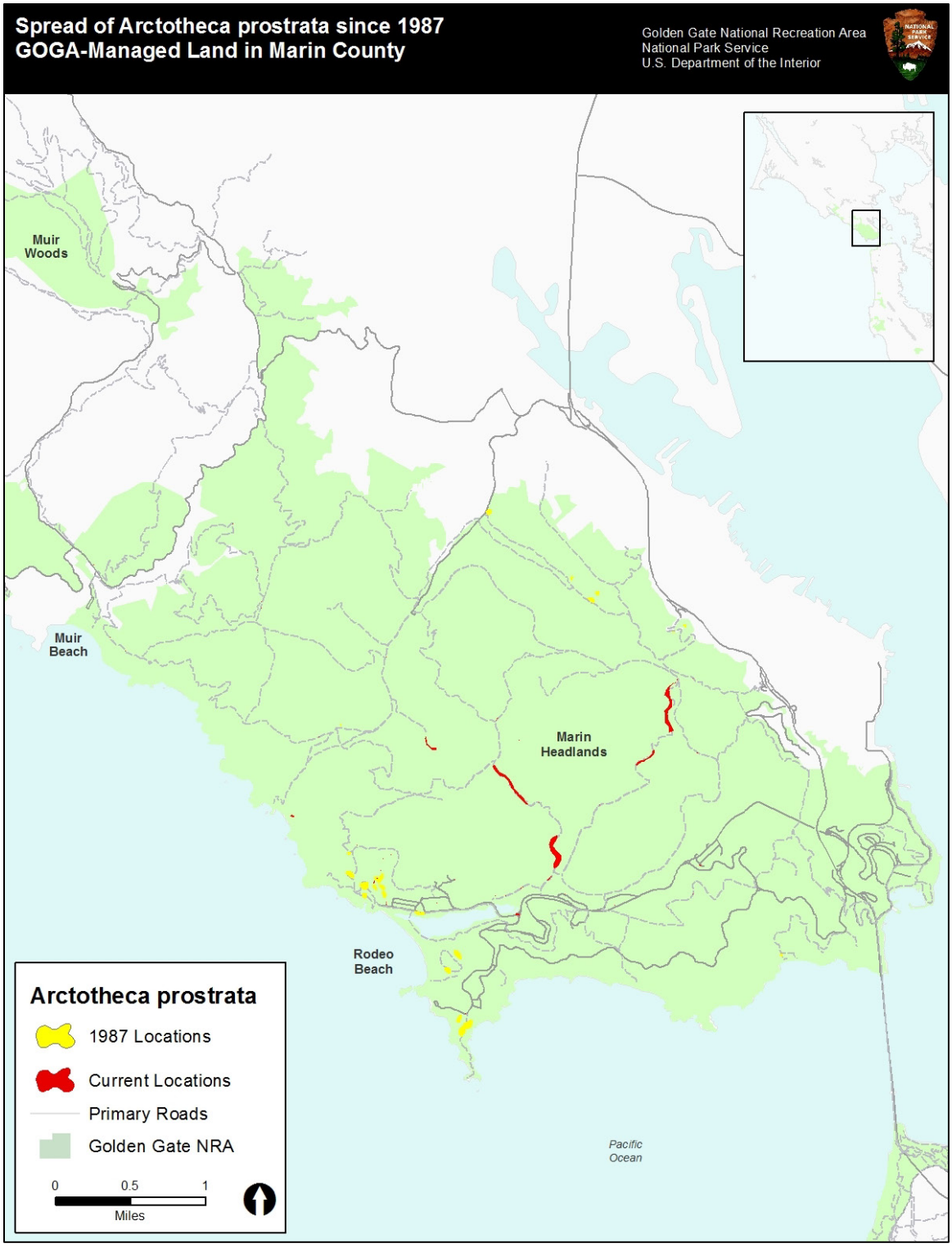


Figure 4.4.25. Areas in which *Arctotheca prostrata* presence was documented in 1987 and in subsequent surveys in GOGA managed lands in Marin County. The area of recorded occurrence increased by 13.6 acres since 1987 (NPS).

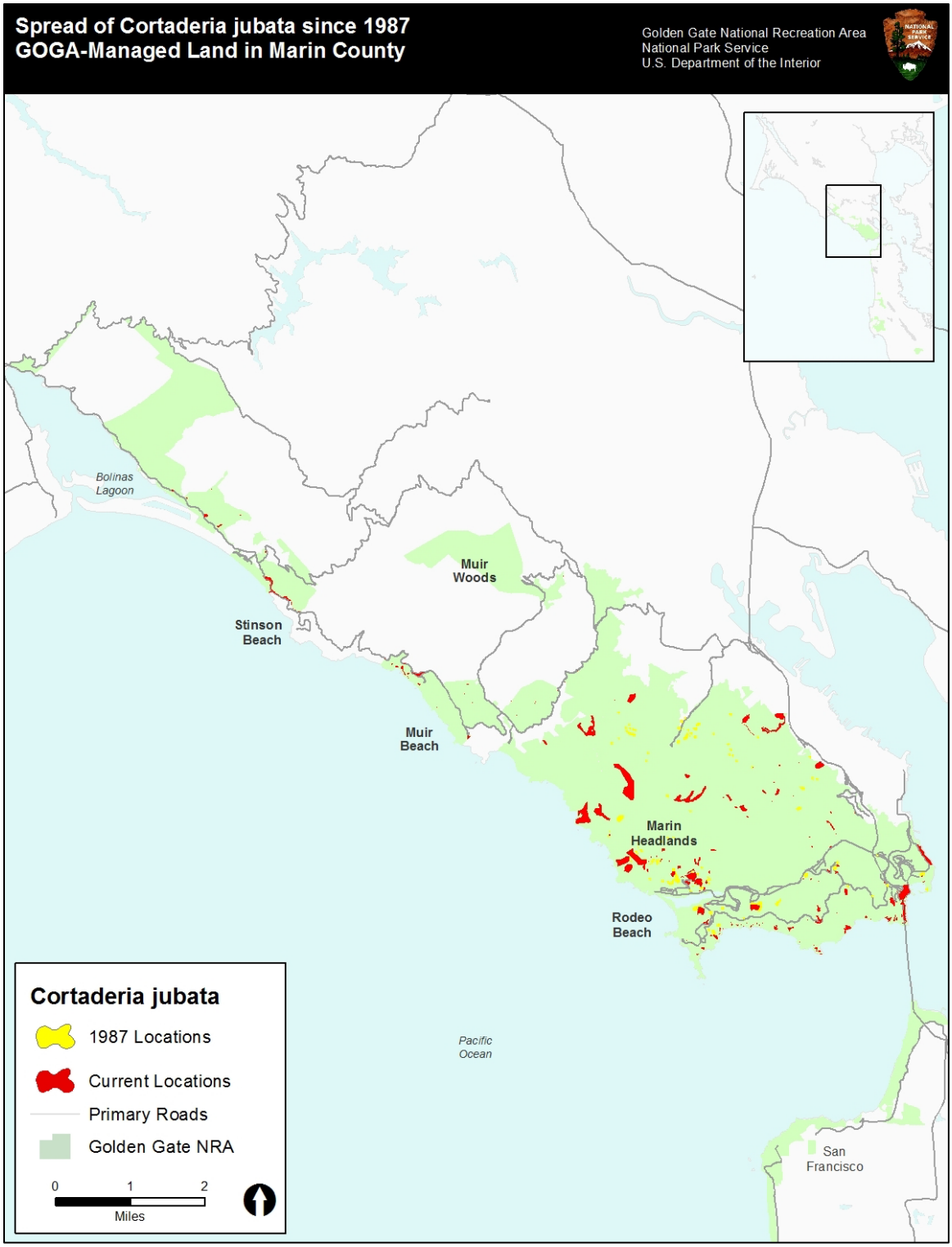


Figure 4.4.26. Areas in which *Cortaderia jubata* presence was documented in 1987 and in subsequent surveys in GOGA managed lands in Marin County. The area of recorded occurrence increased by 253.0 acres since 1987 (NPS).

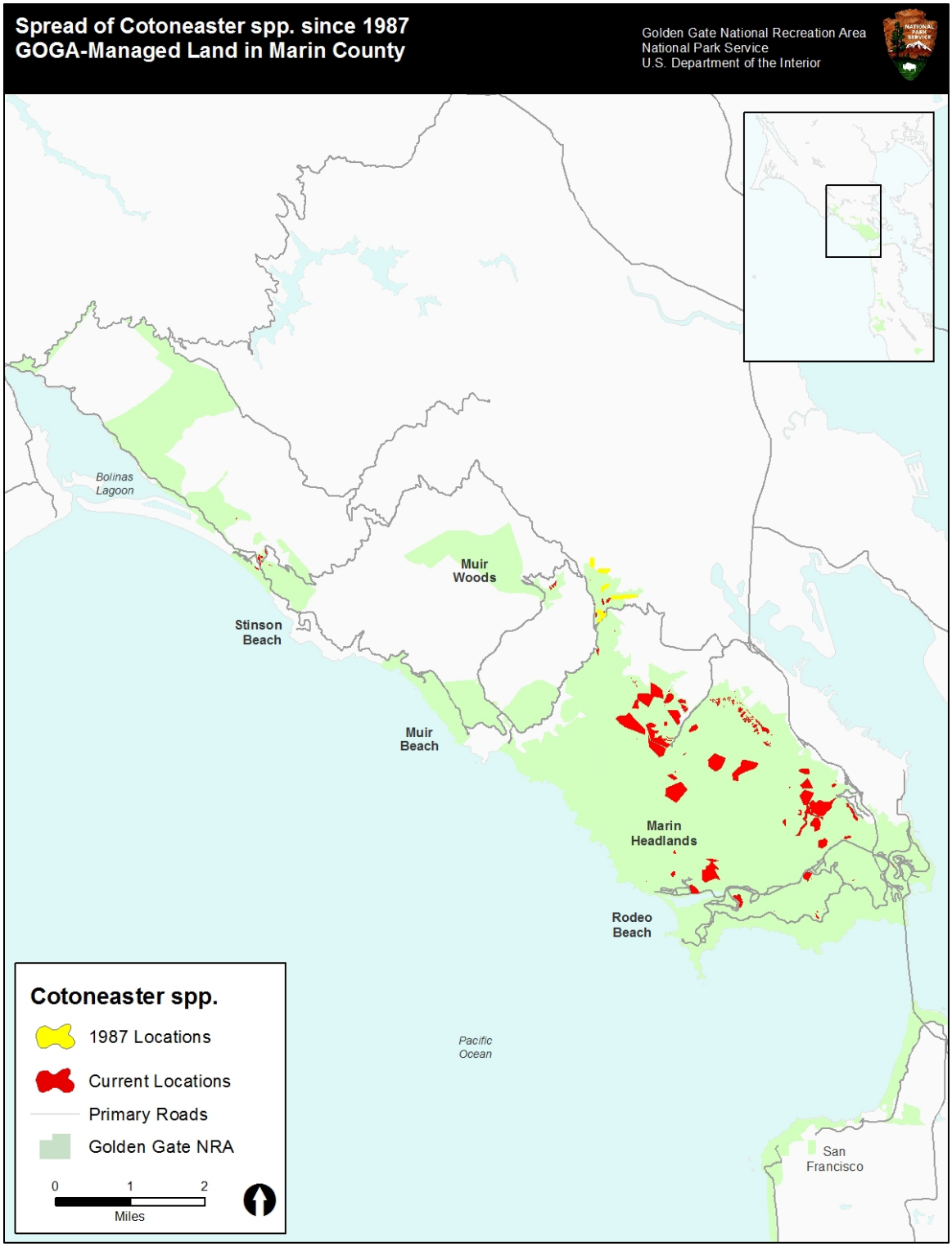


Figure 4.4.27. Areas in which *Cotoneaster* spp. presence was documented in 1987 and in subsequent surveys in GOGA managed lands in Marin County. The area of recorded occurrence increased by 404.6 acres since 1987 (NPS).

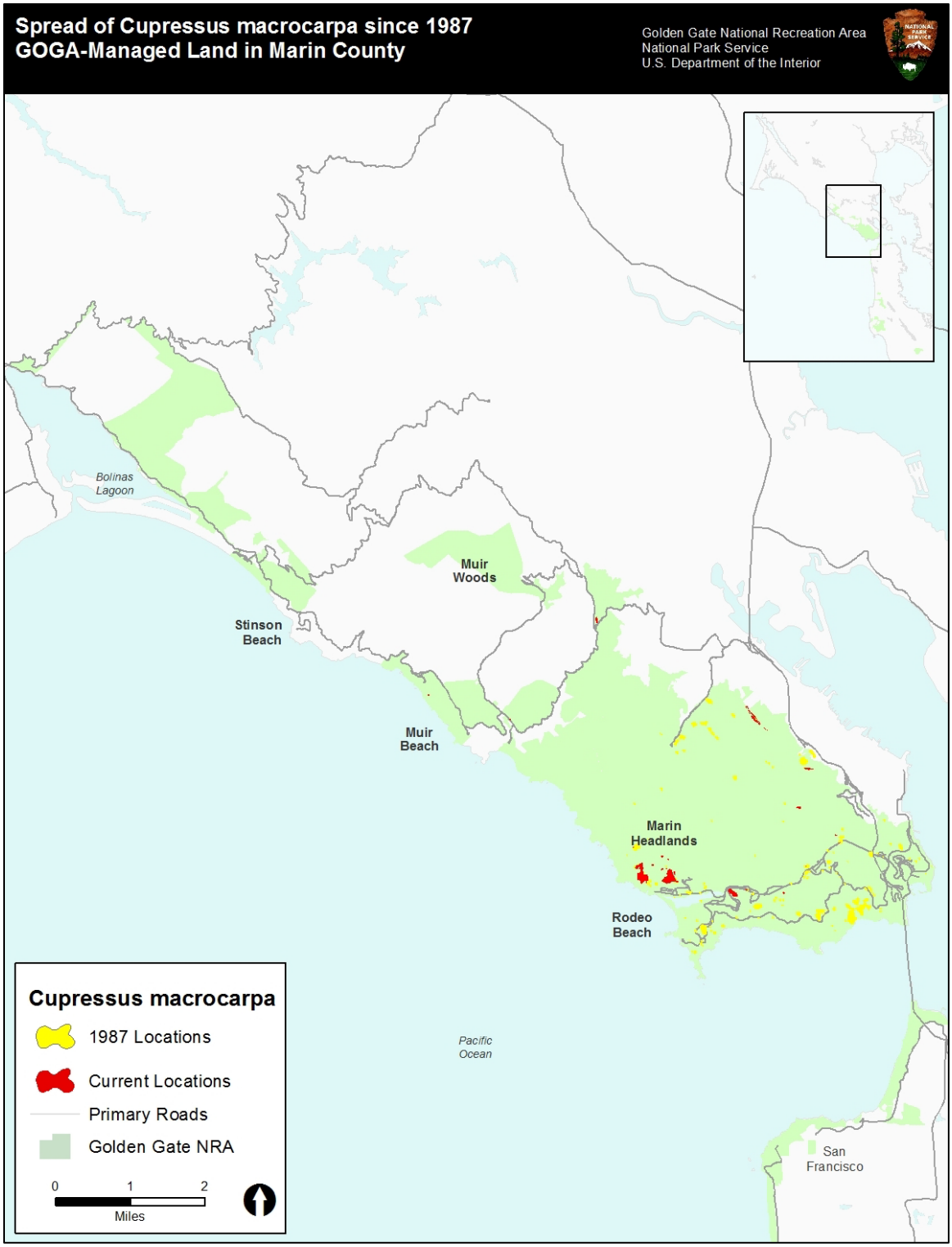


Figure 4.4.28. Areas in which *Cupressus macrocarpa* presence was documented in 1987 and in subsequent surveys in GOGA managed lands in Marin County. The area of recorded occurrence increased by 16.4 acres since 1987 (NPS).

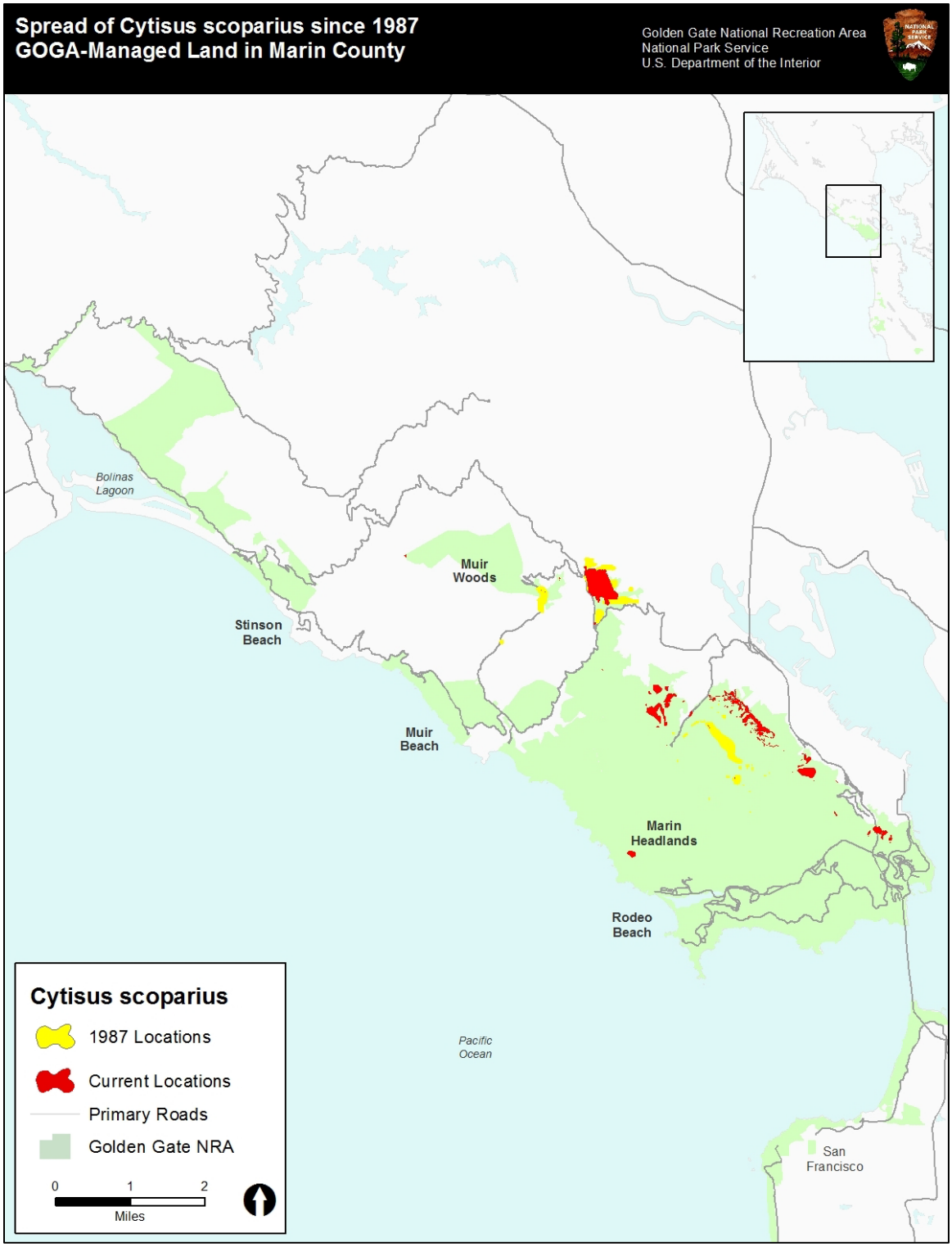


Figure 4.4.29. Areas in which *Cytisus scoparius* presence was documented in 1987 and in subsequent surveys in GOGA managed lands in Marin County. The area of recorded occurrence increased by 62.3 acres since 1987 (NPS).

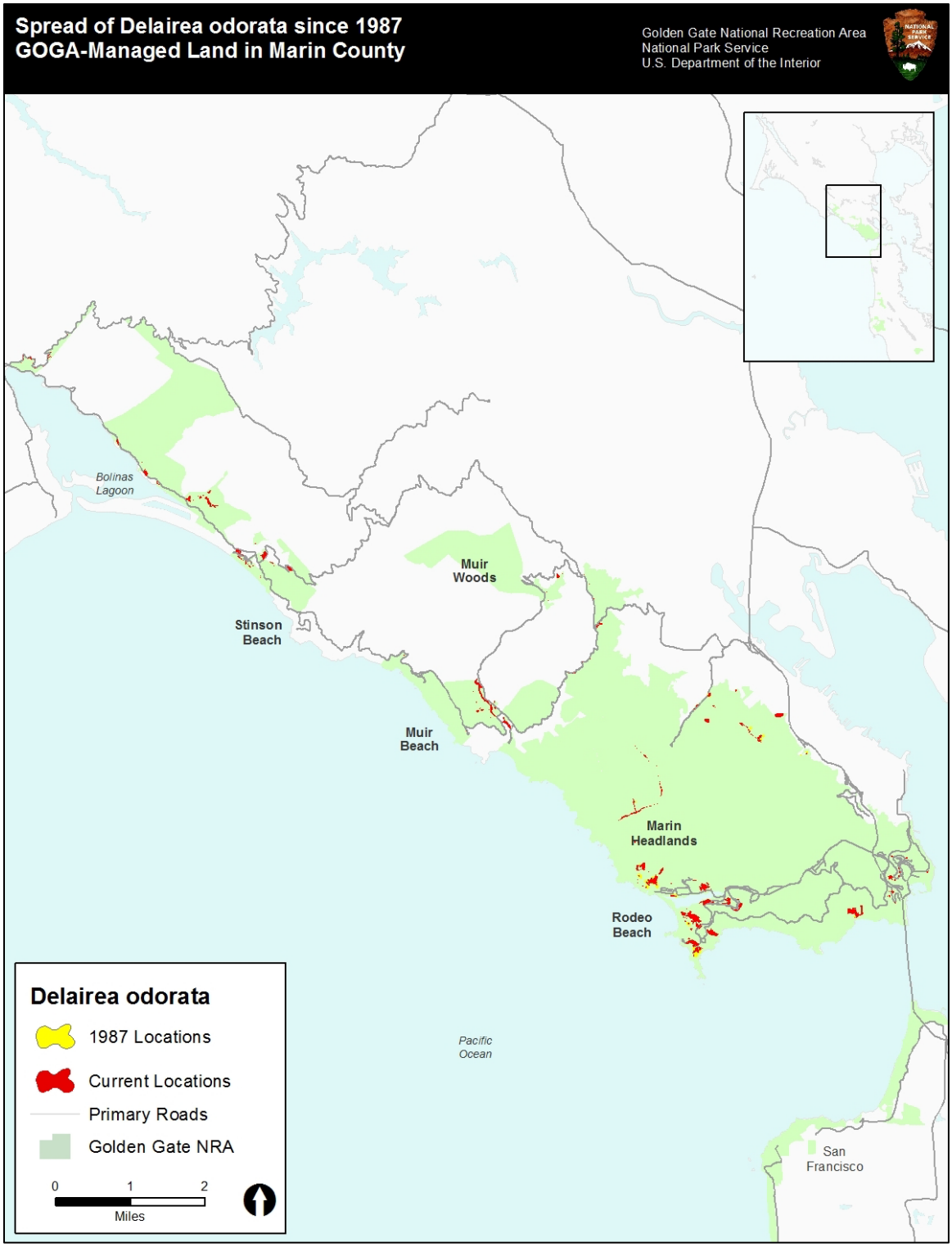


Figure 4.4.30. Areas in which *Delairea odorata* presence was documented in 1987 and in subsequent surveys in GOGA managed lands in Marin County. The area of recorded occurrence increased by 137.6 acres since 1987 (NPS).

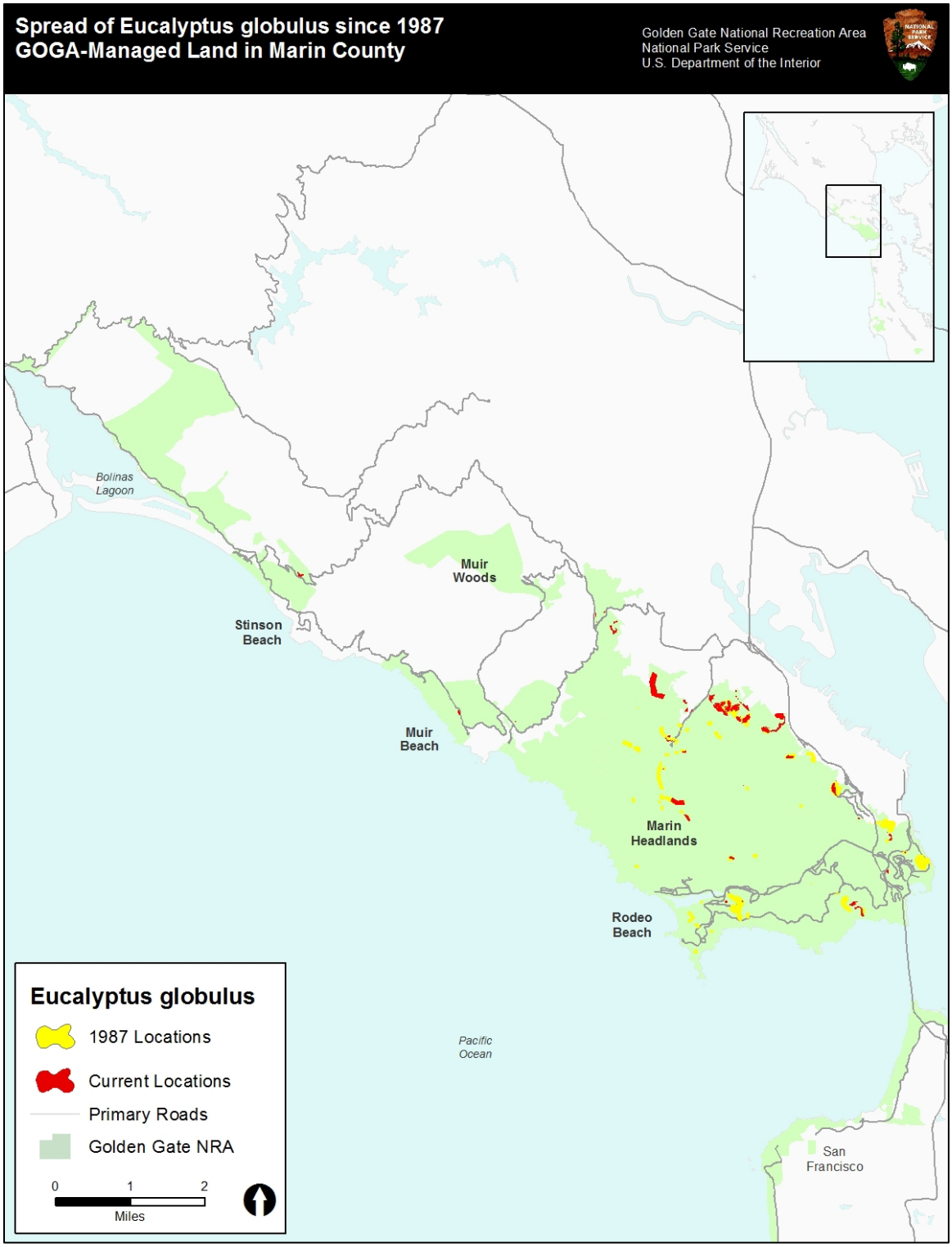


Figure 4.4.31. Areas in which *Eucalyptus globulus* presence was documented in 1987 and in subsequent surveys in GOGA managed lands in Marin County. The area of recorded occurrence increased by 199.8 acres since 1987 (NPS).

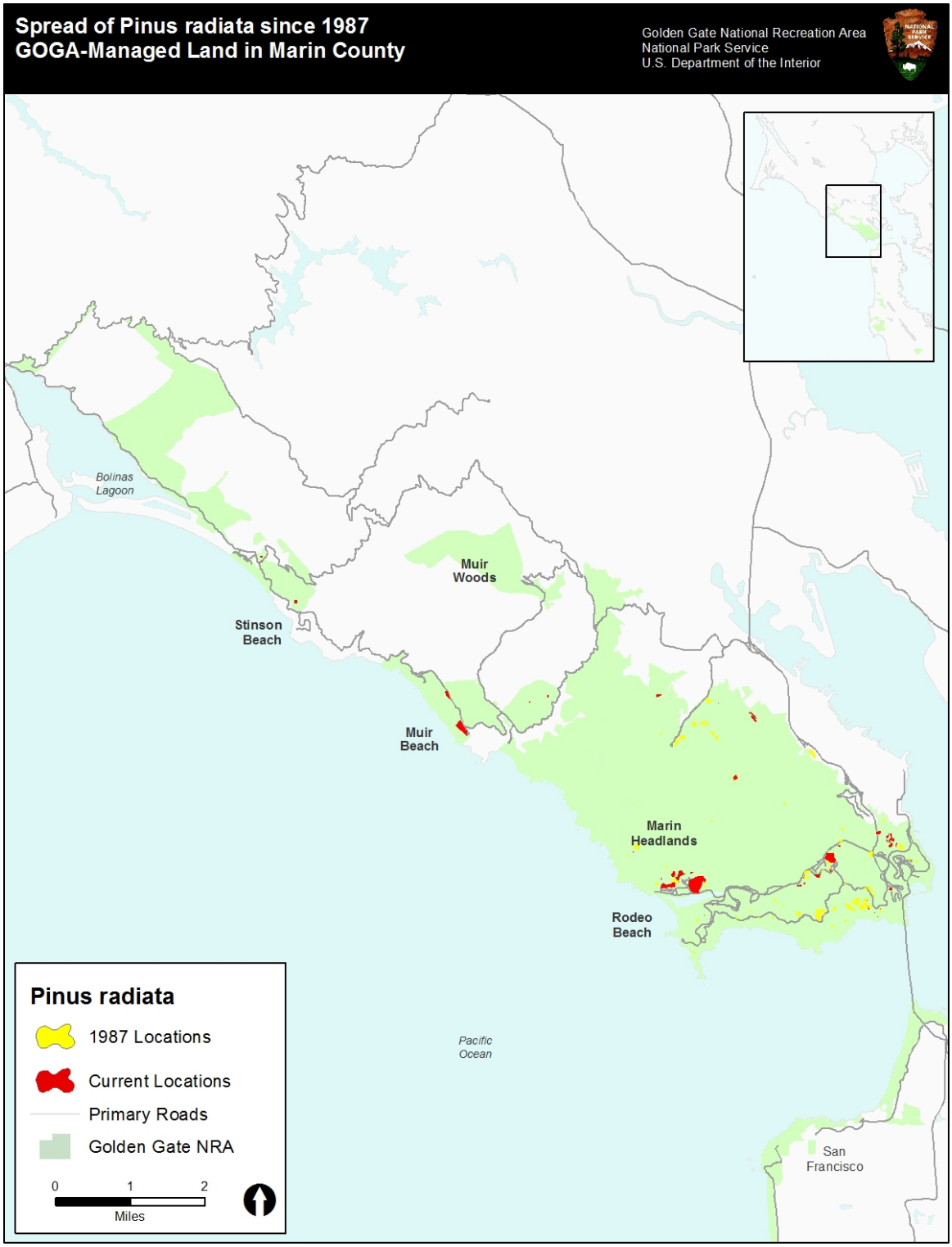


Figure 4.4.32. Areas in which *Pinus radiata* presence was documented in 1987 and in subsequent surveys in GOGA managed lands in Marin County. The area of recorded occurrence increased by 62.0 acres since 1987 (NPS).

From 1987 through current surveys, the vast majority of the area invaded by these focal species was in the Natural Zone with a recorded increase of nearly 5,000 acres (Table 4.4.2). The Evolved Cultural Zone also had a significant increase in the area recorded as invaded by these high priority plant species since 1987. Although the expansion of these species in the Evolved Cultural Zone was recorded at only around 500 acres, the entire zone is only about 830 acres and, therefore, this zone had by far the greatest relative increase in invasion extent since 1987. The recorded expansion of the high priority invasive species was very low in the Historic Immersion Zone and the Sensitive Resources Zone (approximately 1 acre). Though the increase in area invaded in the Scenic Corridor Zone was recorded to be 45 acres, this zone is the second largest zone (nearly 5675 acres) in the analyzed GOGA lands and, therefore, the zone had one of the lowest relative rates of spread of these species since initial mapping in 1987. For this analysis, data was not available for the Interpretive Corridor Zone.

Table 4.4.2. Recorded acres invaded by management zone (NPS 2014, NPS unpub. Data).

Management Zone	1987 Acres Invaded	Current Acres Invaded
Diverse Opportunities Zone	31	128
Evolved Cultural Landscape Zone	57	562
Historic Immersion Zone	2	3
Natural Zone	303	5284
Park Operations Zone	0	6
Scenic Corridor Zone	1	46
Sensitive Resources Zone	0	1

Detailed Mapping History and Selected Interpretation of Invasives Spread Data

Throughout the 1990's staff and interns re-mapped a subset of the plants mapped in 1987 from the Marin Headlands to determine relative rates of spread for prioritization and funding request purposes. In order to get the most accurate estimate of rate of spread per species, populations were chosen that had not been managed since the original survey was conducted in 1987.

During 1996–1997 several interns on the Habitat Restoration Team (HRT) spent a year re-mapping Cape-ivy (*Delairea odorata*) infestations. In 1987 there were 8.8 acres of Cape-ivy in the Marin Headlands. In just ten years, these same infestations expanded into 67.3 acres of infestation, on over 800% increase (Vaghti 1997).

In 1998 a park intern re-mapped the following focal species for the HRT; *Acacia melanoxylon, Acacia verticilata, Acacia sp*. Fourteen *Acacia* populations consisting of three different species showed wide variability in growth ranging from none to 2,500%. On average, the four Cotoneaster species populations doubled in a ten year period. Four *Hedera helix* populations grew a range of 450–2500% while three 1987 *Vinca major* infestations grew 100 to 600 % over a 10 year period.

In 1997 HRT focused re-mapping efforts on thoroughwart (*Ageratina adenophora*) documenting a doubling in growth among identified patches. In 1999 an inventory and GIS-based analysis of the

expansion and rate of spread of thoroughwort indicates that patches that currently threaten mission blue butterfly habitat have grown more than 475% in less than 10 years (Farrell and Gennett 1999)

In 1998 three invasive tree species were also re-mapped. From 1987 to 1998 Eucalyptus increased 130% growing from 91 acres to 201 acres. In the same time period Monterey pine increased 90% growing from 19 acres to 34 acres. Monterey Cypress grew from 21 acres mapped in 1987 to 39 acres in 1998 a 185% increase (Wood and Farrell 1998).

Because of the size of GOGA and a lack of funding for natural resources until several decades after park inception, a thorough mapping of all GOGA lands has not been completed. The most comprehensive mapping of the Marin Headlands ever attempted occurred in 1987. A number of plant species were re-mapped in the 1990's as interest and funding for projects became available.

Almost simultaneous management began as the mapping was completed but the start time for invasive plant management varied by region. From 1987–1991 a small number of invasive plant species were intensively managed in the Marin Headlands and Milagra Ridge. In 1991 invasive plant management expanded to new areas including: the Fairfax-Bolinas Road and White gate in the Stinson region. Many more Marin Headlands sites were also added from 1991–1995 as well as Area A on the Presidio, Fort Funston, and Milagra & Sweeney Ridge. In 1994, the interior areas of the Presidio were added. In 1998 more of Bolinas Ridge north of Stinson town also came under first time invasive plant management.

How many new invasive species (i.e., formerly unknown in the park) are detected in GOGA each year?
Analysis of new invasions from 2011–2014 was conducted using the I&M Early Detection Data. Over this time period, 46 invasive plant species were observed in PORE and GOGA that were not previously on the NPSpecies working lists (Table 4.4.3). 41 of these species were located in GOGA. Appendix 4.4.2 provides a complete list of these newly documented invasive plant species.

Table 4.4.3. Number of new invasive species (i.e., formerly unknown in the park) detected in Golden Gate National Recreation Area (GOGA) and Point Reyes National Seashore (PORE) from 2011–2014 (NPS unpub. Data).

Park	2011	2012	2013	2014	Total
GOGA	18	12	7	4	41
PORE	1	1	0	3	5
Total	19	13	7	7	46

While the occurrence of some of these species may have been previously known by individual park workers or other groups, their presence had not been documented in the NPSpecies working lists at the time they were observed by ISED. The NPSpecies list was the best reference for the presence/absence of vascular plants in the parks at the time these taxa were observed and, therefore, in this report we refer to these species as new or formerly unknown in the park. Figures 4.4.33 through 4.4.36 display the locations of these newly detected species in different regions of GOGA managed land in Marin County, San Francisco, and San Mateo County.



Figure 4.4.33. Locations of newly detected invasive plant species in the north central region of GOGA managed lands in Marin County (2011–2014) (NPS).



Figure 4.4.34. Locations of newly detected invasive plant species in the central region of GOGA managed lands in Marin County (2011–2014) (NPS).



Figure 4.4.35. Locations of newly detected invasive plant species in GOGA managed lands in San Francisco (2011–2014) (NPS).

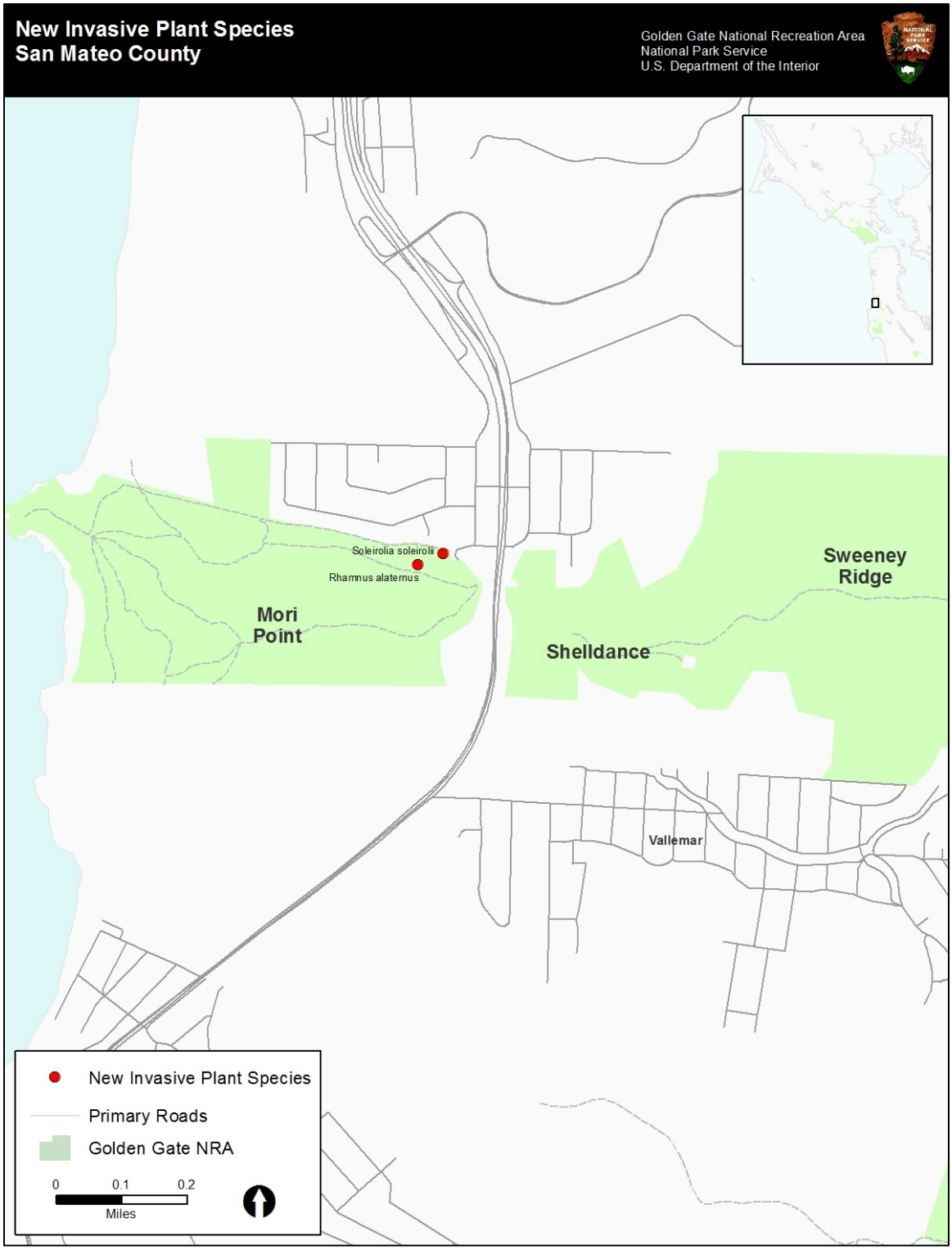


Figure 4.4.36. Locations of newly detected invasive plant species in GOGA managed lands in San Mateo County (2011–2014) (NPS).

More than half of the newly recorded species were detected in the Natural Zone (22 species). The Diverse Opportunities Zone (6 species) and Evolved Cultural Landscape Zone (7 species) also had significant numbers of newly recorded invasive plant species.

How does survey effort impact the number of invasive species detected per subwatershed each year?
For the I&M early detection data, we analyzed the relationship between survey effort and detections. To investigate the impact of survey effort on the number of species detected each year, we generated species discovery curves for each of the 40 subwatersheds in GOGA that received at least five consecutive annual surveys by Early Detection teams (Figure 4.4.37). When the total number of species detected in all subwatersheds is combined by year, the resulting graph illustrates a relatively linear increase in the number of species recorded annually from 2008 to 2014 (Figure 4.4.38). The number of new invasive species occurrences within these subwatersheds was similar in all studied years. These species discovery curves suggest the importance of annual surveys and relatively rapid changes in the invasive species populations by subwatershed. For instance, in these 40 subwatersheds, on average of approximately 43 new occurrences of an invasive plant species were recorded annually from 2008 to 2014 (Figure 4.4.38).

In 2008, 35 of the 40 subwatersheds in GOGA that received at least five consecutive annual surveys by Early Detection teams had five or fewer documented invasive species present. By 2014, only eight of these subwatersheds had five or fewer recorded invasive plant species. In addition, eight of these GOGA subwatersheds contained 15 or more invasive plant species by 2014. The subwatershed with the highest recorded number of invasive plants recorded by 2014 was GGNRA17-4 with 22 invasive plant species documented between 2008 and 2014.

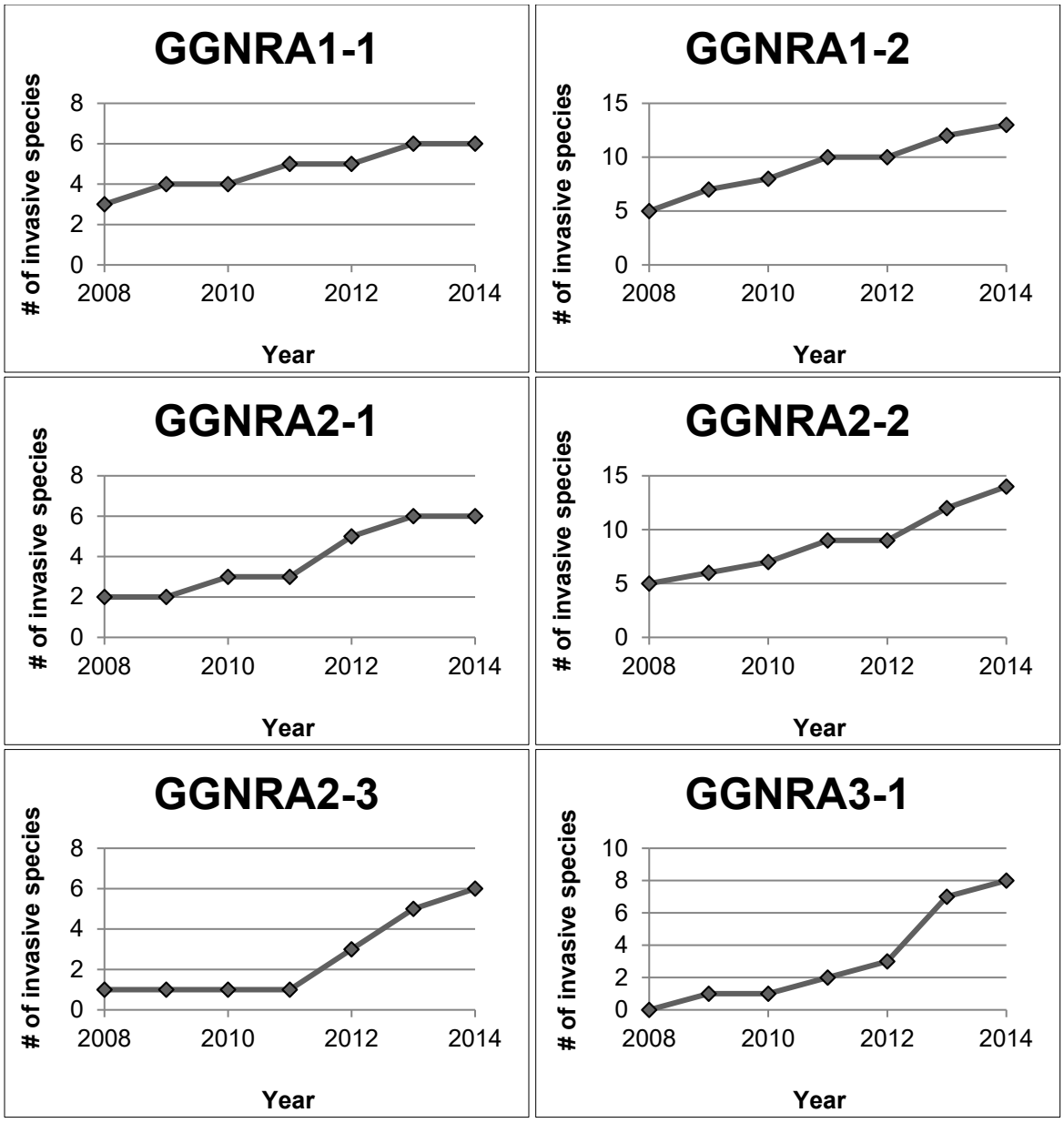


Figure 4.4.37a. Species discovery curves for subwatersheds 1-1, 1-2, 2-1, 2-2, 2-3, and 3-1 with at least five consecutive years of annual surveys by Early Detection teams (2008 to 2014). Data presented for each year represents the cumulative number of invasive plant species documented in each subwatershed (see Appendix 4.4.1 and 4.4.2).

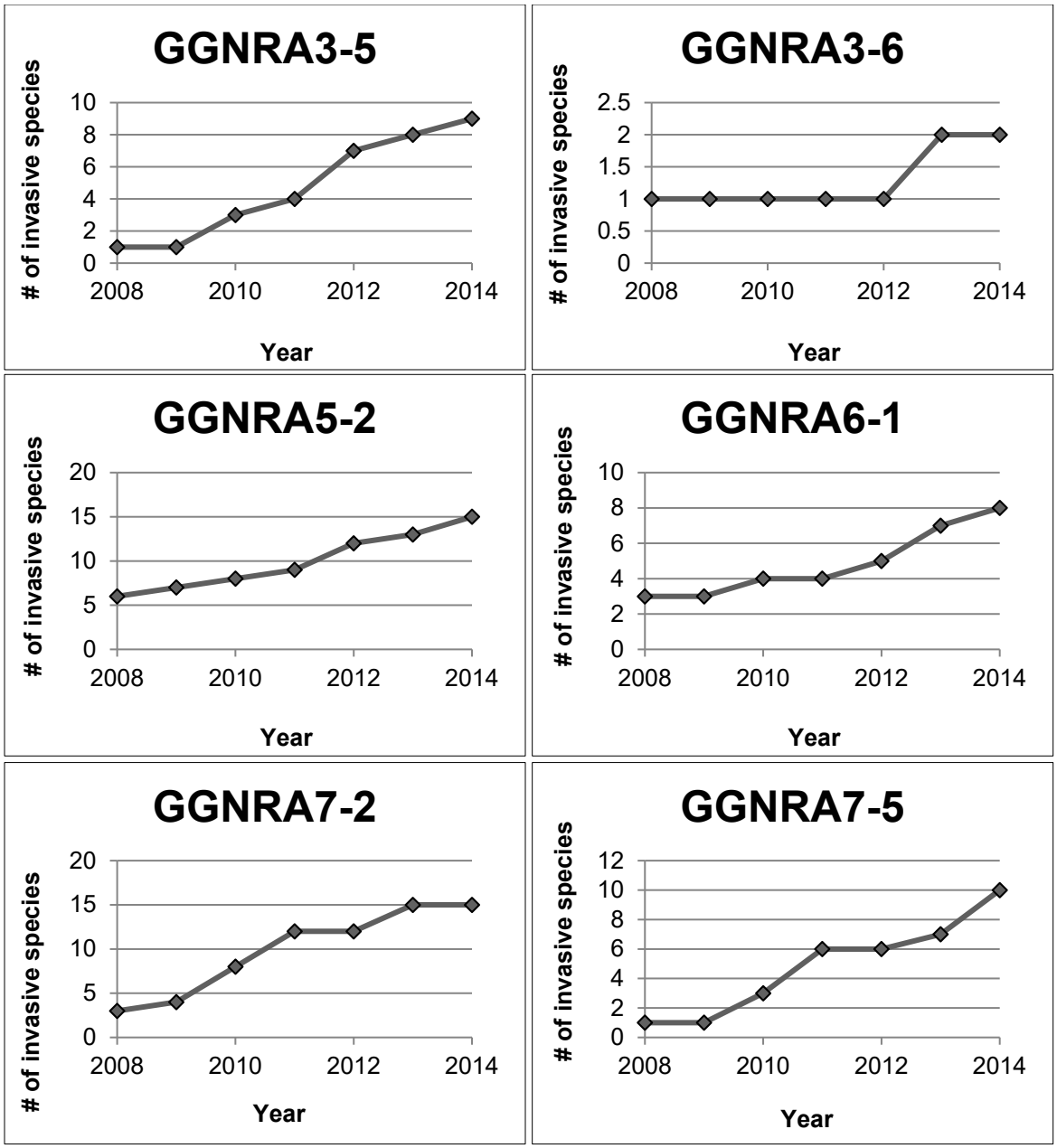


Figure 4.4.37b. Species discovery curves for subwatersheds 3-5, 3-6, 5-2, 6-1, 7-2, and 7-5 with at least five consecutive years of annual surveys by Early Detection teams (2008 to 2014). Data presented for each year represents the cumulative number of invasive plant species documented in each subwatershed (see Appendix 4.4.1 and 4.4.2).

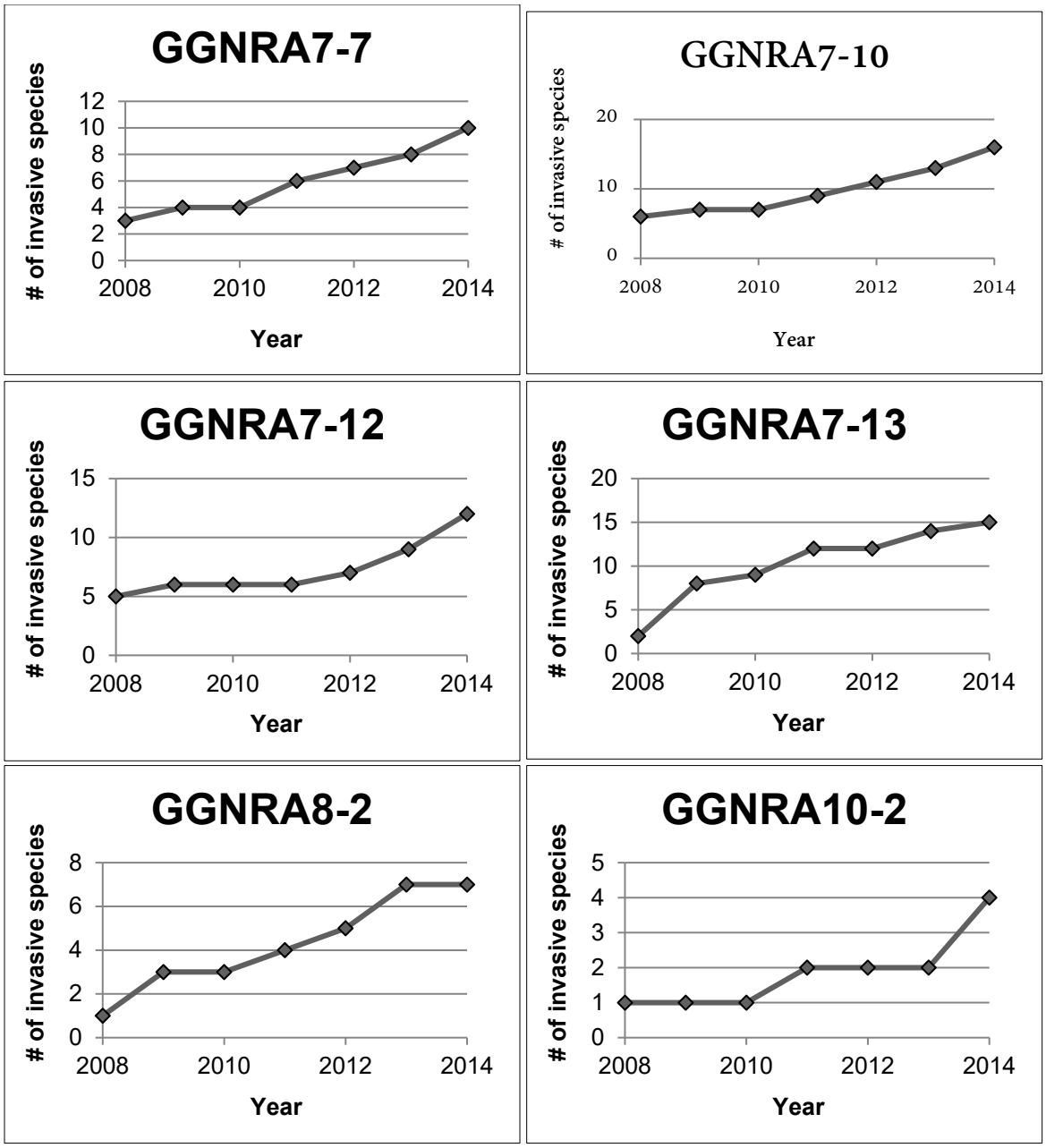


Figure 4.4.37c. Species discovery curves for subwatersheds 7-7, 7-10, 7-12, A7-13, 8-2, and 10-2 with at least five consecutive years of annual surveys by Early Detection teams (2008 to 2014). Data presented for each year represents the cumulative number of invasive plant species documented in each subwatershed (see Appendix 4.4.1 and 4.4.2).

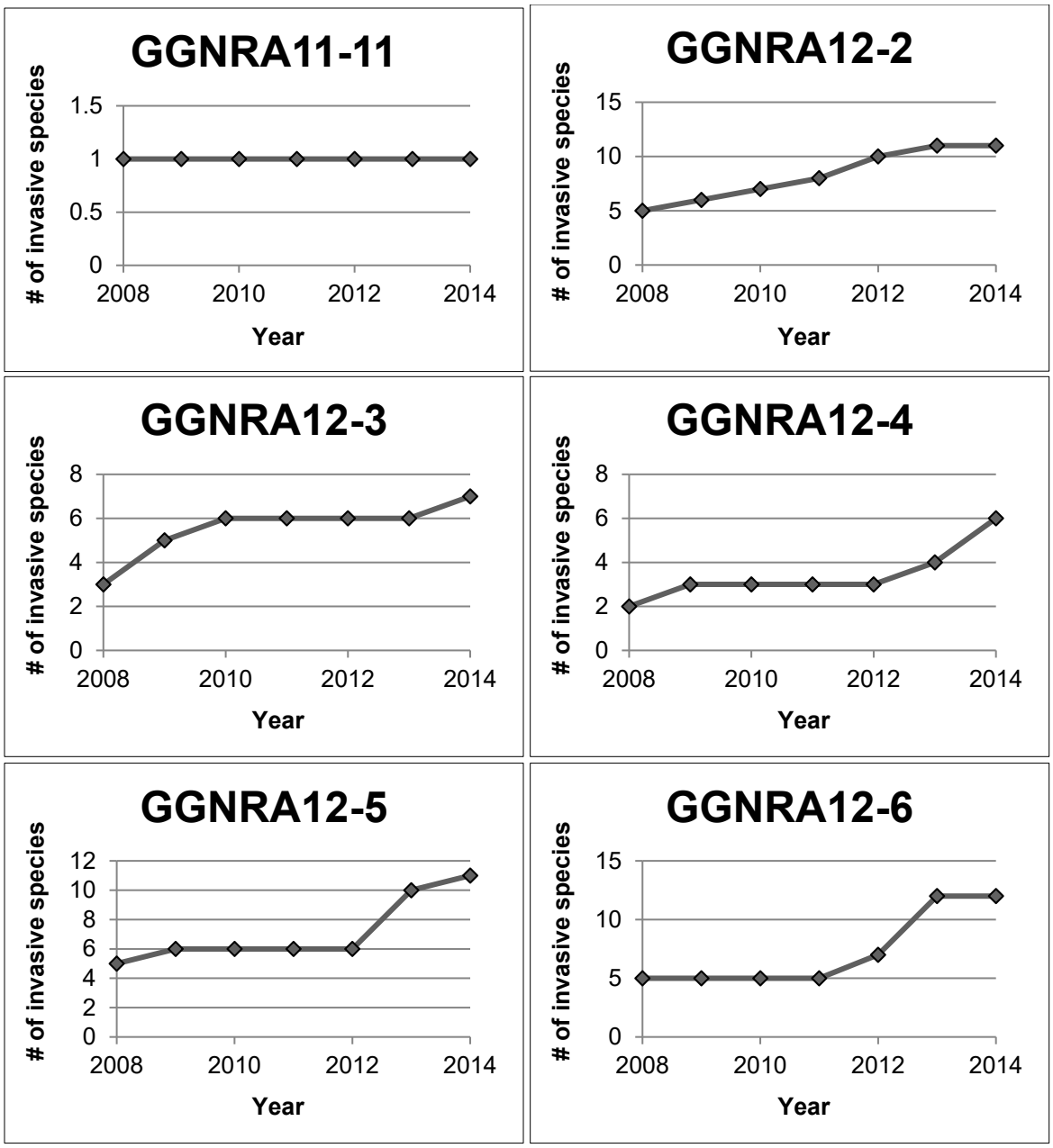


Figure 4.4.37d. Species discovery curves for subwatersheds 11-11, 12-2, 12-3, 12-4, 12-5, and 12-6 with at least five consecutive years of annual surveys by Early Detection teams (2008 to 2014). Data presented for each year represents the cumulative number of invasive plant species documented in each subwatershed (see Appendix 4.4.1 and 4.4.2).

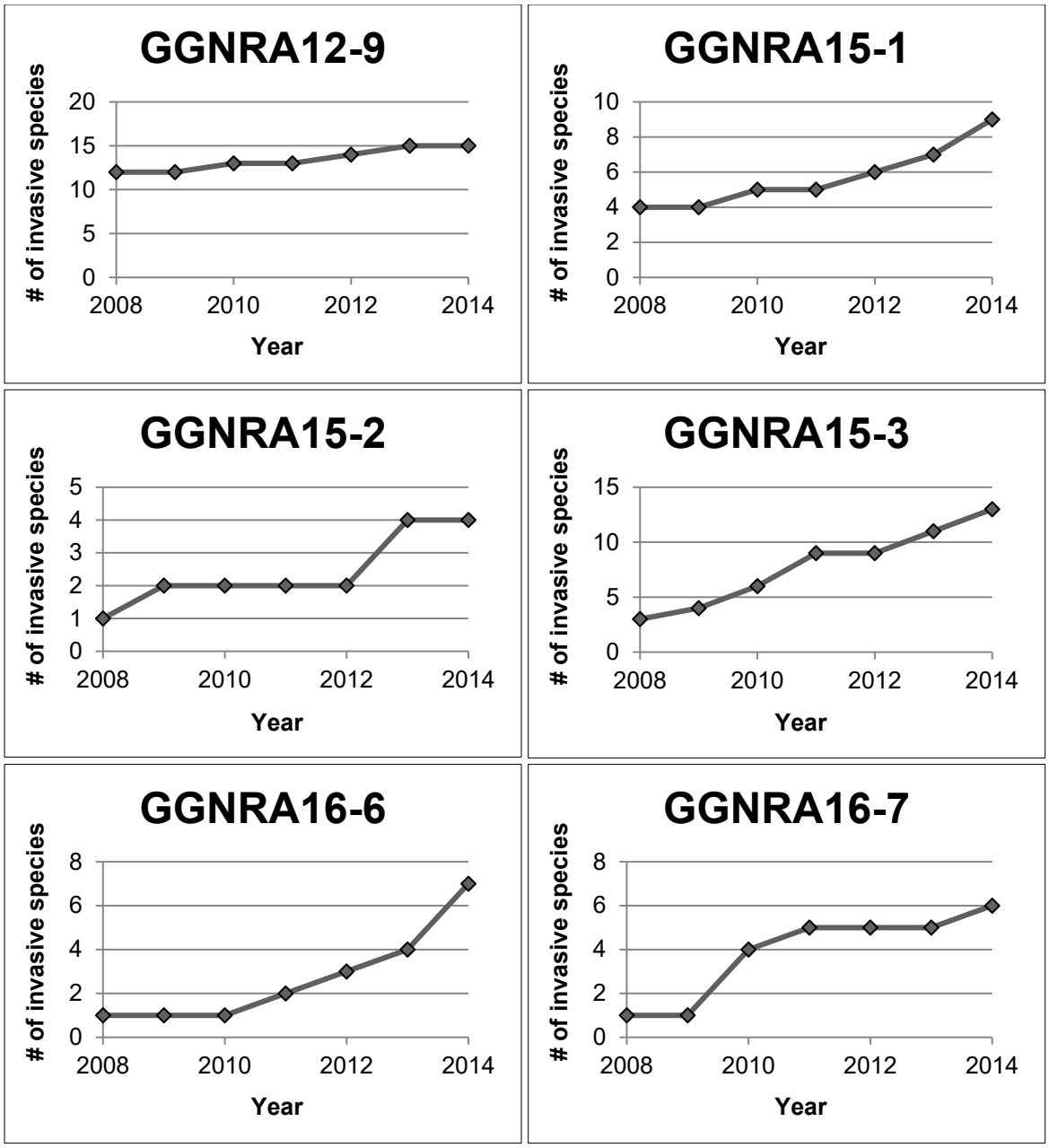


Figure 4.4.37e. Species discovery curves for subwatersheds 12-9, 15-1, 15-2, 15-3, 16-6, and 16-7 with at least five consecutive years of annual surveys by Early Detection teams (2008 to 2014). Data presented for each year represents the cumulative number of invasive plant species documented in each subwatershed (see Appendix 4.4.1 and 4.4.2).

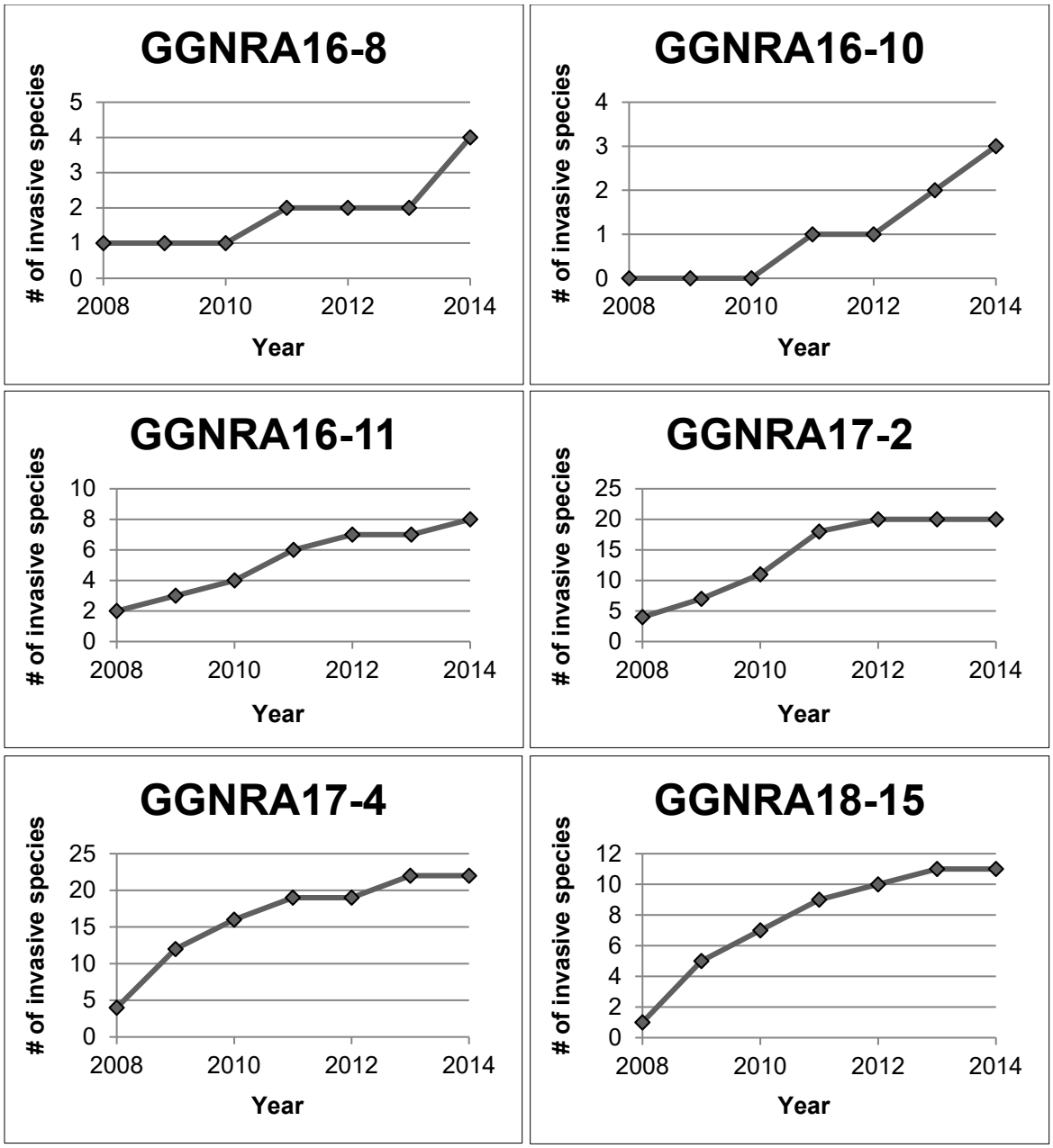


Figure 4.4.37f. Species discovery curves for subwatersheds 16-8, 16-10, 16-11, 17-2, 17-4, and 18-5 with at least five consecutive years of annual surveys by Early Detection teams (2008 to 2014). Data presented for each year represents the cumulative number of invasive plant species documented in each subwatershed (see Appendix 4.4.1 and 4.4.2).

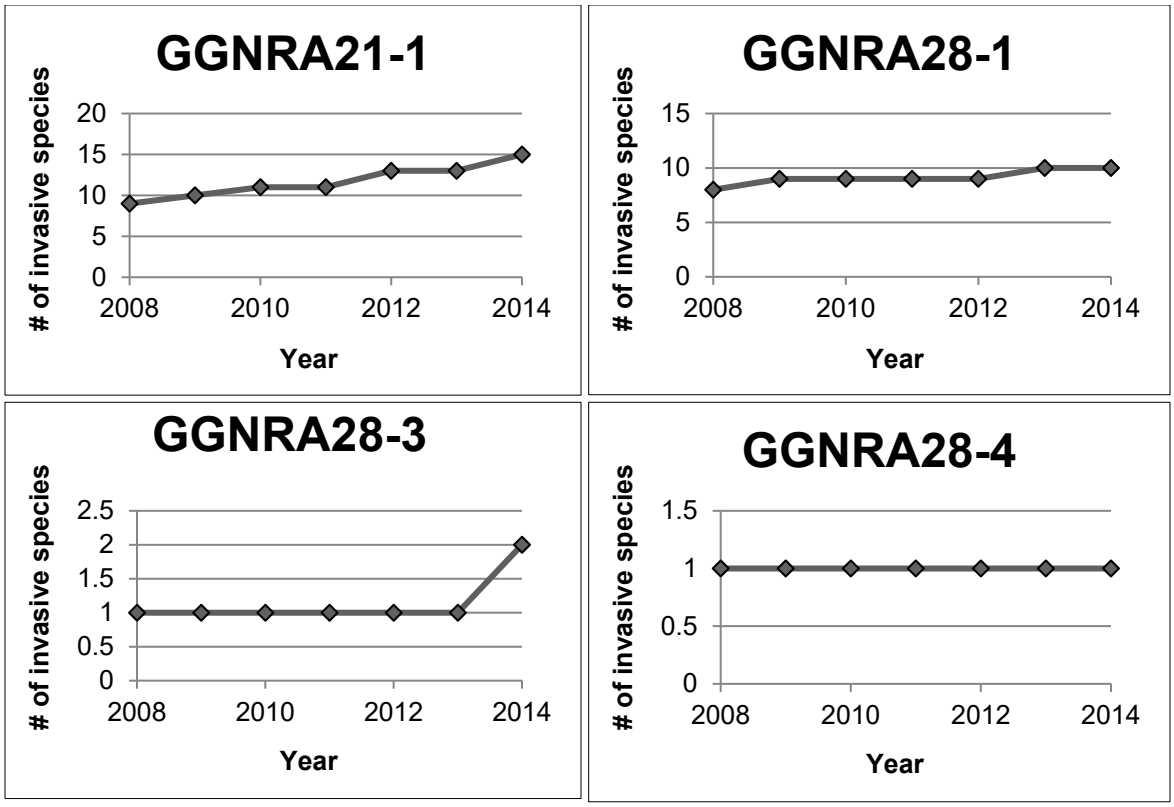


Figure 4.4.37g. Species discovery curves for subwatersheds 21-1, 28-1, 28-3, and 28-4 with at least five consecutive years of annual surveys by Early Detection teams (2008 to 2014). Data presented for each year represents the cumulative number of invasive plant species documented in each subwatershed (see Appendix 4.4.1 and 4.4.2).

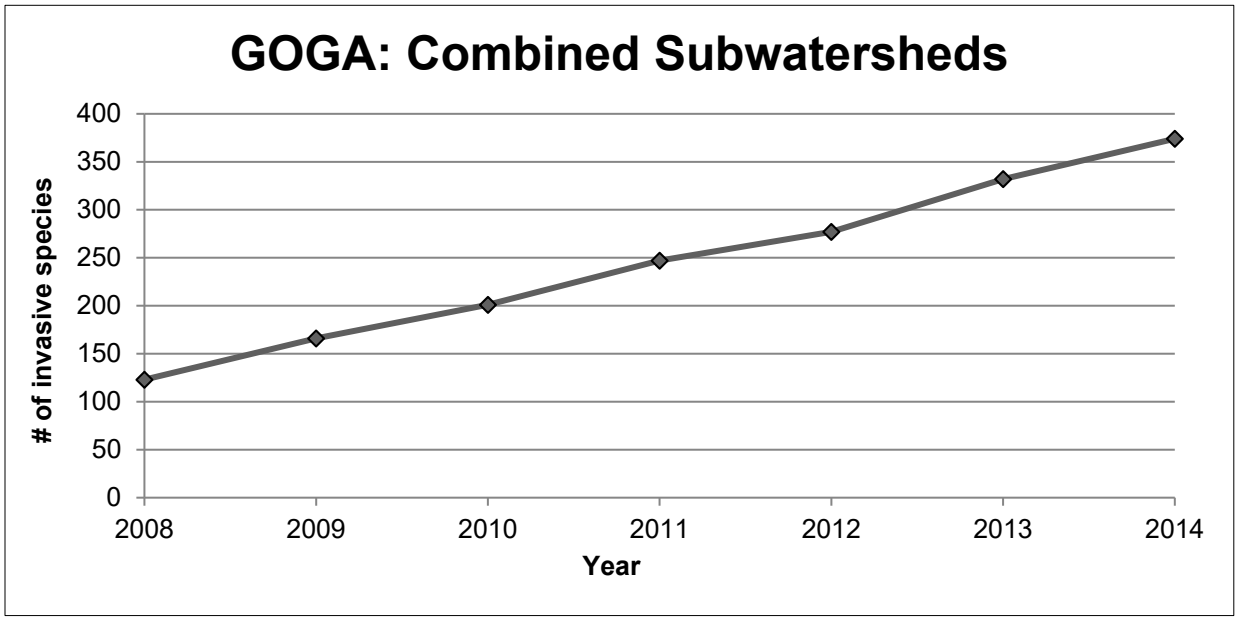


Figure 4.4.38. Sum of the total number of invasive plant species detected in all 40 GOGA subwatersheds with at least five consecutive years of annual surveys from 2008 to 2014 (see Appendix 4.4.1 and 4.4.2).

Stressors

Stressors that have the potential to directly or indirectly cause, impact, or correlate with invasive plant distribution and abundance include:

- Land-use and fragmentation
- Climate change
- Altered fire regime
- Pests and pathogens

Land-use and Fragmentation

Both current disturbance impacts and the legacy of former land-uses can influence the distribution of invasive plant species (Malavasi et al. 2014). Disturbance is commonly implicated in the invasion of exotic plant species (Hobbs and Huenneke 1992, Lodge 1993, D'Antonio et al. 2000). Much empirical support suggests that by providing growing space, decreasing competition from native plants, and releasing a pulse of resources, disturbance promotes the invasion of exotic plants (Davis et al. 2000). In GOGA, activities such as road and trail maintenance create disturbances that allow non-native plant invasions into natural areas. In addition, the high number of visitors in GOGA (approximately 15 million per year) contributes both to disturbance and to a source of invasive plant propagules in many areas. Prior to becoming a national park, GOGA lands had a long history of disturbance from ranching and army-era activities that likely led to the initial invasion of many areas by non-native plants.

Fragmentation of natural habitats has also been associated with enhanced invasibility in ecological communities (Theoharides and Dukes 2007, Malavasi et al. 2014). GOGA is a highly fragmented park with many habitat patches located within a matrix of intensive human land use. Most GOGA lands are adjacent to or near urban settings, with private landowners along park boundaries, and numerous roads and trails. Due to the close proximity of development and urban boundaries, many of the invasive species found in the parks are horticultural species that have spread as an unintended consequence of gardening and landscaping.

Several studies show strong associations between roads and trails and the distribution of invasive species (e.g., Timmens and Williams 1991, D'Antonio et al. 2000, Parendes and Jones 2000, Harrison et al. 2002, Gelbard and Belnap 2003, Gelbard and Harrison 2003, Watkins et al. 2003). These corridors may contribute to the success of invasive plants by providing disturbed soil, high light, altered hydrology, and destruction of the native seed bank (D'Antonio et al. 2000, Trombulak and Frissell 2000) and by increasing propagule pressure by providing pathways for dispersal vectors. For instance, dispersal of propagules along trails has been attributed to humans and horses (MacDonald et al. 1988, Timmens and Williams 1991, Campbell and Gibson 2001). Vehicles can also transport propagules along roadways (Lonsdale and Lane 1994). In a review of the impact of disturbance corridors on the distribution and abundance of invasive plant species, D'Antonio et al. (2000) found that half of studies reported that invasive species spread into adjacent undisturbed habitat, while the other half reported that invasive plant species remained only in corridors. The likelihood and rate of invasive plant spread from corridors into adjacent natural systems likely

depends on the nature of the ecosystem, the traits of the invasive plant species, and the time since invasion (D'Antonio et al.2000).

Climate Change

Climate change is expected to favor the spread of invasive species. Climate change scenarios predict alterations in fire regime, hydrological changes, change in precipitation and increased temperature, as well as an increase in extreme weather events. Many invasive plants are projected to benefit from these shifting conditions and to colonize and spread to new sites. Changing resource availability may allow invasive plants that could once only survive in gardens or disturbance corridors to spread into natural areas (Dukes and Mooney 1999, Higgins and Richardson 1999, Simberloff 2000). Rapid warming may disproportionately benefit invasive plants as these species are more likely than native species to have traits such as rapid dispersal, short juvenile periods, high fecundity, and small seed mass (Rejmanek 1996, Dukes and Mooney 1999, Simberloff 2000).

Climate change and increasing CO_2 may also affect patterns of invasive plant trade and introduction success. Warming is likely to cause shifts in the ranges of horticultural imports. Similarly, patterns of transport of agricultural species are likely to change, and agricultural weeds may expand into new environments (Theoharides and Dukes 2007).

Altered Fire Regime

Altered fire regimes, specifically fire intensity, severity, and frequency (or fire return interval) can increase the richness and extent of invasive plants. In turn, some invasive plants, such as cheatgrass and other annual grasses, can alter fire regimes through the creation of dense loads of continuous fine fuels in habitat types that can lead to increased fire frequency, size, and completeness of burning (D'Antonio et al. 2000, Brooks et al. 2004).

Pests and Pathogens

In California, a number of infectious diseases and insects use invasive plants as host organisms, may interact with invasive plants, or may be found with them. Invasive plants can also indirectly aid in the spread of pathogens by increasing competition for resources, thereby lowering the resistance of native plants to infection. At GOGA, some pathogens may have a negative impact on non-native plants such as the effect of pine pitch canker on Monterey pine. In other cases, pathogens may clear the way for new invaders, such as oak and tanoak stands that are being killed by Sudden Oak Death and may be replaced by non-natives in some locations.

Level of confidence in assessment

Low Confidence in the existing data for GOGA is limited by the non-systematic temporal and spatial coverage of past sampling efforts. Although surveys of invasive, non-native plants were initiated at GOGA in 1987, the majority of surveys in GOGA since that time have been ad hoc and targeted towards specific projects. There have not been park wide, systematic invasive plant surveys in recent decades. Different park programs and projects used a variety of mapping protocols based upon their variable needs and available resources. As a result, the existing dataset is extensive but it is highly disjointed. Inconsistencies in data availability and methodology limit the usefulness of much of this

data. While I & M Early Detection data provides a relatively more systematic sampling program, data are currently too temporally and spatially limited to draw reliable park wide conclusions.

Gaps in understanding

The most pressing data need at GOGA is a protocol to establish more consistent sampling strategy, survey methodology, and data management. Despite many years of invasive plant surveys in GOGA, we were unable to make reliable assessments or determine trends due to a history of inconsistently implemented surveys and large areas that have not been studied.

A consistent monitoring program that establishes baseline data for unmapped locations and repeats surveys in previously mapped areas would help managers assess any changes in invasive plant condition over time. The Early Detection data will continue to meet some of this need but it is restricted to areas along roads and trails. To address concerns regarding mapping protocol inconsistences, GOGA staff developed the "Manual for Surveying and Mapping Invasive Species" in 1999 (GGNRA 1999). While the manual provided consistency and a protocol for data collection that was used in a number of park watersheds, it was not widely used. Currently, GOGA staff are mapping invasive species occurrences and treatments in CalFlora's Weed Manager. Finally, only a small fraction of invasive plant mapping efforts record the actual survey areas and list of species inventoried. Therefore, while some historic and current locations of many invasive non-native plants are known, there is no way to be sure that areas with no data are weed-free. Staff and volunteers work on 140 of the 340 invasive plant species known in the parks, focusing on incipient populations and high-priority sites, but detection and treatment capacity varies by area and staffing availability.

Another priority for monitoring is newly acquired and other previously unmapped areas. For instance, Golden Gate National Recreation Area acquired lands at Rancho Corral de Tierra (RCDT) in 2012. In 2013, the 17 subwatersheds within RCDT were prioritized for monitoring using the SFAN Early Detection of Invasive Species methodology previously used for all GOGA subwatersheds. Five of the subwatersheds were deemed at high risk of invasion and harm to significant biological resources. Subsequent to this analysis, invasive plants were mapped on RCDT lands.

Condition Summary

The number of invasive plant species and the extent of area invaded in Golden Gate National Recreation Area are high and continue to increase. Data indicate that nearly 5650 acres have been invaded by high priority species since baseline data was collected in 1987. Our assessment suggests that invasive plants in GOGA are ranked as a significant concern (red). The condition of each individual indicator was ranked as either moderate or significant concern for the majority of management zones (Figure 4.4.39). Invasive plants were rated as low concern in only two zones, the Sensitive Resources Zone and Historic Immersion Zone (Figure 4.4.39). The reported values are likely underestimates of plant invasion indicators because of the limited area surveyed. In addition, the accuracy of comparisons among management zones is reduced because the percentage of land area surveyed in each zone varied significantly. Confidence in existing data is limited by the non-systematic temporal and spatial coverage of past sampling efforts (Table 4.4.4).

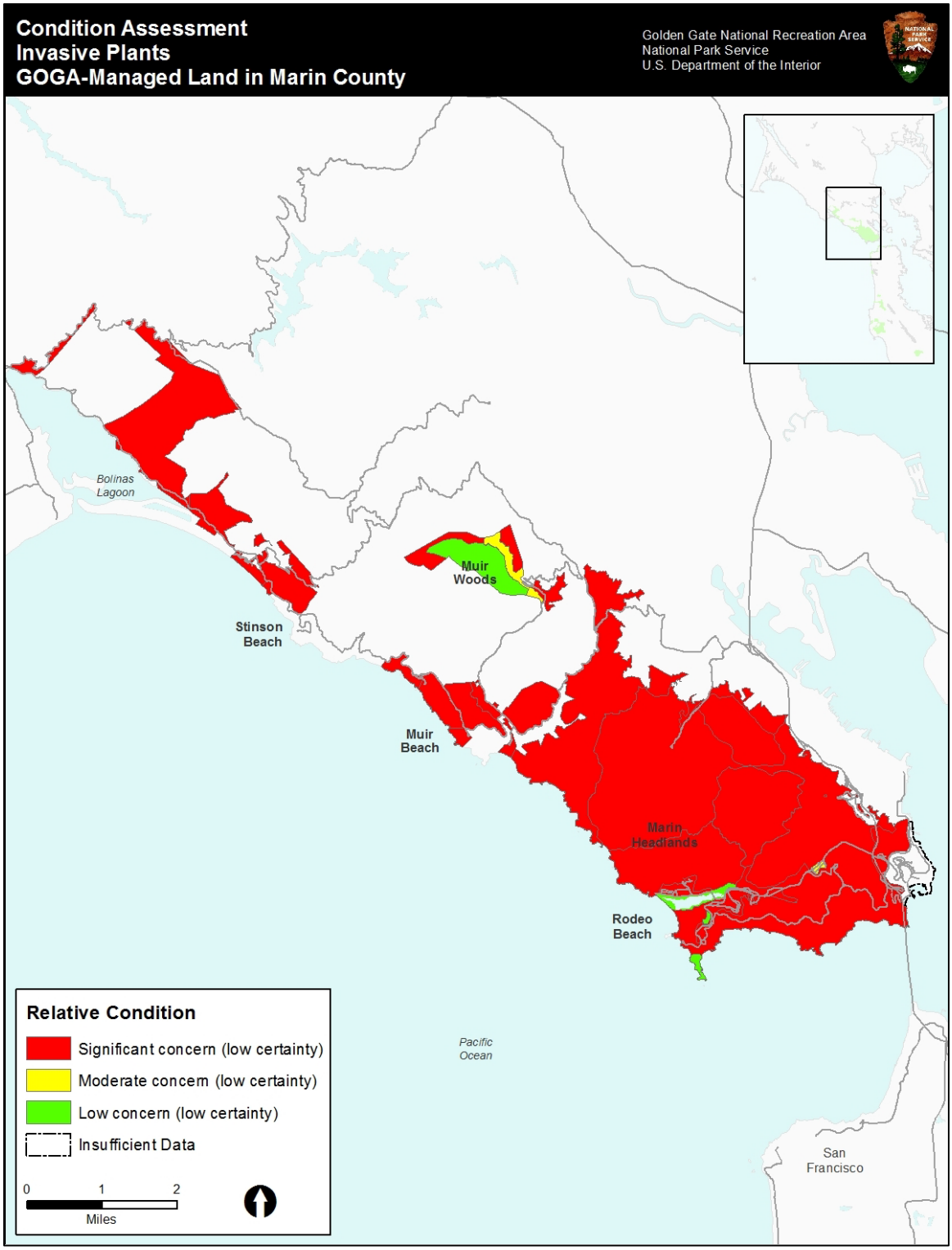
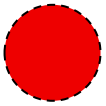
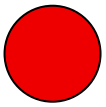
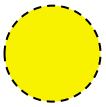
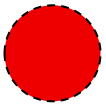


Figure 4.4.39. Condition assessment of invasive plants by management zone. Color indicates condition: red = significant concern; yellow = moderate concern; green = low concern. The confidence level for this assessment was low (NPS).

Table 4.4.4. Resource Condition Summary for Invasive Plants.

Indicators of Condition	Specific Measures	Condition Status	Rationale
Potential for spread	Spread of high priority invasive species		Increase of more than 5,500 acres invaded since 1987
Propagule pressure/invasibility	Number of invasive species		174 invasive plant species identified for monitoring by the Early Detection program
	Number of new introductions		41 additional invasive species documented since 2011
Potential impacts on native species/ ecosystems	Extent of area invaded		Surveys have documented the presence of at least one invasive species in approximately 25% of park area
Overall Condition Status for Invasive Plants			**The number of invasive plant species and the extent of area invaded are high and continue to increase. Confidence in existing data is limited by the non-systematic temporal and spatial coverage of past sampling efforts.**

4.4.4. Information Sources

Sources of Expertise

- Alison Forrestel, Vegetation Ecologist, Golden Gate National Recreation Area
- Maria Alvarez, Vegetation Ecologist, Golden Gate National Recreation Area
- Daniel George, Program Manager, San Francisco Bay Area Network Inventory and Monitoring Program
- Eric Wrubel, Botanist, San Francisco Bay Area Network Inventory and Monitoring Program
- Stephen Skartvedt, GIS Specialist, Golden Gate National Recreation Area

Literature Cited

Asher, J.A., and D.W. Harmon. 1995. Invasive exotic plants are destroying the naturalness of U.S. Wilderness areas. International Journal of Wilderness 1:35–37.

Brooks, M.L., C.M. D'Antonio, D.M. Richardson, J.B. Grace, J.E. Keeley, J.M. DiTomaso, R.J. Hobbs, M. Pellant, and D. Pyke. 2004. Effects of Alien Invasive Plants on Fire Regime. Bioscience 54: 677–688.

Campbell, J.E. and D.J. Gibson. 2001. The effect of seeds of exotic species transported via horse dung on vegetation along trail corridors. Plant Ecology 157:23–35.

D'Antonio, C.M. and B.E. Mahall. 1991. Root profiles and competition between the invasive, exotic perennial, *Carpobrotus edulis,* and two native shrub species in California coastal scrub. American Journal of Botany 78:885–894.

D'Antonio, C.M., and P.M. Vitousek. 1992. Biological invasions by exotic grasses, the grass fire cycle, and global change. Annu. Rev. Ecol. Syst. 23:63–87.

D'Antonio, C.M., T.L. Dudley, and M. Mack. 2000. Disturbance and biological invasions: Direct effects and feedbacks. In: Walker L.R., ed. *Ecosystems of disturbed ground*, Vol. 16. New York, NY, USA: Elsevier Science, 429–468.

Davis, M. A., J. P. Grime, and K. Thompson. 2000. Fluctuating resources in plant communities: a general theory of invasibility. Journal of Ecology 88:528–534.

Dukes, J.S. and H.A. Mooney. 1999. Does global change increase the success of biological invaders? *Trends in Ecology and Evolution* 14:135–139.

Ehrenfeld, J.G. 2003. The effects of exotic plant invasions on soil nutrient cycling processes. Ecosystems 6:503–523. Farrell, S. and Gennett. 1999. Golden Gate National Recreation Area Unpublished Report, Fort Cronkhite, California.

Gelbard, J. L. and J. Belnap. 2003. Roads as conduits for exotic plant invasions in a semiarid landscape. Conservation Biology 17:420–432.

Gelbard, J.L. and S. Harrison. 2003. Roadless habitats as refuges for native grasslands: Interactions with soil, aspect, and grazing. Ecological Applications 13: 404–415.

Gordon, D. R. 1998. Effects of invasive, non-indigenous plant species on ecosystem processes: Lessons from Florida. Ecol. Appl. 8:975–989.

Harrison, S., C. Hohn, and S. Ratay. 2002. Distribution of exotic plants along roads in a peninsular nature reserve. Biological Invasions 4: 425–430.

Higgins, S.I. and D.M. Richardson. 1999. Predicting plant migration rates in a changing world: The role of long-distance dispersal. American Naturalist **153**: 464–475.

Hobbs, R. J., and L. F. Huenneke. 1992. Disturbance, Diversity, and Invasion – Implications for Conservations. Conservation Biology 6:324–337.

King, W. B. 1985. Island birds: will the future repeat the past? Pages 3–15 *in* P. J. Moors, editor. Conservation of Island Birds. International Council for Bird Preservation. Cambridge University Press, Cambridge, UK.

Lodge, D. M. 1993. Biological invasions – lessons for ecology. Trends in Ecology and Evolution 8:133–137.

Lonsdale, W.M. and A.M. Lane. 1994. Tourist vehicles as vectors of weed seeds in Kakadu National Park, Northern Australia. Biological Conservation 69: 277–283.

Mack, R. N., D. Simberloff, W. M. Lonsdale, H. Evans, M. Clout, and F. A. Bazzaz. 2000. Biotic invasions: Causes, epidemiology, global consequences, and control. Ecological Applications **10**:689–710.

MacDonald, I.A., D.M. Graber, S. De Benedettii, R.H. Groves, and E.R. Fuentes. 1988. Introduced species in nature reserves in Mediterranean-type climatic regions of the world. Biological Conservation 44: 37–66.

Malavasi, M., M. Carboni, M. Cutini, M. L. Carranza, A.T.R. Acosta. 2014. Landscape fragmentation, land-use legacy and propagule pressure promote plant invasion on coastal dunes: a patch-based approach. Landscape Ecology 29: 1541–1550.

National Park Service (NPS). 2004. Rare plant monitoring report. Golden Gate National Recreation Area Unpublished Report, Fort Cronkhite, California.

Parendes, L. A., and J. A. Jones. 2000. Role of light availability and dispersal in exotic plant invasion along roads and streams in the H. J. Andrews Experimental Forest, Oregon. Conservation Biology 14:64–75.

Rejmanek, M. 1996. A theory of seed plant invasiveness: The first sketch. Biological Conservation **78**: 171–181.

Simberloff, D. 2000. Global climate change and introduced species in United States forests. Science of the Total Environment 262:253–261.

Theoharides, K. A. and J.S. Dukes. 2007. Plant invasion across space and time: factors affecting nonindigenous species success during four stages of invasion. New Phytologist 2: 256–273.

Thomas, T. 1987. Alien Plant Inventory of the GGNRA. Golden Gate National Recreation Area Unpublished Report, Fort Cronkhite, California.

Tilman, D. 1999. The ecological consequences of changes in biodiversity: a search for general principles. Ecology 80:1455–1474.

Timmens, S.M. and P.A. Williams. 1991. Weed numbers in New Zealand's forest and scrub reserves. New Zealand Journal of Ecology 15:153–162.

Trombulak, S.C. and C.A. Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology14: 18–30.

Vaghti, M. 1997. Parkwide Cape-ivy Maps and Statistics. Golden Gate National Recreation Area Unpublished Report, Fort Cronkhite, California.

Vitousek, P. M. 1990. Biological invasions and ecosystem processes: towards an integration of population biology and ecosystem studies. Oikos 57:7–13.

Vitousek, P. M., and L. R. Walker. 1989. Biological Invasion by *Myrica faya* in Hawaii – Plant Demography, Nitrogen-Fixation, Ecosystem Effects. Ecol. Monogr 59:247–265.

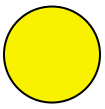
Watkins, R.Z., J.Q. Chen, J. Pickens, and K.D. Brosofske. 2003. Effects of forest roads on understory plants in a managed hardwood landscape. Conservation Biology 17: 411–419.

Welch, B.A., Geissler, P.H., and Latham, Penelope. 2014. Early detection of invasive plants – Principles and practices: U.S. Geological Survey Scientific Investigations Report 2012–5162, 193 p.

Wood, L. and S. Farrell. 1998. Inventory of Exotic Trees in the GGNRA 1997–1998. Golden Gate National Recreation Area Unpublished Report, Fort Cronkhite, California.

4.5. Landscape Context

Collectively, GOGA land holdings provide relatively more intact wildlands than the region with a greater proportion of core area. However, the limited core area in San Francisco County is cause for concern.



4.5.1. Why Focal Resource Was Assessed

Description

The Golden Gate National Recreation Area (GOGA) is a national park that consists of many individual land holdings dispersed through three Bay Area counties: Marin, San Francisco, and San Mateo. GOGA currently recognizes 60 discrete parcels (GOGA GIS database). These lands range in size from large contiguous wildlands (e.g., Marin Headlands, 3,933 acres) to small inholdings in the urban core (e.g., China Beach, 6.5 acres). They include majestic forests (e.g., Muir Woods, 556 acres), historical icons (e.g., Alcatraz Island, 23.5 acres), former military bases (e.g., Crissy Field, 88.8 acres), and popular beaches (e.g., Stinson Beach, 614.5 acres). Clearly, GOGA encompasses a diversity of ecosystems embedded within vastly different landscapes.

These differences in the landscape matter to the assessment of resources conditions in the Park. Not only is the nature of the individual patch important but also its landscape context. In a recent review, Wurtzebach and Schultz (2016) concluded that land cover/land use change outside of parks was one of the greatest threats to the ecological integrity within parks. Wang et al. (2009) emphasized the importance of measuring the landscape surrounding parks so managers could better understand how ecosystems in the park interact with the surrounding landscape. For example at GOGA, the size of the parcel and the extent of developed features influence organisms from bobcats (Riley 2006) to bees (McFrederick and Le Buhn 2006). Furthermore, the characteristics of habitats on the edges of protected areas can affect key ecological processes like nest predation (Donovan et al. 1997) and plant invasion (Pauchard and Alaback 2004).

Given the potential impact of lands adjacent to parks on focal resources, the National Park Service included landscape dynamics as a priority measure in its ecological monitoring framework (Fancy et al. 2009). Specifically, landscape dynamics refers to changes in natural land cover types and human land use in the areas surrounding national parks (Piekielek and Hansen 2012). Landscape context defines the relevant characteristics and spatial scales to consider. In short, landscape dynamics measures how the landscape context changes over time.

The distribution of diverse parcels through a spatially heterogeneous landscape is an essential feature of GOGA but it poses major challenges to management and assessment. There is no one landscape context. It changes from parcel to parcel. Moreover the public interacts very differently with the portfolio of GOGA's holdings through the three Bay Area counties. The perceptions and expectations of constituents can directly impinge on natural resources (e.g., Banks and Bryant 2007). Thus, quantifying the spatial arrangement of each parcel and its interface with the surrounding

community is key aspect of a natural resource condition assessment. The landscape context provides a "logical and appropriate reference condition" for land holdings that span an urban-rural gradient (NPS 2014). As part of the condition assessment for GOGA, defining the landscape context was a vital first step.

Assessment Framework

To summarize the landscape context of GOGA, the geographic characteristics of each land holding were evaluated. The analysis was conducted at three spatial scales: the assemblage of Park land holdings in comparison to a defined region; the relationship of each parcel to its immediate neighborhood; and the spatial dimensions of the individual parcel. The specific dimensions evaluated as part of the landscape context were:

1. The regional unit analysis compared GOGA's land holdings contribute to the regional ecological context.
2. The parcel-patch analysis compared individual land holdings within GOGA to neighboring lands.
3. The core area analysis calculated the core area within each parcel in order to determine the total extent of core currently managed by GOGA.

4.5.2. How Focal Resource Was Assessed

Measures

Regional unit analysis

The goal of this analysis was to place GOGA units in the appropriate regional context in order to provide valid comparisons regarding their condition. This approach recognizes that the regional context of GOGA's land holdings is critical to their management success. For example, in the urban areas, small land holdings with a moderate level of vegetation cover may provide a higher quality habitat in relation to its surroundings compared to a similar parcel in a more rural environment. To provide this context, parcel statistics were summarized based on the regions recognized by GOGA. In consultation with GOGA resource managers (primarily Stephen Skartvedt, GIS specialist for GOGA), the three counties containing GOGA units were chosen to define the regional comparison. These three counties, while geographically adjacent and constituents of the San Francisco Bay Metropolitan Area, span a range along the urban-rural gradient (US Census 2016). Marin (520 mi^2) and San Mateo (448 mi^2) counties are ten times larger in area than San Francisco County (47 mi^2). In terms of population density, the more urban San Francisco County has 17,179 people mi^{-2} compared to San Mateo with 1,602 people mi^{-2}. Marin is the least populous with 485 people mi^{-2}. Thus all three counties represent comparatively urban landscapes with parklands embedded in a developed matrix. To define the regional landscape context, average landscape elements were calculated for each county (e.g., canopy cover, impervious surface, road density) and then were compared to the same metrics calculated for parcels in the region. Also summarized were the number of land holdings, the average parcel size, and the average perimeter-to-area ratios for each parcel within a region (McGarigal et al. 2002).

Parcel-patch analysis

The goal of the parcel-patch analysis was to understand the local context of the individual parcel. This analysis quantified internal parcel-patch characteristics (e.g., number of unique land cover types, stream density). In addition, these patches exist in a specific neighborhood. Therefore the similarity between the parcel and its neighbor was estimated.

Core area analysis

Given the urban nature of GOGA, the extent of core area is a particularly important aspect of the landscape context. Core areas provide locations where habitat loss and fragmentation are minimized (Liu et al. 2016). They represent intact ecosystems that maintain their ecological function and experience limited impact from surrounding areas (Kupfer 2012). The specific definition of a core area in GOGA depended on the results from the parcel-patch analysis. However in general, the assumption was that Park holdings will have negative elements (e.g., roads that divide) and positive elements (e.g., riparian strips that connect) which influence the ecological value of the core area. When defining core areas, the extent to which a core area met other management priorities was also considered. For example, tracts of non-native vegetation were excluded from core areas, even though the non-native vegetation might contribute to the continuity in plant cover, because minimizing invasive species is a Park management goal. In summary, core areas have internal continuity and limited intrusion of developed elements (e.g., urban edges, roads, buildings).

Data Sources and Methods

As noted previously, the assessment was completed using three types of analysis: 1) regional unit analysis, 2) parcel-patch analysis and 3) core area analysis. Parcel boundary datasets were provided for each of the study regions (Marin, San Francisco, and San Mateo). Several geospatial datasets were identified in order to calculate the landscape metrics, namely canopy cover, impervious surface, roads, rivers, and vegetation data. Below is a brief description of each.

Reporting Units & GOGA Landholding (Parcels)

These layers were defined by merging GOGA landholdings as defined by the National Park Service (NPS) and the county boundaries of Marin, San Francisco, and San Mateo. Areas outside of GOGA jurisdiction were described as the “matrix” (Figure 4.5.1).

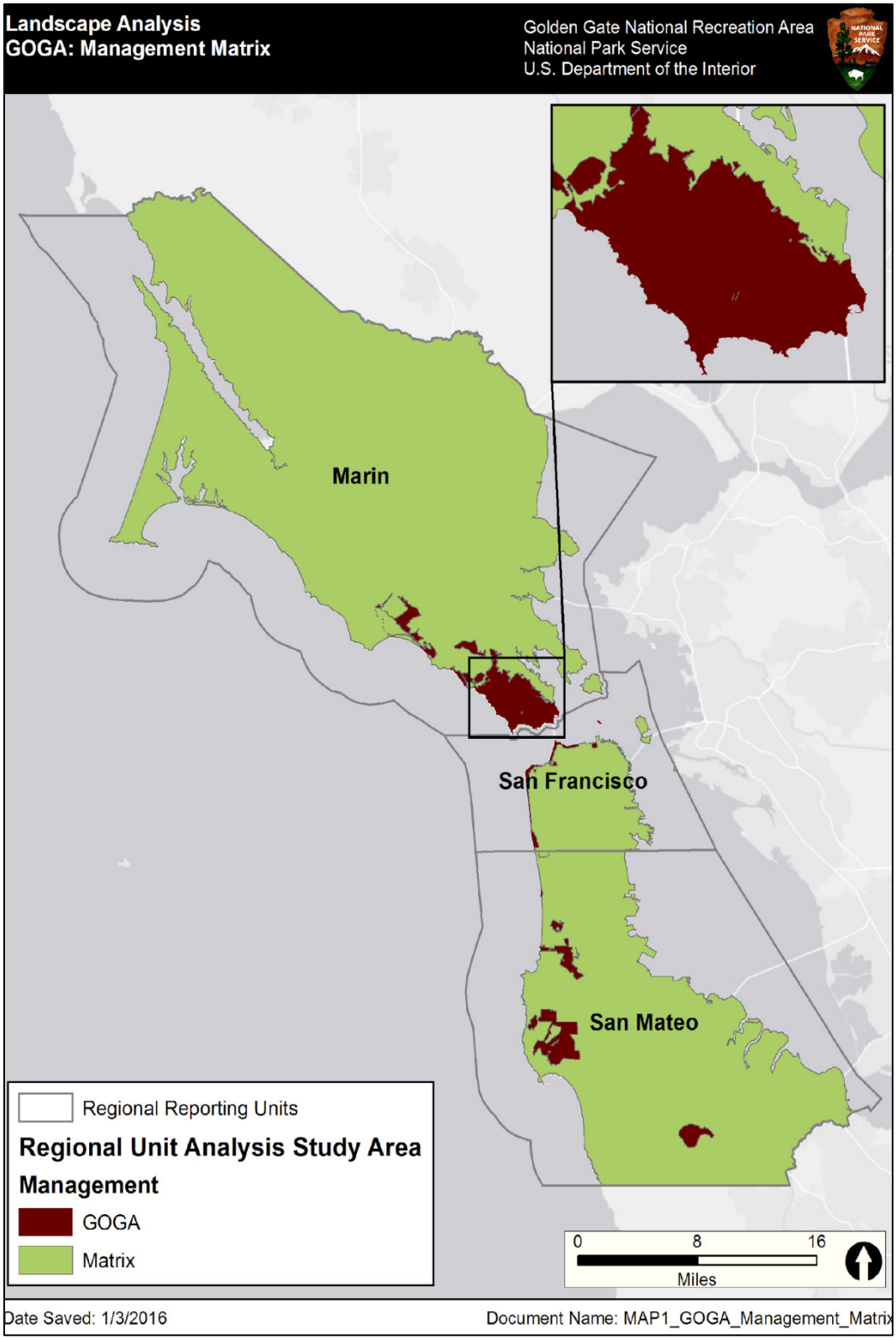


Figure 4.5.1. Location of the individual GOGA parcels in relation to the region/county (NPS).

Canopy Cover

Canopy cover was obtained from the National Land Cover Dataset (NLCD) for 2011 (Figure 4.5.2). The NLCD is now produced every 5 years by a consortium of nine federal agencies in order to generate consistent and relevant land cover information at the national scale. The NLCD primarily relies on Landsat imagery which imposes a 30-m pixel resolution. For 2011, the most recent version of the NLCD, canopy cover refers to the percentage of area covered by plants with a tree life form (i.e., a woody, single-stemmed plant). There is no minimum height specification as in previous versions of the NLCD (Homer et al. 2015). The extent of the tree canopy provides basic structural information about the vegetation that is particularly important in more developed areas where trees deliver key ecosystem services and amenities (Nowak and Greenfield 2010). The data and the definitions for all the NLCD 2011 products can be found at http://www.mrlc.gov/nlcd2011.php. The canopy cover data was clipped to the study area as defined by the regional unit layer (Figure 4.5.1).

Impervious Surface

Anthopogenic impervious surfaces typically include roads, parking lots, driveways and building footprints (Jennings et al. 2004). Jennings et al. (2004) argue that the extent of impervious surfaces is one of the best indicators of the negative impact of urbanizing watersheds. Nowak and Greenfield (2010) consider tree canopy and impervious surface cover essential information related to the condition of natural resources. For this analysis, the impervious surface layer (IS) was developed by buffering the Roads layers (supplied by the NPS) by 20 feet and combining it with the Building layer (supplied by the NPS), the fortification layer (supplied by the NPS), the parking lot layer (supplied by the NPS) and the NLCD impervious surface layer. This layer was created in close collaboration with GOGA staff (Figure 4.5.3).

Rivers

The Rivers layer was supplied by the NPS and originated from the National Hydrography Dataset. (http://nhd.usgs.gov/). The Feature codes included were Streams/Rivers and Artificial Paths (Figure 4.5.4).

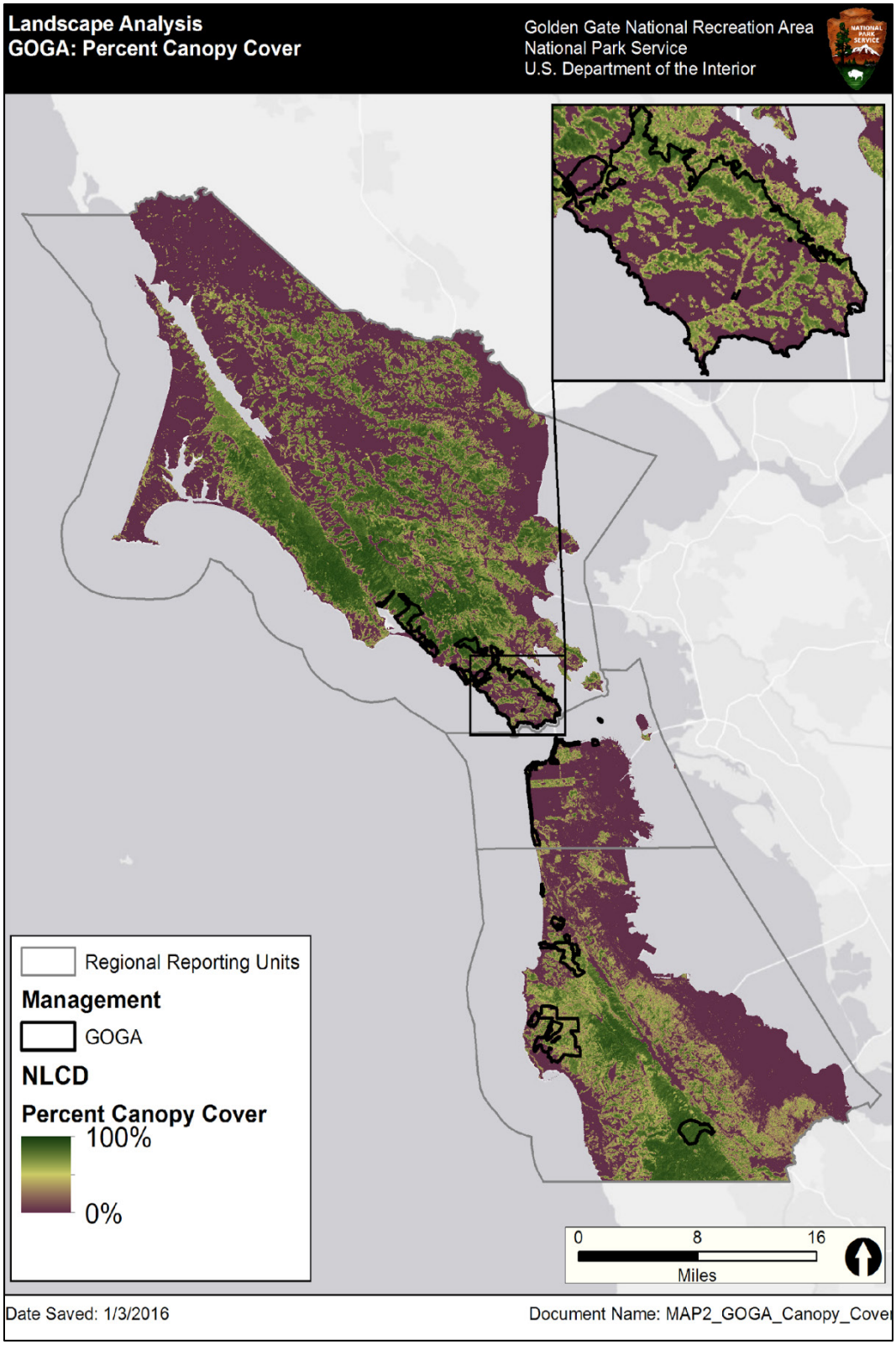


Figure 4.5.2. Gradient of canopy cover in GOGA parcels in relation to the region/county (NPS).

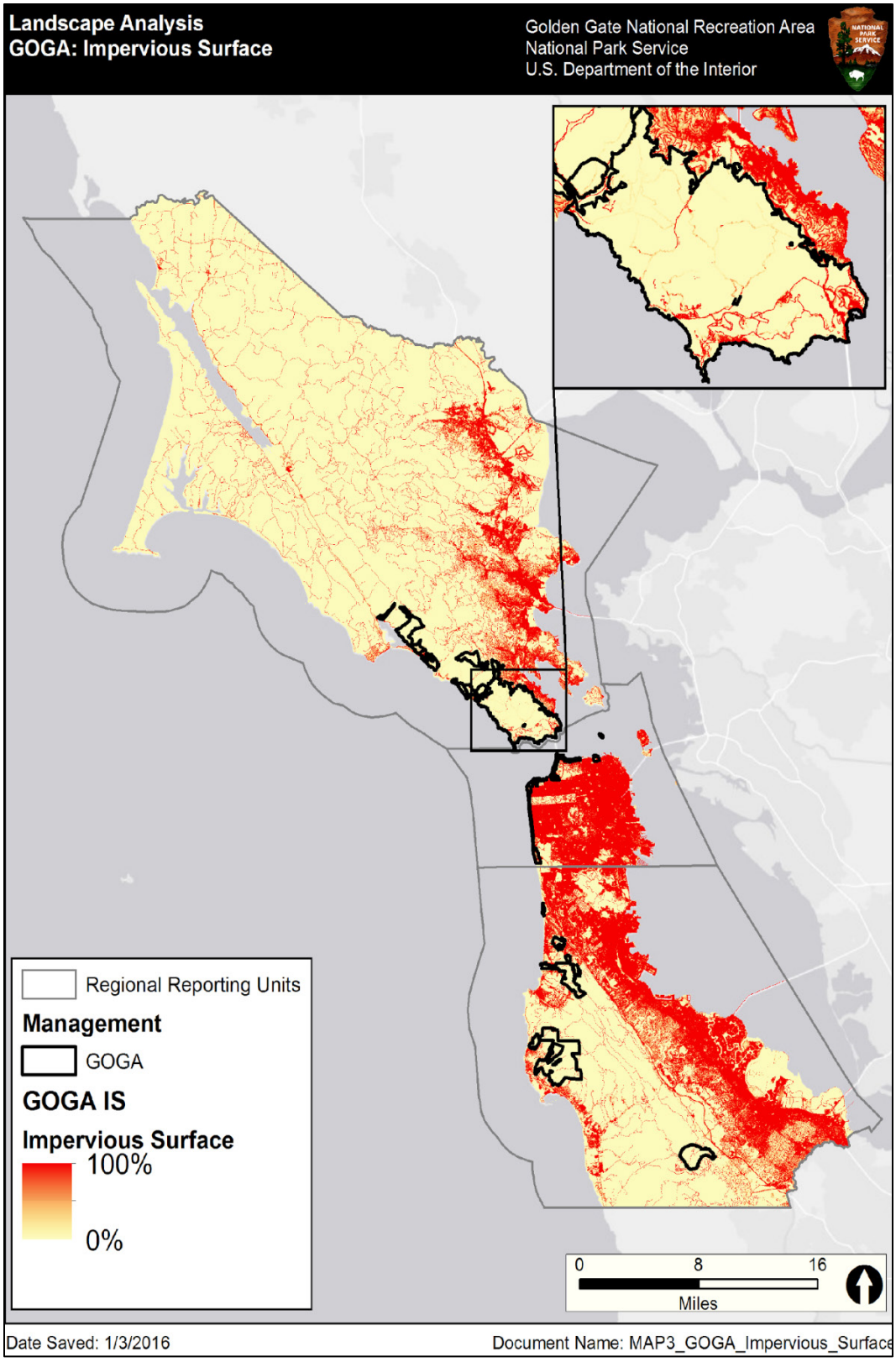


Figure 4.5.3. Density and distribution of impervious surfaces in the GOGA parcels in relation to the region/county (NPS).

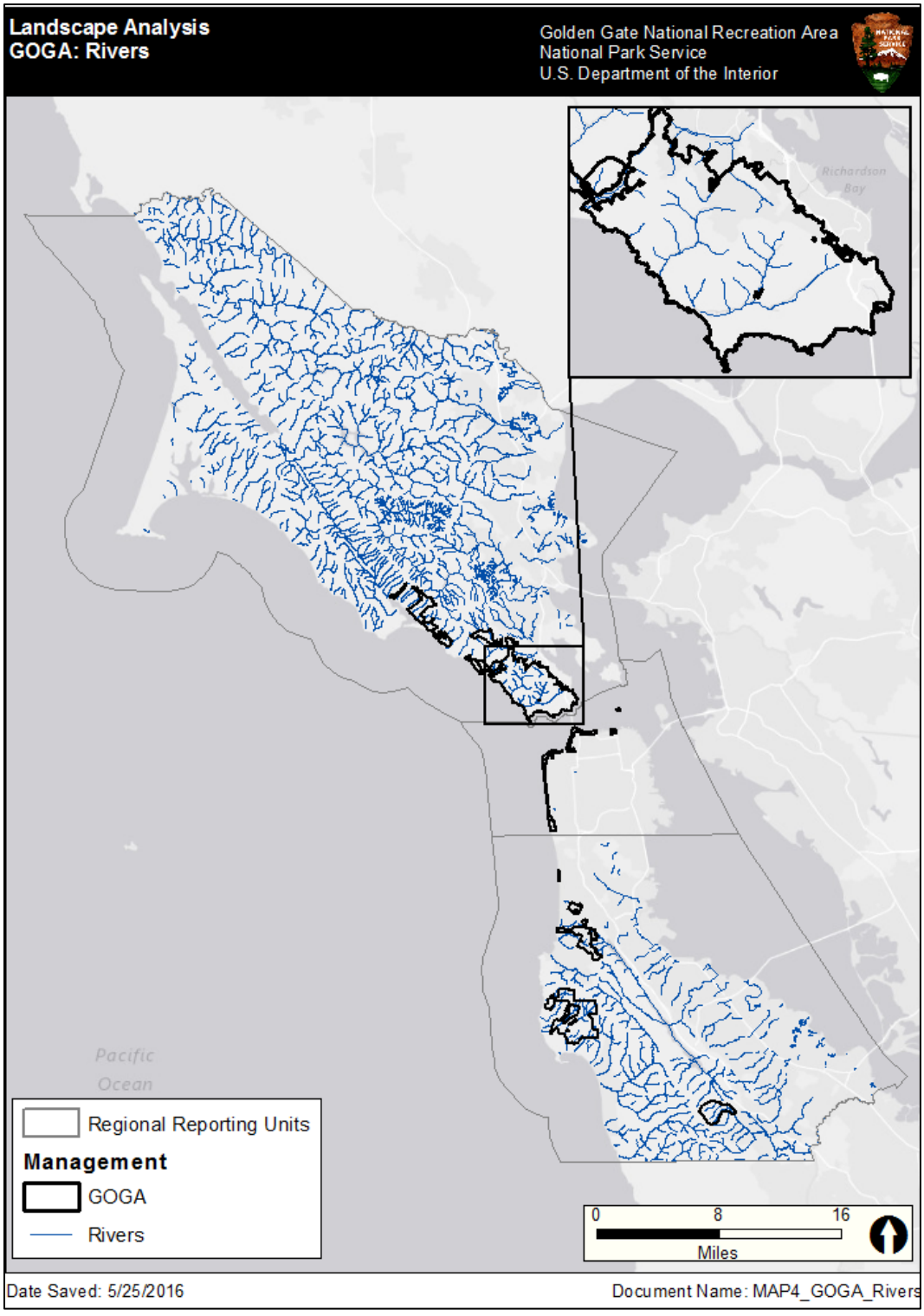


Figure 4.5.4. Distribution of streams and rivers in the GOGA parcels in relation to the region/county (NPS).

Roads

The roads layer was developed by combining the Thomas Maps Roads layers (http://stores.thomasmaps.com/) for Marin and San Mateo Counties (supplied by the NPS), the San Francisco Roads layer (supplied by the NPS), and a Trails layer (supplied by the NPS, Figure 4.5.5).

Vegetation Class

This dataset was originally developed/compiled for use in the San Francisco Bay Area Upland Habitat Goals Project (2014) and contributed to the development of the Conservation Lands Network (http://www.bayarealands.org/mapsdata.html). The relatively fine-scale vegetation types used for conservation planning (Table 4.5.1) were aggregated into more coarse-scale physiognomic units (i.e., forest vs grassland) for the parcel-patch analysis. This data was supplied by NPS staff (Figure 4.5.6).

Native/ Non-native Vegetation

For the vegetation classes defined by the Conservation Lands Network, each type was assigned as being dominated by native or non-native species (Table 4.5.1). This designation did not take into account the presence of invasive plants in the understory. Rather its intent was to identify tracts of non-native vegetation in order to excludethem from the core area analysis. The layer was created with extensive direction and input from NPS staff.

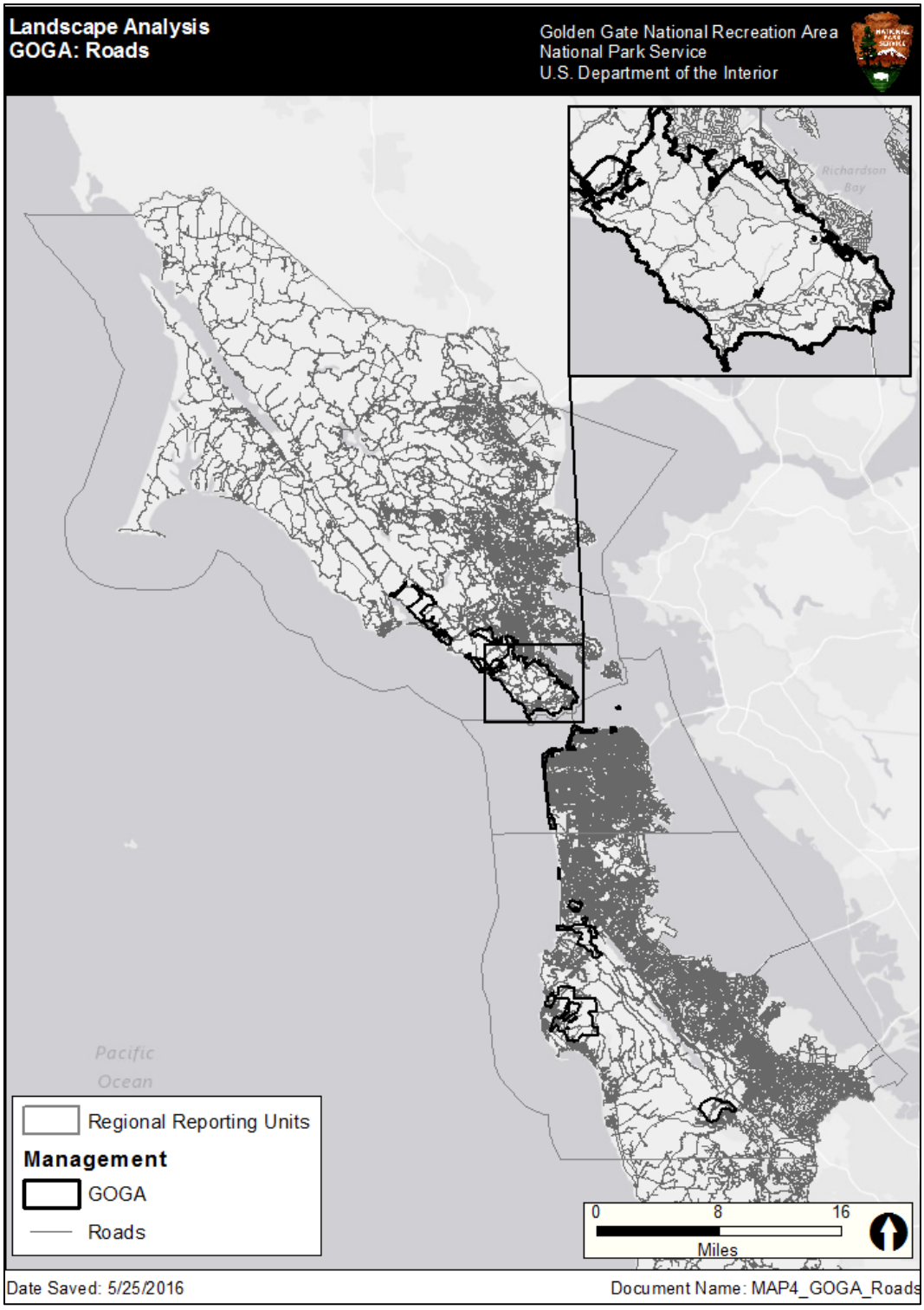


Figure 4.5.5. Distribution of roads in the GOGA parcels in relation to the region/county (NPS).

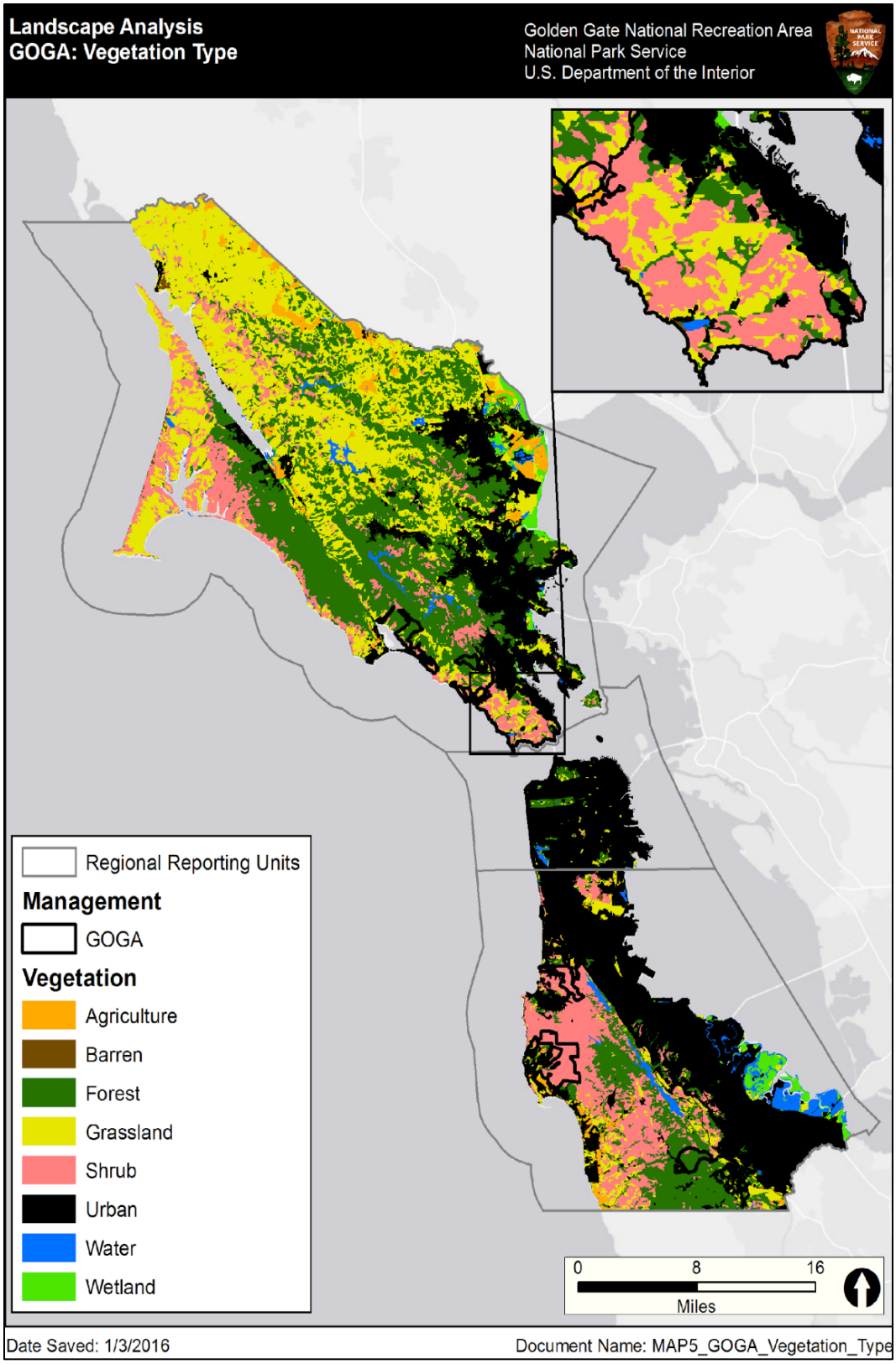


Figure 4.5.6. Distribution of vegetation classes in the GOGA parcels in relation to the region/county (NPS).

Table 4.5.1. Assignment of vegetation types to categories defined by native/non-native status of dominant vegetation. Non-vegetated categories assigned as “NA” (not applicable). Vegetation types from the Conservation Lands Network.

Vegetation Type	Status
Bishop Pine Forest	Native
Black Oak Forest / Woodland	Native
Blue Oak- Foothill Pine Woodland	Native
Blue Oak Forest / Woodland	Native
California Bay Forest	Native
Canyon Live Oak Forest	Native
Central Coast Riparian Forests	Native
Chamise Chaparral	Native
Coast Live Oak Forest / Woodland	Native
Coastal Salt Marsh / Coastal Brackish Marsh	Native
Coastal Scrub	Native
Coastal Terrace Prairie	Native
Cool Grasslands	Native
Coulter Pine Forest	Native
Douglas Fir Forest	Native
Grand Fir	Native
Hot Grasslands	Native
Interior Live Oak Forest / Woodland	Native
Juniper Woodland and Scrub	Native
Knobcone Pine Forest	Native
Mcnab Cypress	Native
Mixed Chaparral	Native
Mixed Conifer-Pine	Native
Mixed Montane Chaparral	Native
Moderate Grasslands	Native
Montane Hardwoods	Native
Monterey Cypress Forest	Native
Monterey Pine Forest	Native
Native Grassland	Native
Oregon Oak Woodland	Native
Permanent Freshwater Marsh	Native
Pygmy Cypress	Native
Redwood Forest	Native
Sargent Cypress Forest / Woodland	Native

Table 4.5.1 (continued). Assignment of vegetation types to categories defined by native/non-native status of dominant vegetation. Non-vegetated categories assigned as “NA” (not applicable). Vegetation types from the Conservation Lands Network.

Vegetation Type	Status
Semi-Desert Scrub / Desert Scrub	Native
Serpentine Conifer	Native
Serpentine Grassland	Native
Serpentine Hardwoods	Native
Serpentine Knobcone	Native
Serpentine Leather-Oak Chaparral	Native
Serpentine Riparian	Native
Serpentine Scrub	Native
Sycamore Alluvial Woodland	Native
Tanoak Forest	Native
Valley Oak Forest / Woodland	Native
Warm Grasslands	Native
Wet Meadows	Native
Barren/Rock	NA
Cultivated	NA
Dune	NA
Rural Residential	NA
Serpentine Barren	NA
Urban	NA
Water	NA
Eucalyptus	Non-native
Non-Native Ornamental Conifer-Hardwood Mixture	Non-native
Non-Native/Ornamental Conifer	Non-native
Non-native/Ornamental Grass	Non-native
Non-native/Ornamental Hardwood	Non-native
Non-Native/Ornamental Shrub	Non-native
Ponderosa Pine Forest (Non-Maritime)	Non-native

All of the spatial analyses used ArcGIS Pro (http://www.esri.com/). The geoprocessing workflow was documented using ESRI’s ModelBuilder. These models not only provide visual, step-by-step instructions of the processes and tools used to create the results but also the means to recreate and/or modify all the analyses contained in this report (Appendix 4.5.1). The specific methods for each analysis follow. The landscape metrics for each parcel are provided in Table 4.5.2.

Table 4.5.2. Reference condition indicators based on the landscape elements.

Measure	Description	Indicator
Proportion of Area in Wildlands (region only)	Larger values indicate more wildlands	Bigger is desired
Average Canopy Cover	Larger values indicate ecosystems with more tree cover	Indication is context dependent
Average Impervious Surface	Small values indicate better water quality	Smaller is desired
Acres per Road Miles	Larger values indicate less road density	Larger is desired
Acres per Trail Mile (region only)	Larger values indicate less trail density indicate more recreational access	Larger is desired
Acres per River Mile	Small values indicate a larger exposed stream density	Smaller is desired
Core Area Ratio	Larger values indicate more core area	Larger is desired

Regional unit analysis

The regional unit analysis used the parcel boundary to establish the GOGA units within each county/region. The regions were further quantified by the number of land holdings, the average parcel size, and the average perimeter/area ratios for each parcel within each county boundary. Land holdings were classified as either GOGA or matrix. Once parcel types were identified, the regional unit analysis was used to quantify the average landscape elements (e.g., canopy cover, impervious surface, road density, and vegetated surfaces) at the county and parcel level. The condition of the GOGA land was quantified by comparing each of the average landscape elements for GOGA's land holdings to the matrix land holdings. See Appendix 4.5.1 ESRI Model Builder Regional Unit Analysis for details.

Parcel-patch analysis

The parcel-patch analysis used the same parcel boundary layer elements (i.e., county boundaries and parcel type) identified in the regional unit analysis, along with the landscape element datasets. The condition of the GOGA land was quantified by comparing the GOGA land holdings to its neighboring land holdings. The neighboring area was defined by calculating a scaled buffer distance immediately surrounding each parcel. In consultation with NPS staff, the buffer distance was estimated as 1/8 of the radius of the parcel. For simplicity, the shape of each parcel was approximated as a circle of a similar area. The buffer area was then defined by a torus around the parcel with the width of the torus equal to a scaled buffer radius:

$$BR_i = \frac{\sqrt{parcel\ area\ (ac)_i * \frac{43{,}560\ ft^2 ac^{-1}}{\pi}}}{8}$$

where BR_i is the buffer radius in feet for parcel i and the parcel area is the size, in acres, of parcel i. The neighboring land holding for parcel i is then defined as the area surrounding parcel i to a distance of BR_i. For each region, the landscape elements were compared between the target parcels and their neighbors. See Appendix 4.5.1 ESRI Model Builder Parcel-Patch Analysis A and B for details.

Core area analysis

A core area was defined as a contiguously vegetated area dominated by native plants. The core also needed to be further than 50 feet from a road centerline and further than 50 feet from an impervious surface edge. The definition of a core area was developed in consultation with NPS staff. Core area was calculated for each GOGA parcel and summarized by region. Additionally, a core area ratio was generated by dividing the total core area for parcels in the region by the total area of all the parcels in the region. See Appendix 4.5.1 ESRI Model Builder Core Area Analysis for details.

Reference Conditions/Values

Condition indicators were defined from the landscape elements calculated (Table 4.5.2). In general, the expectation was that GOGA holdings would provide relatively more intact wildlands with larger core areas. Wildlands were defined as vegetation classes (Figure 4.5.6) that were not in agricultural production or developed for settlement. Several indicators measured direct human impacts on natural resources: proportion of wildlands, extent of impervious surfaces, and road density. Others estimated indirect or cumulative effects of anthropogenic influences, namely the core area ratio. The extent of trails is directly tied to efforts to increase recreational opportunities. However hiking trails can fragment habitats and recreationists can be a source of disturbance to some wildlife species. For example, Miller et al. (1998) found that in grasslands, breeding birds were less likely to nest near trails and there was higher nest predation near trails. This local result based on open space in Boulder, CO was confirmed by a regional analysis of the human footprint in the American West that specifically corroborated the impact of trails on breeding birds (Leu et al. 2008).

Given the urban context of GOGA, it is challenging to establish absolute reference conditions. Concepts such as ecological integrity (Parrish et al. 2003, Tierney et al. 2009, Wurtzebach and Schultz 2016) assume expansive protected areas large enough to potentially maintain ecological form and function. Such a framework does not fit the distributed patchwork of GOGA's parcels. Instead, the region and GOGA's immediate neighbors were used to define the relative condition for the landscape context. This approach acknowledges that the structure and function of a protected parcel located in a diverse and humanized landscape can only be evaluated in comparison to adjacent units. Understanding the "ecological context" of greenspace is essential to resource management and planning (Flores et al. 1998). Moreover the metrics developed to describe the current landscape context provide quantitative baselines to monitor landscape dynamics.

Tree canopy cover is an essential ecological indicator for urban ecosystems (Forgione et al. 2016). For some parcels in GOGA, the extent of tree cover is a relevant measure of resource condition and a valuable comparative metric. However GOGA's holdings span environmental gradients that include forest as well as grassland habitats. Tree cover would not be an appropriate measure of grassland conditions. Given the ambiguity, tree cover was reported but not included in the condition assessment.

For the regional analysis, the condition was judged as good (green) when GOGA exceeded the mean indicators in Table 4.5.2 by 25% or more. The condition was judge as poor (red) when GOGA fell short of the indicators in Table 4.5.2 by 25% or more. For comparisons that fell within 25% of the mean, the condition was considered cause for concern (yellow).

For the parcel-patch analysis, the results for the individual parcels were compared to their neighbors. The same standards used for the regional analysis were applied except that instead of comparing percent differences in the means, conditions were assigned based on overlap with the interquartile range (25th to 75th percentile). The condition was judged as good (green) or poor (red) when the mean of target GOGA parcels in the region lay beyond the interquartile range (25th to 75th percentile) of the neighbors for a specific indicator in Table 4.5.2. For comparisons where the mean for the GOGA parcels fell within the interquartile range for the neighbors, the condition was considered cause for concern (yellow). Two regional indictors, specifically percent wildlands and trail density, were excluded from the parcel-patch analysis. These two indicators provided no independent information given that the neighboring lands literally surround the target parcel. The only instance where an absolute measure of condition was used was for the core area analysis. In consultation with the NPS staff, 50% core area ratio was set as the reference condition. Regions where the 75th percentile of the core area ratio for the parcels was less than 50% were assumed to be in poor condition; regions where the 25th percentile for the core area ratio was greater than 50% were assumed to be good condition. If the interquartile range for parcels in a region included 50% core area ratio, the condition was cause for concern.

4.5.3. Condition Assessment

GOGA consisted of 60 discrete parcels totaling 18,461 acres distributed through three counties (Table 4.5.3). The parcels ranged from small isolated patches along highways (e.g., Marin Headlands along Hwy, 0.3 acre) to large intact tracts (e.g., Rancho Corral de Tierra, 3,853 acres). The parcels in San Francisco County were 10 times smaller with a much lower fraction of wildlands and a larger perimeter-to-area ratio (Table 4.5.3). San Mateo County had larger parcels on average but more than half the area of GOGA was in Marin County.

Table 4.5.3. Summary of the dimensions of GOGA parcels by region. PA ratio = perimeter-to-area ratio (NPS unpub. Data).

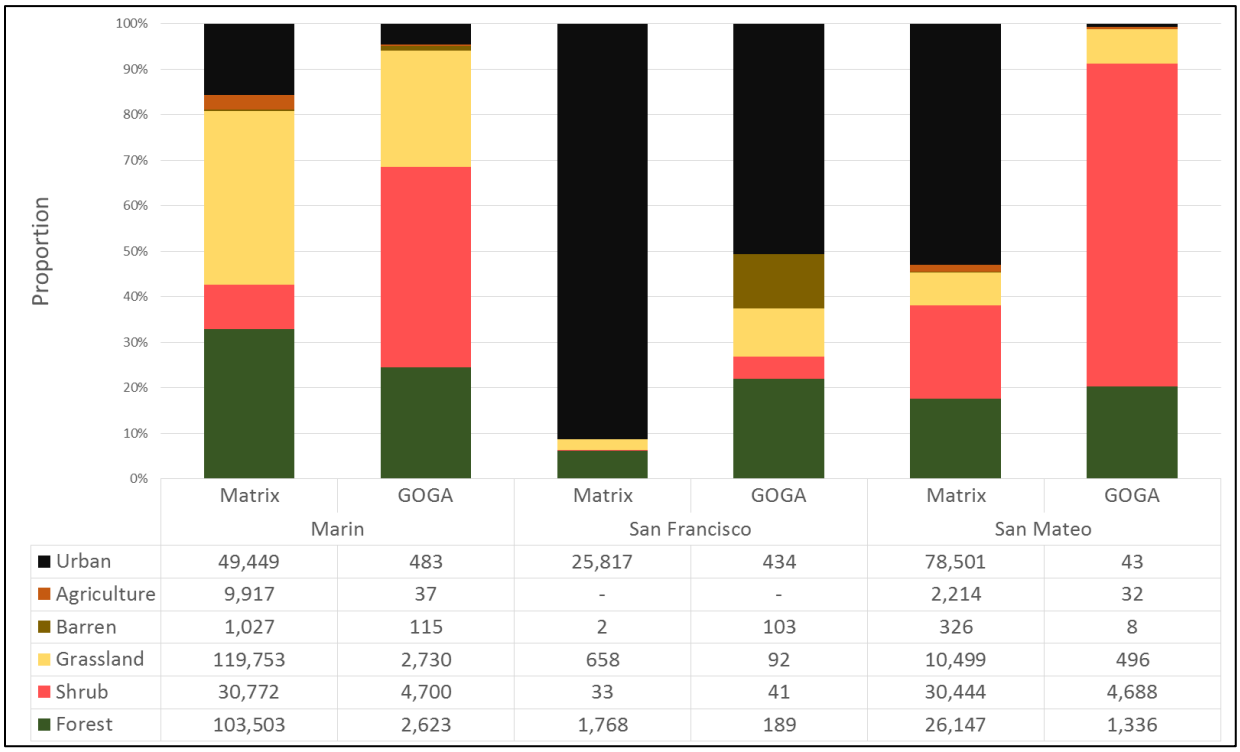
Region (county)	Parcel (n)	Total Area (ac)	Mean Area (ac)	Mean PA ratio (ft^2ac^{-1})	Wildlands (%)
Marin	34	10,892	320	195	80
San Francisco	18	964	54	291	43
San Mateo	8	6,605	826	240	96
Total	**60**	**18,461**	**308**	**230**	**71**

Condition and Trend

Regional unit analysis

GOGA parcels were consistently in better landscape condition compared to the region (Figure 4.5.7, Figure 4.5.8). For San Mateo and San Francisco counties, land in GOGA contained a higher proportion of wildlands, less impervious surfaces, more acres per road (i.e., lower road density), and fewer acres per river (i.e., higher river density). In Marin County, the contrast between the matrix and GOGA was not as stark. There was no meaningful difference between the parcels and the region in

the fraction of wildlands and river density. However in all counties, there were fewer acres per trail (i.e., higher trail density) in GOGA compared to the matrix.



	Marin		San Francisco		San Mateo	
	Matrix	GOGA	Matrix	GOGA	Matrix	GOGA
Urban	49,449	483	25,817	434	78,501	43
Agriculture	9,917	37	-	-	2,214	32
Barren	1,027	115	2	103	326	8
Grassland	119,753	2,730	658	92	10,499	496
Shrub	30,772	4,700	33	41	30,444	4,688
Forest	103,503	2,623	1,768	189	26,147	1,336

Figure 4.5.7. Comparison of vegetation class distributions between GOGA parcels and the region. “Matrix” refers to all lands in the county not part of GOGA. Areas reported in acres (ac) (Bay Area Open Space Council 2011).

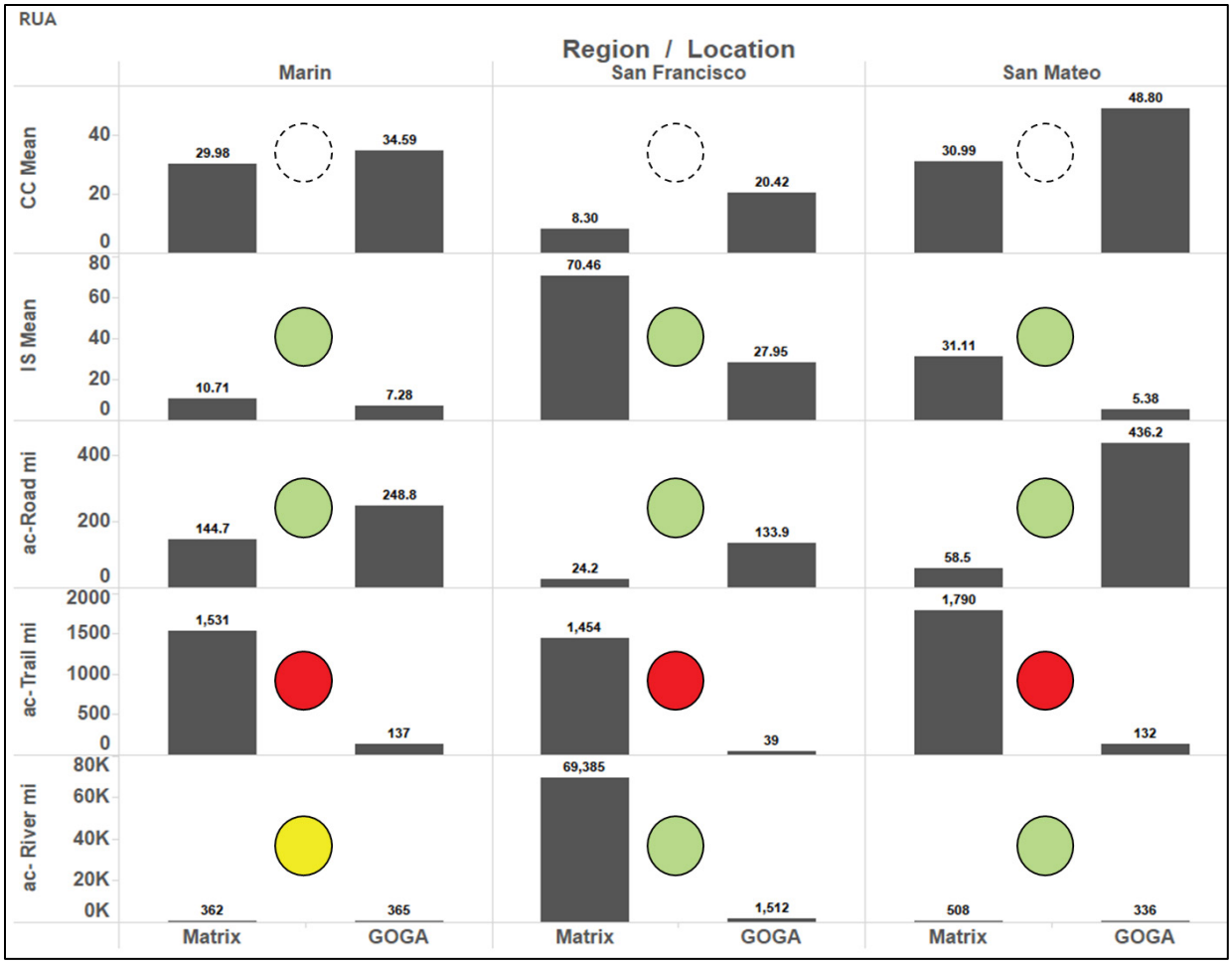


Figure 4.5.8. Comparison of landscape metrics for the region with the mean for the GOGA parcels in the region. Symbols represent the condition of each indicator by region. Y-axis definitions and units follow: "CC" is the tree canopy cover in percent; "IS" is percentage of impervious surface; "ac-Road mi" is the land area (ac) per mile of road; "ac-Trail mi" is the land area (ac) per mile of trail; "ac-River mi" is the land area (ac) per mile of river. "Matrix" refers to all lands in the county not part of GOGA (NPS unpub. Data).

Parcel-patch analysis

In terms of their landscape context, the GOGA parcels were more similar to their immediate neighbors than to the region as a whole (Figure 4.5.9). However, most GOGA parcels were in similar or better condition than their immediate neighbors. In particular, the targets in each region supported lower road density (i.e., higher ac-Road_mi indicator, Figure 4.5.9).

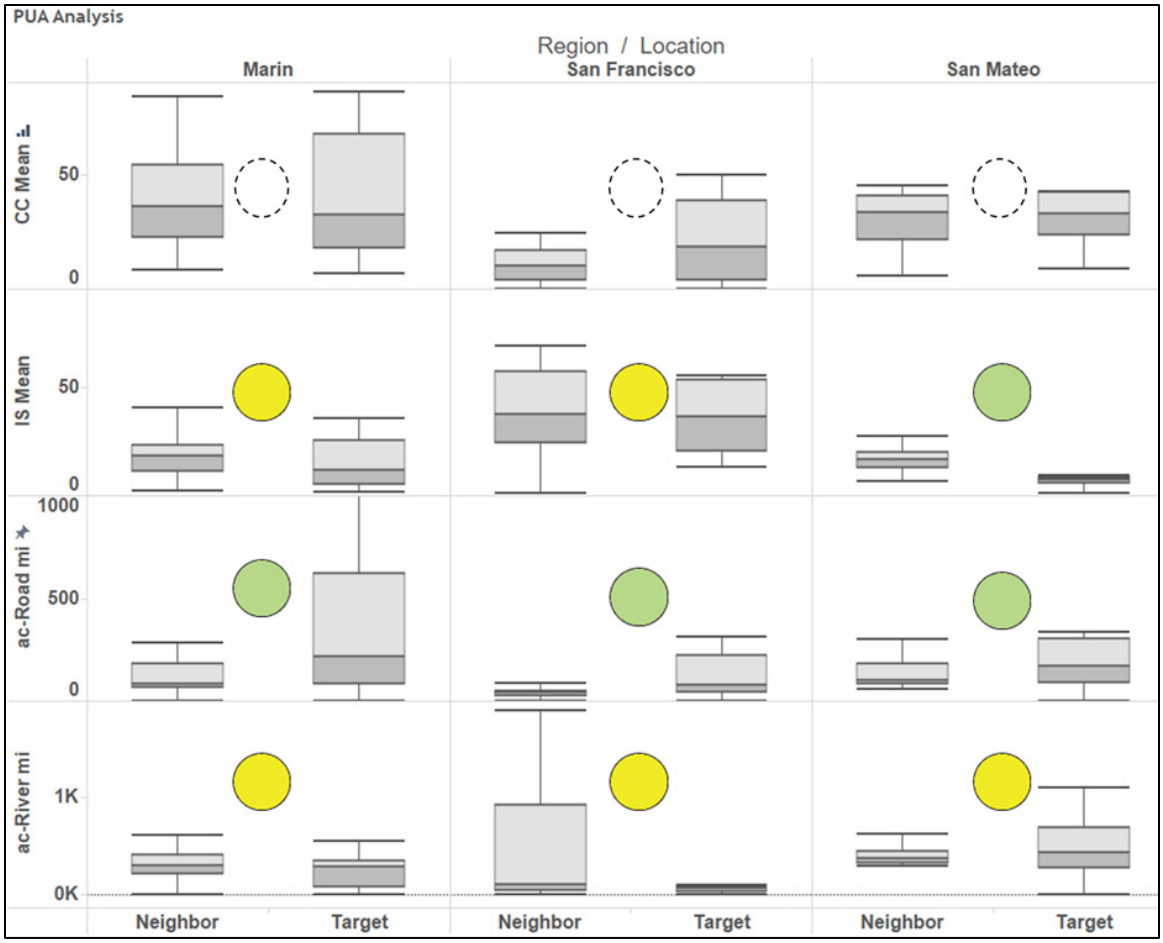


Figure 4.5.9. Comparison of landscape metrics for each parcel (target) with its neighboring area (neighbor). Results summarized by region. Symbols represent the condition of each indicator by region. The box and whisker diagrams display the mean (central line) with the grey box representing the 75th and 25th percentiles and the upper and lower bars denoting the 95% confidence intervals. Y-axis definitions and units follow: “CC” is the tree canopy cover in percent; “IS” is percentage of impervious surface; “ac-Road mi” is the land area (ac) per mile of road; “ac-Trail mi” is the land area (ac) per mile of trail; “ac-River mi” is the land area (ac) per mile of river (NPS unpub. Data).

Core area analysis

In aggregate, GOGA provides the three Bay Area counties with more than 14,000 acres of core area – contiguous areas of native vegetation set-back from roads and other human development (Table 4.5.4). By far the largest core areas were in San Mateo County with a mean core area of 698 ac. In contrast, the core areas in San Francisco County were more than 60 times smaller with a mean core area of 11 ac. One shared characteristics among the counties was the large variation in core area by parcel. The coefficient of variation (i.e., the standard deviation/mean) ranged from 1.6 in Marin to 2.3 in San Mateo (Table 4.5.4).

Table 4.5.4. Extent of core area in the GOGA parcels by region. The “Mean Core Area Ratio” was calculated as the mean for each parcel in the region. For mean values, the standard deviation is reported in parentheses (NPS unpub. Data).

Region (county)	Parcel (n)	Total Core Area (ac)	Mean Core Area (ac)	Mean Core Area (ft^2ac^{-1})
Marin	34	8,321	245 (399)	49 (33)
San Francisco	18	203	11 (20)	15 (17)
San Mateo	8	5,582	698 (1137)	70 (30)
Total	**60**	**14,105**	**235 (536)**	**42 (34)**

The relationship of core area to edge (i.e., the core area ratio) follows the same trend as core area. All but one of GOGA’s holdings in San Mateo County had a core area ratio ≥ 50% and 6 out of the eight San Mateo parcels had more than 70% core area. In contrast, none of the parcels in San Francisco County had a core area ratio ≥ 50% (Figure 4.5.10). The size and ratio of the core area in Marin County was more similar in magnitude to San Mateo but appreciably less. In terms of the reference condition, GOGA parcels in San Mateo were in good condition with the lower quartile of the core area ratio greater than the 50% threshold (Figure 4.5.11). San Francisco was in poorer condition with it upper quartile less than the 50% threshold. The interquartile range of the core area ratio for GOGA’s holdings in Marin overlapped the threshold.

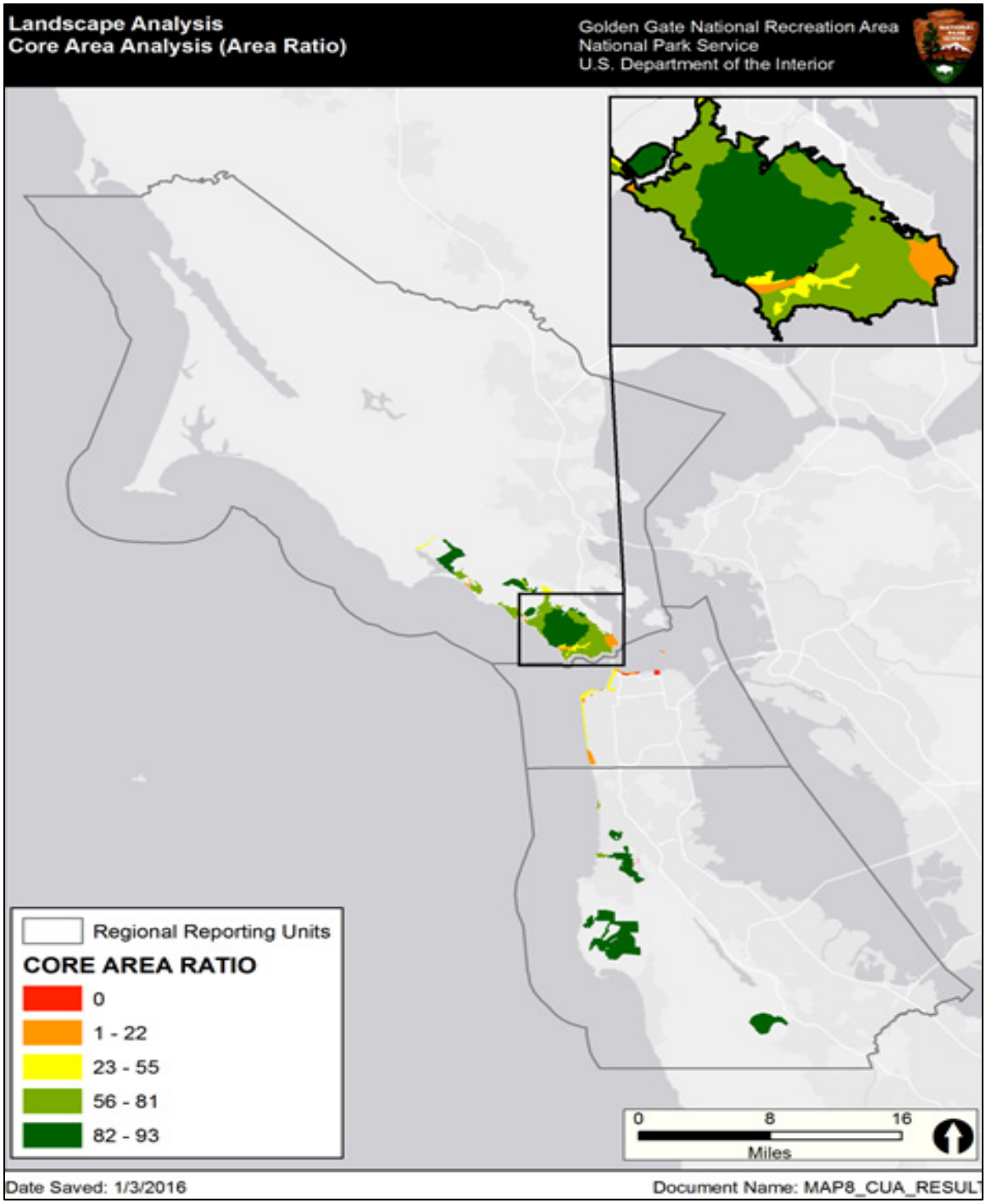


Figure 4.5.10. Distribution of core area ratio in the GOGA parcels throughout the three county region (NPS).

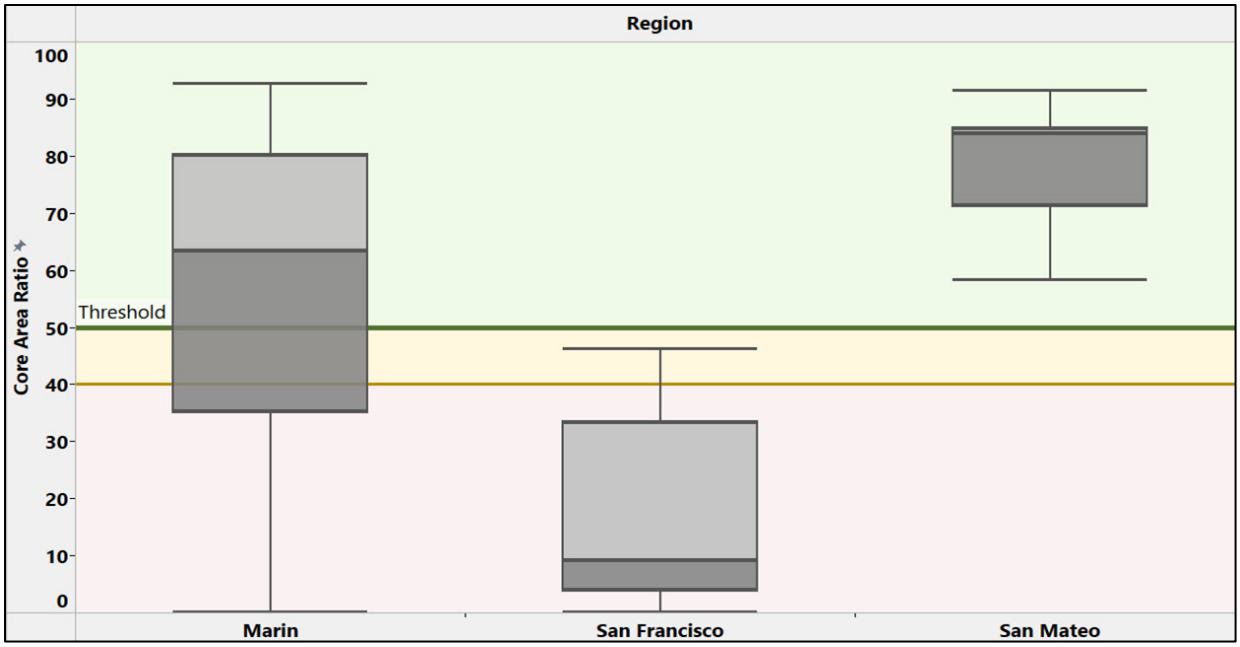


Figure 4.5.11. Summary of the core area ratio by GOGA parcel for each region. The box and whisker diagrams display the mean (central line) with the grey box representing the 75th and 25th percentiles and the upper and lower bars denoting the 95% confidence interval (NPS unpub. Data).

Stressors

The primary stressor in terms of the spatial dimensions of GOGA is the population pressure in the San Francisco Metropolitan Area, an area that encompasses all of GOGA's holdings. This metropolitan statistical area is the second most densely populated region of the country with 6,266 people mi^{-2} (US Census 2016). Between 2010 and 2015, the average population of Marin, San Francisco, and San Mateo Counties increased by 6.5% (US Census 2016). This increase continues to spur development with a corresponding expansion of impervious surfaces (Xian et al. 2011). Moreover, the population increase is expected to continue through 2060. The California Department of Finance (Schwarm 2016) projects exponential population growth for the three counties at annual per capita rates of 0.23 for Marin, 0.53 for San Mateo, and 0.62 for San Francisco. There rates will add on average more than 10,000 new residents to the three-county area each year from now until 2060 (Schwarm 2016). Urbanization is an inevitable consequence of this growing population. This trend poses challenges to both public policy and resource management (ABAG 2015).

Using long-term data for 16 urban areas, Li et al. (2016) documented a consistent pattern where increasing urbanization, as measured by population density and the extent of the built environment, lead to increasing habitat loss and fragmentation. This pattern was apparent among the regions in this analysis. San Francisco County was the most urban, had the largest percentage of impervious surfaces (an indicator of development, Figure 4.5.8), and the GOGA parcels in San Francisco were smaller in total area, % wildlands (Table 4.5.3) and core area (Table 4.5.4, Figure 4.5.10).

Even if GOGA parcels are retained intact, region wide development would result in increasing isolation of the parcels. Currently there are relatively small differences between GOGA holdings and

their immediate neighborhood (Figure 4.5.9). However this may change if development expands to accommodate more people.

Level of confidence in assessment

All indicators were assigned a moderate level of confidence. The underlying geographic data is sound. Most of the layers were created and curated by the National Park Service and thus follow established standards for geospatial data quality (https://www.nps.gov/gis/data_info/nps_standards.html). The other primary source of spatial data was from the 2011 National Land Cover Database. The NLCD is a well-vetted and thoroughly audited source of land cover information (Homer et al. 2015). The most uncertain source of information was the vegetation type map, in particular, the assignment of dominance by native or non-native plants (Table 4.5.1). However the underlying vegetation map (http://www.bayarealands.org/mapsdata.html) is sound since it was based on the US Forest Services' Calveg classification system. Calveg is an established and tested classification system (http://www.fs.fed.us/r5/rsl/projects/classification/system.shtml).

The indicators used to assess the landscape context followed established methods (McGarigal, et al 2002). The main sources of analytical uncertainty were definitions of scale. For example, one could imagine alternative specifications of the region, the neighborhood and the core area that might shift conclusions. The definitions used in this assessment were created in close collaboration with GOGA staff. All of the spatial data used in this analysis along with the analytical scripts have been provided (Appendix 4.5.1). So the consequences of alternative definitions of scale and/or indicators can be explored.

Gaps in understanding

This analysis was the first quantitative description of the landscape context of GOGA. Thus there were no previous results to assess trends. The absence of information on trends in patch geometry and habitat quality is a major gap in understanding.

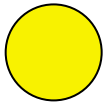
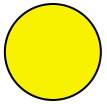
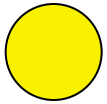
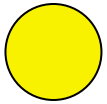
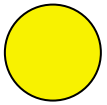
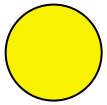
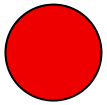
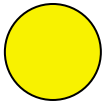
The extent and abundance of invasive plant species represent significant threats to resource condition at GOGA (Eschtruth, Chapter 4.4). Moreover, based on surveys of GOGA parcels in Marin County, the number of invasive species detected has steadily increased over time. This spread is directly linked to the landscape context in that invasive species are more abundant near roads and trails (Eschtruth, Chapter 4.4). These results raise two issues for the landscape context analysis. First, while the data on invasive species in the Park is extensive, it is too disjointed (Eschtruth, Chapter 4.4) for use in the systematic spatial analysis of core areas. Instead the analysis relied on the coarse filter designation of vegetation class (Table 4.5.1) to exclude non-native vegetation from the core areas. As the spatial database of invasive plant populations improves, the analysis of core areas can be refined to accommodate the new information. Second, the link between invasive species spread and trails highlights a management challenge. In all three regions, trail density was higher in GOGA as a result of the Park's effort to provide recreational opportunities. However from a resource condition perspective, trails are a disturbance with negative impacts on animal and plant communities.

Condition Summary

A host of indicators were calculated to quantify the landscape context of GOGA at multiple scales. An important key question is how to summarize multiple metrics. As noted by Liu et al. (2016), some metrics are strongly correlated (e.g., patch size and core area; road density and core area ratio) and thus should not be considered independent indicators of condition. In addition, some of the standard landscape measures are not particularly relevant for some ecosystems. For example, the river/stream density (i.e., ac-River mi) did not provide much insight into the landscape context of GOGA. In absolute the terms, the parcels are small and typically do not encompass whole watersheds. Other indicators like tree cover (CC mean) and trail density (ac-Trail mi) provide ambiguous insights. Thus the condition summary relied primarily on three indicators: the extent of wildlands, the percentage of impervious surface, and the core area ratio. Following Theobald's (2013) recommendation for landscape assessments, the goal was to estimate the magnitude of human modification while limiting redundancy. As noted earlier, impervious surface is an excellent synoptic measure of the built environment (Nowak and Greenfield 2010). In combination with the percentage wildland area (which includes agricultural as well as urban modification of the landscape), impervious surface estimates the degree of human modification. Liu et al.'s (2016) showed that core area was one of the best predictors of habitat fragmentation, hence its inclusion in the summary assessment. The other metrics were considered but as secondary indicators.

Overall the GOGA parcels provided relatively more contiguous wildlands dominated by native vegetation with larger core areas than the region and their neighbors. However condition varied by region. At every scale, GOGA holdings in San Mateo County were in better condition (Table 4.5.5). The modest size of the core areas in Marin County was cause for concern. In San Francisco, the small core area ratio was the most prominent threat.

Table 4.5.5. Resource Condition Summary for Landscape Context.

Scale of Analysis	Indicators	GOGA Condition Status	Regional Condition Status			Rationale
			Marin	San Francisco	San Mateo	
Regional Unit	See Table 4.5.2					Collectively, GOGA parcels should provide relatively more intact wildlands composed of native vegetation than the region
Parcel-patch	See Table 4.5.2					Individual GOGA parcels should provide relatively more intact wildlands composed of native vegetation than the neighboring lands
Core Area	Core area ratio					Individual GOGA parcels should have a core area greater than 50% of their total size
Overall Condition Status for Landscape Context			–	–	–	**Collectively, GOGA land holdings provide relatively more intact wildlands than the region with a greater proportion of core area. However, the limited core area in San Francisco County is cause for concern**

4.5.4. Information Sources

Sources of Expertise

- John Battles, Professor, UC Berkeley
- Megan Danielson, Research Associate, University of San Francisco
- Stephen Skartvedt, GIS Specialist, Golden Gate National Recreation Area

Literature Cited

ABAG. 2015. Association of Bay Area Governments. State of the Region: Economy, Population, Housing 2015. http://reports.abag.ca.gov/sotr/2015/.

Bay Area Open Space Council. 2011. The Conservation Lands Network: San Francisco Bay Area Upland Habitat Goals Project Report. Berkeley, CA.

Bay Area Upland Habitat Assessment. 2014. http://californialcc.org/projects/san-francisco-bay-area-upland-habitat-goals (accessed Sept. 11, 2014).

Banks, P.B. and J.V. Bryant. 2007. Four-legged friend or foe? Dog walking displaces native birds from natural areas. Biology letters 3: 611–613.

Donovan, T. M., P. W. Jones, E. M. Annand, and F. R. Thompson. 1997. Variation in the local-scale edge effects: Mechanisms and landscape context. Ecology 78:2064–2075.

Fancy, S., J. Gross, and S. Carter. 2009. Monitoring the condition of natural resources in US national parks. Environmental Monitoring and Assessment 151:161–174.

Flores, A., S.T. Pickett, W.C. Zipperer, R.V. Pouyat, and R. Pirani. 1998. Adopting a modern ecological view of the metropolitan landscape: the case of a greenspace system for the New York City region. Landscape and Urban Planning, 39:295–308.

Forgione, H.M., C.C. Pregitzer, S. Charlop-Powers, and B. Gunther. 2016. Advancing urban ecosystem governance in New York City: Shifting towards a unified perspective for conservation management. Environmental Science & Policy, 62:127–132.

Homer, C.G., J.A. Dewitz, L. Yang, S. Jin, P. Danielson, G. Xian, J. Coulston, N.D. Herold, J.D. Wickham, and K. Megown. 2015. Completion of the 2011 National Land Cover Database for the conterminous United States-Representing a decade of land cover change information. Photogrammetric Engineering and Remote Sensing 81: 345–354.

Jennings, D.B., S.T. Jarnagin, D.W. Ebert. 2004. A modeling approach for estimating watershed impervious surface area from National Land Cover Data 92. Photogrammetric Engineering & Remote Sensing 70:1295–1307.

Kupfer, J. A. 2012. Landscape ecology and biogeography: Rethinking landscape metrics in a post-FRAGSTATS landscape. Progress in Physical Geography: DOI 0309133312439594.

Leu, M., S. E. Hanser, and S. T. Knick. 2008. The human footprint in the west: a large-scale analysis of anthropogenic impacts. Ecological Applications 18:1119–1139.

Liu, Z., C. He, and J. Wu. 2016. The relationship between habitat loss and fragmentation during urbanization: An empirical evaluation from 16 world cities. PlosOne 11:e0154613.

McFrederick, Q. S., and G. Le Buhn. 2006. Are urban parks refuges for bumble bees *Bombus* spp. (Hymenoptera: Apidae)? Biological Conservation 129: 372–382.

McGarigal, K., S.A. Cushman, M.C. Neel and E, Ene. 2002. FRAGSTATS: Spatial Pattern Analysis Program for Categorical Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst, available at the following web site: http://www.umass.edu/landeco/research/fragstats/fragstats.html.

Miller, S. G., R. L. Knight, and C. K. Miller. 1998. Influence of recreational trails on breeding bird communities. Ecological Applications 8:162–169.

Nowak, D.J. and E.J. Greenfield. 2010. Evaluating the National Land Cover Database tree canopy and impervious cover estimates across the conterminous United States: a comparison with photo-interpreted estimates. Environmental Management 46:378–390.

National Park Service (NPS). 2014. National Park Service. Guidelines for Natural Resource Condition Assessment. http://www.nature.nps.gov/water/nrca/guidance.cfm (accessed Sept. 11, 2014).

Parrish, J.D., D.P. Braun, and R.S. Unnasch. 2003. Are we conserving what we say we are? Measuring ecological integrity within protected areas. BioScience 53: 851–60.

Pauchard, A., and P.B. Alaback. 2004. Influence of elevation, land use, and landscape context on patterns of alien plant invasions along roadsides in protected areas of South-Central Chile. Conservation Biology 18:238–248.

Piekielek, N.B., and A.J. Hansen. 2012. Extent of fragmentation of coarse-scale habitats in and around US National Parks. Biological Conservation 155:13–22.

Riley, S. 2006. Spatial ecology of bobcats and gray foxes in urban and rural zones of a national park. Journal of Wildlife Management 70: 1425–1435.

Schwarm, W. 2016. Report P-1 (Total Population). State and County Population Projections: July 1, 2010–2060. Demographic Research Unit. The California Department of Finance. http://www.dof.ca.gov/research/demographic/reports/projections/P-1/.

Theobald, D.M., 2013. A general model to quantify ecological integrity for landscape assessments and US application. Landscape Ecology 28:1859–1874.

Tierney, G. L., D. Faber-Langendoen, B. R. Mitchell, W. G. Shriver, and J. P. Gibbs. 2009. Monitoring and evaluating the ecological integrity of forest ecosystems. Frontiers in Ecology and the Environment 7:308–316.

US Census. 2016. The United States Census Bureau. http://www.census.gov/ (accessed Jun. 5, 2016).

Xian, G., C. Homer, J. Dewitz, J. Fry, N. Hossain, and J. Wickham. 2011. The change of impervious surface area between 2001 and 2006 in the conterminous United States. Photogrammetric Engineering and Remote Sensing 77:758–762.

Wang, Y., B. R. Mitchell, J. Nugranad-Marzilli, G. Bonynge, Y. Zhou, and G. Shriver. 2009. Remote sensing of land-cover change and landscape context of the National Parks: A case study of the Northeast Temperate Network. Remote Sensing of Environment 113:1453–1461.

Wurtzebach, Z., and C. Schultz. 2016. Measuring Ecological Integrity: History, Practical Applications, and Research Opportunities. Bioscience 66: 446–457.

4.6. Rare Plants

Managed rare plant populations extant; introduction efforts somewhat successful; USFWS Recovery Criteria generally in progress or completed. Data gaps warrant moderate confidence in findings and fail to support trend analysis.



4.6.1. Why Focal Resource Was Assessed

Description

The California Floristic Province, considered a global biodiversity hotspot, hosts more endemic plant taxa (2,125 taxa) and more identifiable subspecies than any comparable area in the continental United States (Mittermeier 1998, Calsbeek et al. 2003). The unique geological history and globally-rare Mediterranean climate have allowed for the diversification of a unique assemblage of plant species (Médail and Pierre Quézel 1999, Calsbeek et al. 2003). California, and the San Francisco Bay Area in particular, are also under major development pressure to support a growing population (Lewis and Neiman 2002). Habitat fragmentation, alteration, and loss are major contributors to the extinction of rare plant species (Matthies et al 2004). Collaboration between the California Native Plant Society, California Department of Fish and Wildlife, US Fish and Wildlife, and land managers, such as the National Park Service, has been essential to the protection and enhancement of existing rare plant species in California (Falk and Holsinger 1991). The conservation of public lands by the National Park Service, including the Golden Gate National Recreation Area (GOGA), allows for the protection and management of landscapes with associated rare flora.

Eight rare plant taxa found within GOGA-managed lands were selected for a detailed review of status and distribution: Franciscan manzanita (*Arctostaphylos franciscana*), Presidio manzanita (*Arctostaphylos montana* ssp. *ravenii*), marsh sandwort (*Arenaria paludicola*), Tiburon paintbrush (*Castilleja affinis* ssp. *neglecta*), Presidio clarkia (*Clarkia franciscana*), Marin dwarf flax (*Hesperolinon congestum*), San Francisco lessingia (*Lessingia germanorum*), and Hickman's cinquefoil (*Potentilla hickmanii*). Additional rare plant taxa with less documentation were added for a more general geospatial analysis of habitat and distribution.

Critical questions

This chapter addresses the following questions regarding the status, trends, distribution, and potential habitat of the plant taxa identified as “of interest” by GOGA.

1. What is the current status and distribution of threatened and endangered species of interest within GOGA?
2. What are significant stressors for threatened and endangered species of interest within GOGA?
3. Has climate influenced population trends for three federally listed annual plant species: Presidio clarkia (Clarkia franciscana), Marin dwarf flax (Hesperolinon congestum), or San Francisco lessingia (Lessingia germanorum)?

4. What areas within GOGA have high numbers of threatened, endangered and rare plant species of interest?

Critical Questions 1, 2, and 3 are addressed in a literature review on a per-species basis in Section 4.6.3. Summary maps in Section 4.6.4 address Critical Question 4.

4.6.2. How Focal Resource Was Assessed

Measures

The measures used to determine the condition of rare plant taxa of interest mirror the critical questions (Table 4.6.1). A literature review addressed the current status, distribution, and stressors for each plant taxon of interest. The following indicators and measures were created in collaboration with NPS staff to capture the condition of rare plant species populations of interest on PRNS lands.

Table 4.6.1. Measures used to determine the Condition status of Rare plants.

Indicator of Condition	Specific Measure	Condition Categories	Confidence Categories
How many of the natural populations observed since GOGA management began are still extant?	Proportion of natural populations with > 0 individuals in 2012 and 2013. Populations not monitored in 2012, 2013, and 2014 will not be counted toward score.	Green: 66–100% natural populations with > 0 individuals in 2012 and 2013	High: All populations were monitored annually with consistent methodology since discovery
	–	Yellow: 33–65%	Medium: 50–99% populations monitored as above, or consistent monitoring plans have been adopted in recent years
	–	Red: 0–32%	Low: 0–50% populations monitored as above, or methods unknown
Have introduction efforts been successful?	Proportion of successful introductions into new sites. This does not include natural populations. Lack of introduction efforts is not counted toward overall score.	Green: 66–100% of introduced populations extant	High: All populations monitored annually with consistent methodology since discovery
	–	Yellow: 33–65%	Medium: 50–99% populations monitored as above, or consistent monitoring plans have been adopted in recent years
	–	Red: 0–32%	Low: 0–50% populations monitored as above or methods unknown

Table 4.6.1 (continued). Measures used to determine the Condition status of Rare plants.

Indicator of Condition	Specific Measure	Condition Categories	Confidence Categories
Have the USFWS Recovery Plan goals been fulfilled for populations within GOGA lands?	Proportion of interim and long-term goals realized, partially-met or in progress. Goals carried out by other entities will not be counted toward score.	Green: 66–100% of recovery criteria met, in progress or partially met	High: Score based on 2013 or more recent USFWS 5-year Report and 2013 or more recent NPS report to USFWS
	–	Yellow: 33–65% of recovery criteria met, in progress or partially met	Medium: Score based on 2012 or earlier USFWS 5-year Report and 2013 or more recent NPS report to USFWS
	–	Red: 0–32% of recovery criteria met, in progress or partially met	Low: USFWS 5-year Report and/or 2013 NPS report not available

Data Sources and Methods

Literature Review

Evaluation of the condition of special status plants began with development of the list of taxa of interest. This analysis is limited to taxa identified by GOGA as "of interest", which includes Franciscan manzanita (*Arctostaphylos franciscana*), Presidio manzanita (*Arctostaphylos montana* ssp. *ravenii*), marsh sandwort (*Arenaria paludicola*), Tiburon paintbrush (*Castilleja affinis* ssp. *neglecta*), Presidio clarkia (*Clarkia franciscana*), Marin dwarf flax (*Hesperolinon congestum*), San Francisco lessingia (*Lessingia germanorum*), and Hickman's cinquefoil (*Potentilla hickmanii*). None of these plants were included in the GOGA Rare Plant Model Report (URS 2005). All of the plant species of interest meet at least one of the following criteria:

- Listed as endangered or threatened under the federal or California state Endangered Species Acts; and/or
- Listed by the California Native Plant Society (CNPS) as rare, threatened, or endangered in California and Elsewhere (Rank 1B).

CNPS designations and descriptions of general plant characteristics were obtained from the California Native Plant Society's Inventory of Rare and Endangered Plants (CNPS 2014). This inventory provides updated federal and state designations as well as CNPS ranking status.

Data Analysis of Climate Effects on Three Rare Plant Population Sizes

The effect of climate variables on long-term population estimates were analyzed for three rare annual plant species: Presidio clarkia (*Clarkia franciscana*), Marin dwarf flax (*Hesperolinon congestum*), and San Francisco lessingia (*Lessingia germanorum*). One population was analyzed for each of the

three rare plant species of interest. In the case of Marin dwarf flax, two related populations were analyzed as one population with the sum of the two survey values. Each population was analyzed independently. Sampling methodology was consistent over survey dates for a given population (Chassé and Forrestel 2014). Climate data was taken from the National Oceanic and Atmospheric Administration's Global Historical Climatology Network (NOAA 2015). Monthly summarized climate data from 1994 to 2014 were used from the San Francisco Downtown land-based weather station (located at 37.76667, -122.43333). Climate variables included monthly total precipitation, monthly mean maximum temperature, monthly mean minimum temperature, extreme minimum temperature per month, and extreme maximum temperature per month.

Population data for the Presidio clarkia and San Francisco lessingia fit within a normal distribution, as inspected in histograms and confirmed by applying a Shapiro-Wilks test for normality. Original Marin dwarf flax population values were non-normal due to a right skew. A square-root transformation normalized the values visually and were confirmed to be normal with the Shapiro-Wilks test. Eleven models were proposed based on potential biological significance and communication with GOGA staff. The number of parameters included in each model was limited due to the limited sample size, particularly for Marin dwarf flax and San Francisco lessingia. The limited sample sizes reduced the degrees of freedom in the analysis of multiple parameters.

The basic models were: 1) seasonal precipitation totals; 2) monthly spring mean minimum temperature; 3) monthly spring minimum temperature extreme; 4) monthly spring mean maximum temperature; and 5) monthly spring maximum temperature extreme. The seasonal precipitation totals model had four parameters: total spring precipitation (April, May, June); total summer precipitation (July, August, September); total fall precipitation (October, November, December); and total winter precipitation (January, February, March). The monthly spring temperature models include parameters from February, March, April, and May.

Two additional models combine total annual precipitation and spring temperature averages: 1) spring mean minimum temperatures and total precipitation in previous rain-year; and 2) spring mean maximum temperatures and total precipitation in previous rain-year. The total precipitation for the rain year included precipitation observed in July to December of the previous calendar year, and January to June precipitation of the given bloom year. The three months of spring mean maximum temperatures used in the model were adjusted to include the first month of the species' flowering period and the prior two months. For example, the Presidio clarkia is known to flower from May to July (CNPS 2015). Therefore the three months selected for the model were March, April and May.

Four more models considered the interactions between annual precipitation and average temperature in two spring months specific to blooming periods of the species in question: 1) spring mean minimum temperatures (average of two months prior to bloom) and total annual precipitation; 2) spring mean maximum temperatures (average of two months prior to bloom) and total annual precipitation; 3) spring mean minimum temperatures (average of month prior to bloom and month of first bloom) and total annual precipitation; and 4) spring mean maximum temperatures (average of month prior to bloom and month of first bloom) and total annual precipitation. The months were

selected to correspond with the first month of flowering period and prior months. Adding interaction to the models adds another parameter that can be tested for significance.

The model with best fit to data was selected for each of the species by comparing the Akaike Information Criterion (AIC) values for each model. The model with the lowest AIC value, and thus best model fit, was then tested for significance. All models with AIC values within 2 units of the model with the lowest AIC value were considered indistinguishable and results are presents for all such models.

Distribution and Density Mapping

Data sources used to determine the spatial distribution of species of interest within GOGA was limited to NPS survey data. Rare plant survey protocols are described in Chassé and Forrestel 2014. Rare plant density was calculated by summarizing abundance data (number of rare plants) and representing the density within a consistent area (hectare). The point density surface of number of individual species was calculated by buffering each species occurrence, summarizing by species, and identifying unique polygons. GIS metadata associated with final geospatial products contain a detailed methodology.

Reference Conditions/Values

Reference conditions for the rare plants described in the literature review portion of this chapter are based on historical distribution records, as summarized in the USFWS Recovery Plans, which are based on any verifiable documentation, including: botanical collections, the California Natural Diversity Database and notes taken by botanists at the time. Given that this assessment is largely based on USFWS documentation paired with NPS updated information, this historical distribution is the most widely accepted reference condition available. Many of the species were not well documented historically and are thus difficult to compare to current distribution or potentially occupied habitat.

The map-based assessment visually demonstrates the confidence and condition values averaged by the individual populations occurring within a given management unit. Management units were determined by spatial data supplied by GOGA staff (GMP_alt_preferred_2013b.shp). Most management units had only one species and many species only occurred within one management unit. The condition and confidence values of the populations within this unit were averaged for the Presidio unit, which included multiple species of concern.

4.6.3. Status, Distribution, and Stressors for Species of Interest

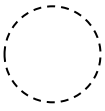
Franciscan manzanita *(Arctostaphylos franciscana)* Condition Assessment

Franciscan manzanita (*Arctostaphylos franciscana*) is a perennial evergreen shrub found in maritime chaparral, mostly on serpentinite substrate. This California endemic shrub blooms from February to April and occurs at 60 to 300 meters of elevation. This manzanita is currently listed as federally endangered and is also listed by the California Native Plant Society (CNPS) as Rare Plant Rank 1B.1, which is defined as “seriously endangered in California.” This species was presumed extinct in the wild since 1947 until rediscovered in 2009. Currently, there is only one known wild extant individual (CNPS 2014).

Condition and Trend

The Franciscan Manzanita was known from three San Francisco locations prior to 1947: the former Masonic Cemetery (unconfirmed), former Laurel Hill Cemetery (both in the Richmond district), and Mount Davidson (in south-central San Francisco). Additional unconfirmed historical sightings may have occurred near Laguna and Haight Streets (USFWS 2003; Chassé 2013). Manzanita expert James Roof observed Franciscan manzanita at Masonic Cemetery in the late 1930's, but without confirmed voucher specimens (M. Chassé personal communication 2015). No naturally occurring individuals of Franciscan Manzanita had been reported between 1947 and 2009, although no systematic surveys were known during that period (Chassé and Forrestel 2014). In 2009, a single wild individual was found in a construction area near Doyle Drive, and was transplanted outside of the construction footprint in 2010 (USFWS 2013). This plant is unique in that its current known population consists of one transplanted genetic individual (with multiple clonal transplants) in GOGA property, and a few individuals raised in botanical gardens (USFWS 2013; Table 4.6.2; Figure 4.6.1).

Table 4.6.2. Condition summary for Franciscan manzanita *(Arctostaphylos franciscana).*

Indicators of Condition	Specific Measures	Condition Status	Rationale
How many of the natural populations observed since GOGA management began are still extant?	Proportion of natural populations with > 0 individuals in 2012 and 2013. Populations not monitored in 2012, 2013, and 2014 will not be counted toward score		Consistently monitored natural population consists of one extant mother plant.
Have introduction efforts been successful?	Proportion of successful introductions into new sites. This does not include natural populations. Lack of introduction efforts is not counted toward score		Of the 58 clones planted on the Presidio Coastal Bluffs in 2013, 47 (81%) were alive in October 2013. No genetic diversity is represented in the clonal populations.
Have the USFWS Recovery Plan goals been fulfilled for populations within GOGA lands?	Proportion of interim and long-term goals realized, partially-met or in progress. Goals carried out by other entities will not be counted toward score		A Recovery Plan is under development but has not been published.

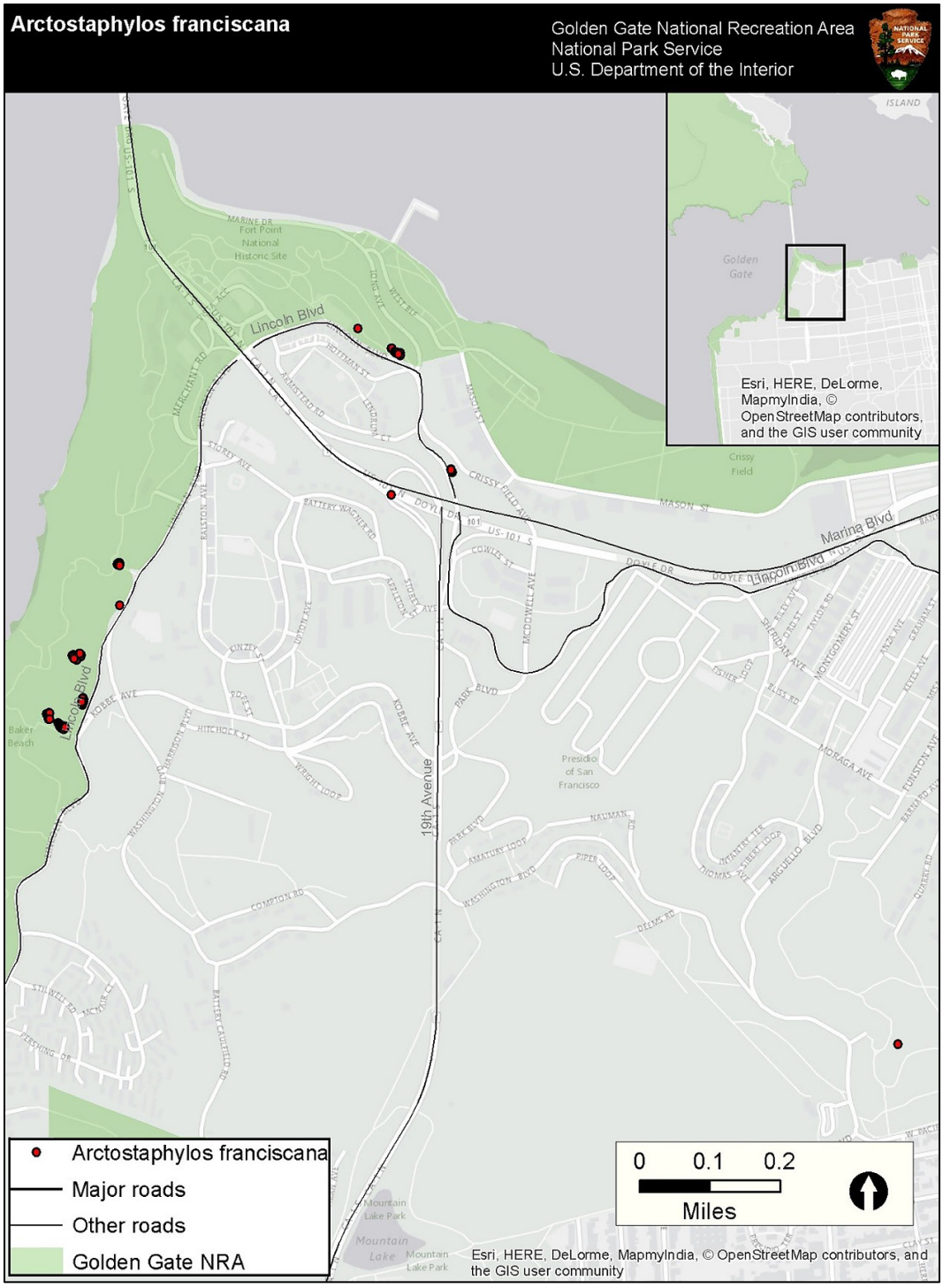


Figure 4.6.1. Distribution of Franciscan manzanita (includes original location and clonal planting sites) (NPS).

The genetic individual from Doyle Drive was confirmed to be Franciscan manzanita by Vasey and Parker (pers. comm. 2010), who also determined that the individual had been crossed with *A. uva-*

ursi at some point in the genetic lineage. Sixty-eight clones from the wild individual were planted within proposed USFWS critical habitat in 2013 (Chassé and Forrestel 2014).

Work to conserve the Franciscan manzanita and its genetic makeup was outlined in the 2009 Conservation Plan (USFWS 2013). Actions to protect the manzanita include: transplanting the wild individual; distributing cuttings of the wild individual to various botanical nurseries; developing a seed germination protocol at Golden Gate National Parks Conservancy Nursery; conducting a pollinator study of the wild individual; and removing voles from the transplanted location (USFWS 2013).

Stressors

Franciscan manzanita is highly limited in its potential to recover due to dramatic loss of maritime chaparral on serpentine or greenstone outcrops within the San Francisco peninsula (USFWS 2003). Urban development and habitat loss due to competition with non-native species are cited as the main factors cited by Chassé et al (2009).

Pests and Pathogens

Potential threats to Franciscan manzanita include fungal pathogens. Twig blight, a fungal infection generally caused by *Botryosphaeria* species in *Arctostaphylos*, was observed on the wild plants during the winter of 2009–2010 but subsided during the summer months (USFWS 2013). Twig blight is of greater concern during wet years (USFWS 2003).

Phytophthora pathogens also impact *Arctostaphylos* species. *Phytophthora ramorum*, the pathogen that causes sudden oak death, is known to cause foliar blight in other Arctostaphylos species and has recently been identified as the cause of severe dieback and mortality of another rare Arctostaphylos, *A. virgata*. *P. cinnamomi* is threatening *A. pallida* (pallid manzanita) in the East San Francisco Bay as well as *A. myrtifolia* (Ione manzanita) in the Sierra foothills and is of concern for Franciscan manzanita (USFWS 2013). If introduced to the mother or clonal plants, it would permanently contaminate soil and seedbank as well as cause the decline or death of adjacent individuals (USFWS 2012a). All tests for this water-borne mold have returned as negative for the transplanted individual.

Voles and other small mammals have been attributed with branch dieback and browsing (Chassé and Forrestell 2014). The native orange tortrix moth (*Argyrotaenia franciscana*), a leaf roller moth, severely infested the transplanted individual, but is not known to cause mortality (USFWS 2013).

Anthropogenic Disturbance

The proximity of GOGA and the Franciscan manzanita clones to dense urban development increases the risk of human damage, both directly and indirectly. Atmospheric nitrogen deposition from automobiles and industrial processes can create a favorable environment for competitive non-native species by altering the soil chemistry of remaining suitable serpentine habitat (USFWS 2013). Publicity surrounding the rediscovery of Franciscan manzanita may have generated public interest in collecting clippings of the planted individuals. Although the location of the individuals is not known, all GOGA lands are publicly accessible and adjacent to a large urban population. However, the transplanted individual is within a larger restoration area protected by post and cable fencing from high use areas (USFWS 2013). Vandals have damaged various trees and shrubs on GOGA property.

Similar damage could incidentally include manzanita populations (Chassé and Forrestel 2014). Soil compaction from trampling by surveyors could reduce water infiltration, reduce soil oxygen levels and damage mycorrhizal fungi in seedling roots (Waltert et al. 2002).

Drought and Climate Change

The managing partner, Presidio Trust, determined that water stress was the primary cause of significant branch dieback on the transplanted individual in 2013. The water stress was speculatively attributed to multiple combined factors, including recent reduced annual rainfall. The Trust natural resource staff conduct ongoing monitoring of soil moisture at the transplanted individual, where low soil moisture readings serve as a trigger for irrigation. Precipitation and temperature are expected to change with future climate change, which could exacerbate the current water stress issue. A U.S. Geological Survey study showed potential for "an increase in average maximum summer air temperatures at Golden Gate National Recreation Area… and a reduction statewide in fog frequency (Madej et al. 2010, p 24; Johnstone and Dawson, 2010, p. 4535)" (as cited in USFWS 2013). In addition to serpentine habitats, cool temperatures and summer fog are primary habitat requirements for Franciscan manzanita (USFWS 2013). The remaining suitable habitat for Franciscan manzanita is fragmented and limited by development and agency control (USFWS 2013). Various projected climate change scenarios could provide ideal conditions for fungal pathogens.

Genetic Bottleneck and Propagation Challenges

As an obligate seeding plant, Franciscan manzanita may require specific pollinators for seed production. The single wild individual may also be sensitive to stochastic events, loss of pollinators or change in long-term climatic variation (USFWS 2013). Various genotypes exist in multiple botanical gardens and may be used to increase the genetic variability of propagated individuals (Gluesenkamp et al 2010). However, caution must be used to avoid contaminating the Franciscan manzanita gene pool with hybrid genotypes (USFWS 2013).

The alteration of fire interval in the general area of Franciscan manzanita may decrease the survival of the wild individual and planted seedlings (USFWS 2013). As an obligate seeding species; *A. franciscana* requires fire to stimulate seed germination. In the highly urban environment of San Francisco, wildfire-induced germination is extremely unlikely. Laskowski et al. found that a pretreatment of a ratio of 1:50 smoke water in distilled water improved germination of a related *Arctostaphylos* species, which may be applied in Franciscan manzanita propagation (2014).

Level of confidence in assessment

The Final Designation of Critical Habitat for Franciscan Manzanita of 2013 undertook a comprehensive review of the status and threats to the species (USFWS 2013). Considerable planning, monitoring and management efforts toward the conservation of the Franciscan manzanita have been undertaken by the USFWS, Presidio Trust, GOGA, San Francisco State University, Golden Gate National Parks Conservancy, CDFW and the City and County of San Francisco. The frequent rate of monitoring and documentation regarding the current threat and trends of the wild individual and clonal population lead to a high level of confidence in determining the status of the Franciscan manzanita. All of the discussion in this report has been based on the comprehensive recent reviews completed by the USFWS and GOGA, as well as a few pertinent scientific research efforts.

Gaps in understanding

Due to the highly managed status of this species, it will be important to continue to monitor the clonal plantings, the mother plant, and any potential negative effects of those monitoring and management actions. Potential unanticipated effects of increased human visitation to the Franciscan manzanita populations could include: soil compaction, introduction of weeds or pathogens, and increased public visibility.

Propagation and establishment of new clonal populations has been initiated, but the methodology could be improved with further study. There is little current knowledge regarding the pollination requirements of Franciscan manzanita in terms of self-pollination, dependence on pollinators and presence of potential pollinators (USFWS 2013). Current research on the ideal conditions for Franciscan manzanita propagation are underway and will inform future propagation efforts.

Appropriate placement of new populations is challenged by the limited study of now extirpated wild populations. All known habitat characteristics are based on the highly disturbed original location of the one wild individual, and on herbarium data from 1889 to the 1940s (USFWS 2013). Future planting efforts will have to incorporate climate change predictions into locating successful new planting areas.

The entire known population of Franciscan manzanita consists of one wild individual receiving careful monitoring and maintenance, clonal plantings (81% survival rate in 2013), and botanical garden specimens (Chassé and Forrestel 2014). Continued multi-agency coordination will be required to plant, monitor, and maintain new populations created from clonal cuttings until the populations are considered self-sustaining (USFWS 2013). The success of new clonal populations depends on identifying areas with required habitat elements, including climate, soil type, lack of pathogens, and presence of pollinators and soil mycorrhiza (USFWS 2013; Chassé 2013). In the absence of major management inputs, the extremely limited genetic diversity and lack of self-propagation of this species is likely to limit the success of the Franciscan manzanita in a future of climate change, urban pressures, and competition from neighboring plants.

Presidio Manzanita (*Arctostaphylos montana* ssp. *ravenii*) Condition Assessment

Presidio manzanita (*Arctostaphylos montana* ssp. *ravenii*), also known as Raven's manzanita, is a perennial evergreen shrub found in maritime chaparral and coastal prairie, often on serpentinite substrate. This California endemic shrub blooms February to March and occurs at 45 to 215 m. This manzanita is currently listed as federally endangered and California endangered, and is also listed by the California Native Plant Society (CNPS) as Rare Plant Rank 1B.1, which is defined as "seriously endangered in California"(CNPS 2014). This species is known from only one native occurrence at the Presidio in San Francisco, consisting of a cluster of plants that all belong to a single clone. There have been significant revisions to the taxonomy of this species and the related Franciscan manzanita (*Arctostaphylos franciscana*) since description (USFWS 2003).

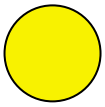
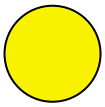
Condition and Trend

The historical distribution of the Presidio manzanita is difficult to assess because the species was not recognized as a distinct taxon until recently, well after the extirpation of the original suspected

occurrences. Now-extirpated locations that may have hosted Presidio manzanita include: the former Laurel Hill Cemetery, the former Masonic Cemetery, Mount Davidson, Mount Tamalpais, and the Protestant Orphan Asylum (Chassé 2013). These occurrences coincide with references to related species, and it is unknown how widespread the Presidio manzanita was historically (USFWS 2012a). The Laurel Hill Cemetery occurrence has one confirmed voucher specimens for both Franciscan and Presidio manzanita branches (M. Chassé personal communication, 2015).

A single wild individual Presidio manzanita plant was rediscovered in 1952 and has been used for clonal propagation in surrounding habitat. Clonal plantings established in 1987 at Inspiration Point did not persist. Three clonal plantings at confidential locations near the Presidio's World War II Memorial have persisted (Table 4.6.3; Figure 4.6.2). Populations are monitored annually for growth and branch dieback, although monitoring individuals is challenging due to intermingling of clonal plants (Chassé and Forrestel 2014). No natural seedling establishment has occurred since the individual was discovered (USFWS 2003).

Table 4.6.3. Condition summary for Presidio Manzanita (*Arctostaphylos montana* ssp. *ravenii*).

Indicators of Condition	Specific Measures	Condition Status	Rationale
How many of the natural populations observed since GOGA management began are still extant?	Proportion of extant natural populations with > 0 individuals in 2012 and 2013.		Only one well-monitored natural individual plant exists.
Have introduction efforts been successful?	Proportion of successful introductions into new sites.		One planting effort had 17 successful clones near the 'mother' plant at the World War II Memorial. Two planting efforts failed at West Crissy Bluffs and Inspiration Point in 1987 and 1988. Clonal plantings have not been attempted at other Presidio sites. Monitoring protocol unknown for failed introductions.
Have the USFWS Recovery Plan goals been fulfilled for populations within GOGA lands?	Proportion of interim and long-term goals realized or in progress. Goals carried out by other entities will not be counted toward score.		According to the 5 year review (USFWS 2012a), three of seven interim goals have been partially met or were in progress (habitat and population stabilization, establishing daughter clones, and population and clone size increases). Three were met, at least partially, by other entities (plant propagation, populations outside Presidio, and taxonomy and reproduction studies). One has not been met (sexually reproduction population). Of long-term criteria, two have not been met (spontaneous reproduction of Presidio population, establishment of new populations) and one is coordinated by another entity (permanent cultivated plants).

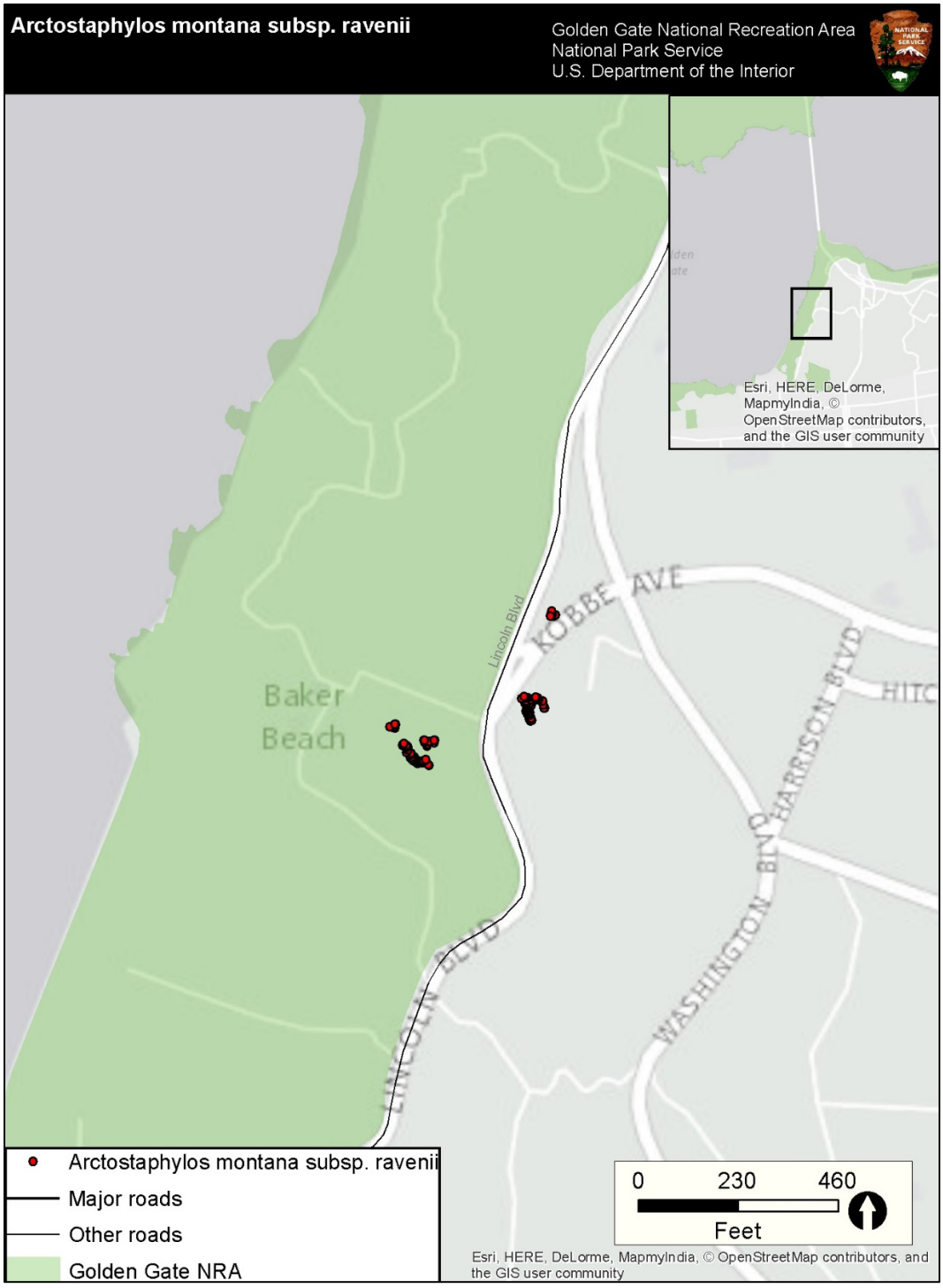


Figure 4.6.2. Distribution of Presidio manzanita (NPS).

Stressors

Plant interactions

Nearby trees could be limiting the expansion of Presidio manzanita into potentially suitable habitat and have indirect effects on local climate variables, such as altered wind patterns, decreased solar

radiation and altered soil hydrology (USFWS 2012a). Branch dieback is attributed to in-growth and encroachment of associated native species, as well as the non-native species, Bermuda buttercup (*Oxalis pes-caprae*) (Chassé and Forrestel 2014). Competitive plants may alter nutrient and water availability on the generally harsh serpentine soils (Parker and Frey 2010). Non-native species may also alter the symbiotic mycorrhizal community to benefit invasion into the Presidio manzanita habitat (Parker and Frey 2010). Leaves from the native plant, soap root (*Chlorogallum pomeridianum* var. *divaricatam*), shade the clonal plantings and cause leaf dieback (Parker and Frey 2010). Other native plants, such as gumweed (*Grindelia hirsutula* ssp. *maritima*), coyote brush (*Baccharis pilularis*), and blue blossom (*Ceanothus thyrsiflorus*) are encroaching on the clonal plantings (Chassé and Forrestell 2014).

Anthropogenic Effects

Irrigation drift from nearby lawn may alter the natural soil moisture regime for mother and clonal plantings (Chassé and Forrestel 2014). No clipping or vandalism has been observed of the mother plant or clonal plantings as the plant's location has been kept confidential (USFWS 2012a). Other potential effects include accidental damage due to indirect or direct effects of road maintenance or vegetation management activities (USFWS 2003).

Pests and Pathogens

A significant infestation of tussock moth caterpillars (Lymantriidae family) partially defoliated multiple clonal plants in 1999. No subsequent infestations were as severe as the initial outbreak and none were observed in 2011 or 2014. Leaf rollers infested the Presidio manzanita population in 2010, but have not been observed since. Twig blight has also caused leaf dieback of the clonal individuals during years with frequent late rains (USFWS 2012a).

Phytophthora pathogens also impact *Arctostaphylos* species. *Phytophthora ramorum*, the pathogen that causes sudden oak death, is known to cause foliar blight in other Arctostaphylos species and has recently been identified as the cause of severe dieback and mortality of another rare *Arctostaphylos*, *A. virgata*. *P. cinnamomi* is threatening *A. pallida* (pallid manzanita) in the East San Francisco Bay as well as *A. myrtifolia* (Ione manzanita) in the Sierra foothills and is of concern for Franciscan manzanita (USFWS 2013). If introduced to the mother or clonal plants, it would permanently contaminate soil and seedbank as well as cause the decline or death of adjacent individuals (USFWS 2012a).

Wildlife Interactions

Native insect loss throughout San Francisco could limit the pollination of Presidio manzanita. However, studies of pollinator populations visiting the area of mother and clonal plants indicate that there has been an increase in overall pollinator visitation and diversity from 2004 to 2008 (Van Den Berg et al. 2010, Wood et al. 2005). Gambel (2012) showed that *Bombus melanopygus* and *B. vosnesenskii* queens were the most frequent pollinators to both Presidio and Franciscan manzanita species, which could indicate species cross-pollination. Although Presidio manzanita can self-pollinate, this results in a decrease in genetic diversity in the following generations (Allendorf and Luikart, 2007).

Arctostaphylos fruits are primarily dispersed by mammals, and can be deposited in scat or harvested and stored by rodents (Parker 2010). Loss of native wildlife and small mammal eradication programs on adjacent properties could limit natural dispersal of Presidio manzanita fruit (USFWS 2012a).

Genetic Bottleneck and Small Population Size

The UC Berkeley Botanic Garden and Presidio Native Plant Nursery have unsuccessfully attempted propagating Presidio manzanita seeds from self-pollinated fruits. "Clonal plantings of Franciscan manzanita have been planted within pollinator distance of Presidio manzanita clones to provide the possibility of gene flow between the two taxa" (Chassé and Forrestel 2014). Other clonal populations are known from botanical gardens and at least one commercial nursery. This lack of genetic variability may limit the species ability to adapt to changes in climate or other environmental variables. The limited distribution and size of Presidio manzanita populations also increases the species' vulnerability to stochastic events, such as fire, storm, drought, or other perturbations (USFWS 2012a).

Climate Change

Precipitation and temperature are expected to change with future climate change, which could exacerbate current water stress. Drought conditions, increased winter flooding, or loss of summer fog could adversely affect the existing population and/or render currently suitable habitat unsuitable for Presidio manzanita (USFWS 2013).

Level of confidence in assessment

The condition and trend of the Presidio manzanita summarized in this report have been based primarily on conclusions found in the most recent GOGA monitoring report (Chassé and Forrestel 2014) and USFWS 5-year Review (USFWS 2012a). USFWS reports are comprehensive reviews of the species and supersede conclusions made in this document. Additional reports were incorporated as needed to fully depict the status of Presidio manzanita. Any discoveries of independent wild populations of Presidio manzanita could greatly improve and/or alter the conclusions made in this report, as all information is gleaned from historical botanical literature, and observations of the one wild plant and clonal propagates.

Gaps in understanding

The wild individual plant has set seed but no natural successful seedling generation has been observed since its discovery in 1952 (USFWS 2012a). Parker and Frey conclude that the Presidio manzanita is an obligate seeder that requires fire or disturbance to germinate seeds (2010). The urban environment and limited number of unique genetic individuals restricts experimental studies involving fires, but further research in fire surrogates may increase the seeding potential of this species.

Further pollination studies could examine the timeline of flower pollination in relation to climate variables, the level of direct and indirect pollination by invertebrates, and the pollinator relationship between Presidio and Franciscan manzanita species (Gambel 2012).

Genetic analyses have explored the relationship of this species with related *Arctostaphylos* species (Parker and Frey 2010, Boykin et al. 2005, Wahlert et al. 2009). Further research into the genetic

makeup of Presidio manzanita could inform potential cross-pollination with botanical garden genotypes to increase the genetic diversity of future generations. Studies of fruit set, seed viability, and self-pollination viability of related *Arctostaphylos* taxa are recommended by the interim recovery guidelines in the 5-year Review (USFWS 2012a).

The Presidio manzanita is limited to a single clonal population in the San Francisco Presidio, established from one wild individual rediscovered in 1952. Extirpated occurrences were observed historically from other locations on the San Francisco peninsula (USFWS 2012a). According to the most recent USFWS 5-year Review (2012a), full recovery of Presidio manzanita is not expected and may not be possible in the foreseeable future. Interim and long-term recovery criteria include establishment of new clonal and sexual populations, and increases in existing populations of Presidio manzanita in the Presidio and elsewhere. Although the National Park Service and Presidio Trust have exhibited considerable effort in managing the existing and new populations of Presidio manzanita, the species remains endangered due to its limited population size, lack of genetic variation, competition from native and non-native plants, lack of successful reproduction, and vulnerability to potential climate impacts (USFWS 2012a).

Marsh sandwort (*Arenaria paludicola*) Condition Assessment

Marsh sandwort (*Arenaria paludicola*) is a perennial stoloniferous herb in the Caryophyllaceae (pink) family. It is found in marshes and swamps (freshwater or brackish), often on sandy openings. This herb, found in California and Washington, blooms from May to August and occurs at 3 to 170 meters of elevation. This sandwort is currently listed as federally endangered and California endangered, and is also listed by the California Native Plant Society (CNPS) as Rare Plant Rank 1B.1, which is defined as "seriously endangered in California."

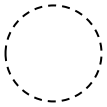
Condition and Trend

This species was known from only two natural occurrences in San Luis Obispo. There are currently 15 known occurrences. Only two of the fifteen occurrences are presently extant. Ten of the other occurrences were recorded over 20 years ago, and have been classified as extirpated by the CNPS (Table 4.6.4; CNPS 2014).

The historical range of marsh sandwort included coastal areas extending from coastal southern and central California to Washington (USFWS 1998). In California, historical populations are known from five areas: in the vicinity of Fort Point in the Presidio of San Francisco, Scotts Valley in Santa Cruz, Guadalupe-Nipomo Dunes in San Luis Obispo County, the Los Angeles basin, and along the Santa Ana River in the vicinity of San Bernardino. Of these, the Presidio location overlaps with current GOGA lands. The sandwort was last observed in 1899 in what was referred to as the "Presidio Swamp," but was extirpated by the filling of marsh lands along the Presidio's northern shore (Brandegee 1892, USFWS 1998). In 2011, this species was introduced to the Marin Headlands through the joint efforts of the USFWS, UC Santa Cruz and GOGA (Chassé and Forrestel 2014; Figure 4.6.3). Planted individuals are monitored for size and health of the plants, which have grown together (Chassé and Forrestel 2014). Initial survivorship ranged from 25 to 65% depending on site location, site preparation and plant propagation (Parker 2012 in Chassé and Forrestel 2014). The

most recent documented survival rates from March 2013, were 39% and 64% at the two planted sites in the Marin Headlands (Chassé and Forrestel 2014).

Table 4.6.4. Condition summary for Marsh sandwort (*Arenaria paludicola*).

Indicators of Condition	Specific Measures	Condition Status	Rationale
How many of the natural populations observed since GOGA management began are still extant?	Proportion of natural populations with > 0 individuals in 2012 and 2013. Populations not monitored in 2012, 2013, and 2014 will not be counted toward score.		The populations within GOGA lands were introduced. There are no known natural population within GOGA lands.
Have introduction efforts been successful?	Proportion of successful introductions into new sites. This does not include natural populations. Lack of introduction efforts is not counted toward score.		710 individuals were introduced to 2 sites and 4 microsites in 2011. The two main sites had a survivorship rate of 39% and 64%. Monitoring was adapted to accommodate growth of population.
Have the USFWS Recovery Plan goals been fulfilled for populations within GOGA lands?	Proportion of interim and long-term goals realized		GOGA manages a successful introduction of marsh sandwort, as recommended by the USFWS. Four of 6 recommendations are fulfilled or in process (protect and enhance habitat, monitor population and habitat, establish new populations, evaluate progress), and two are partially fulfilled or conducted by other parties (conduct research, augment existing populations).

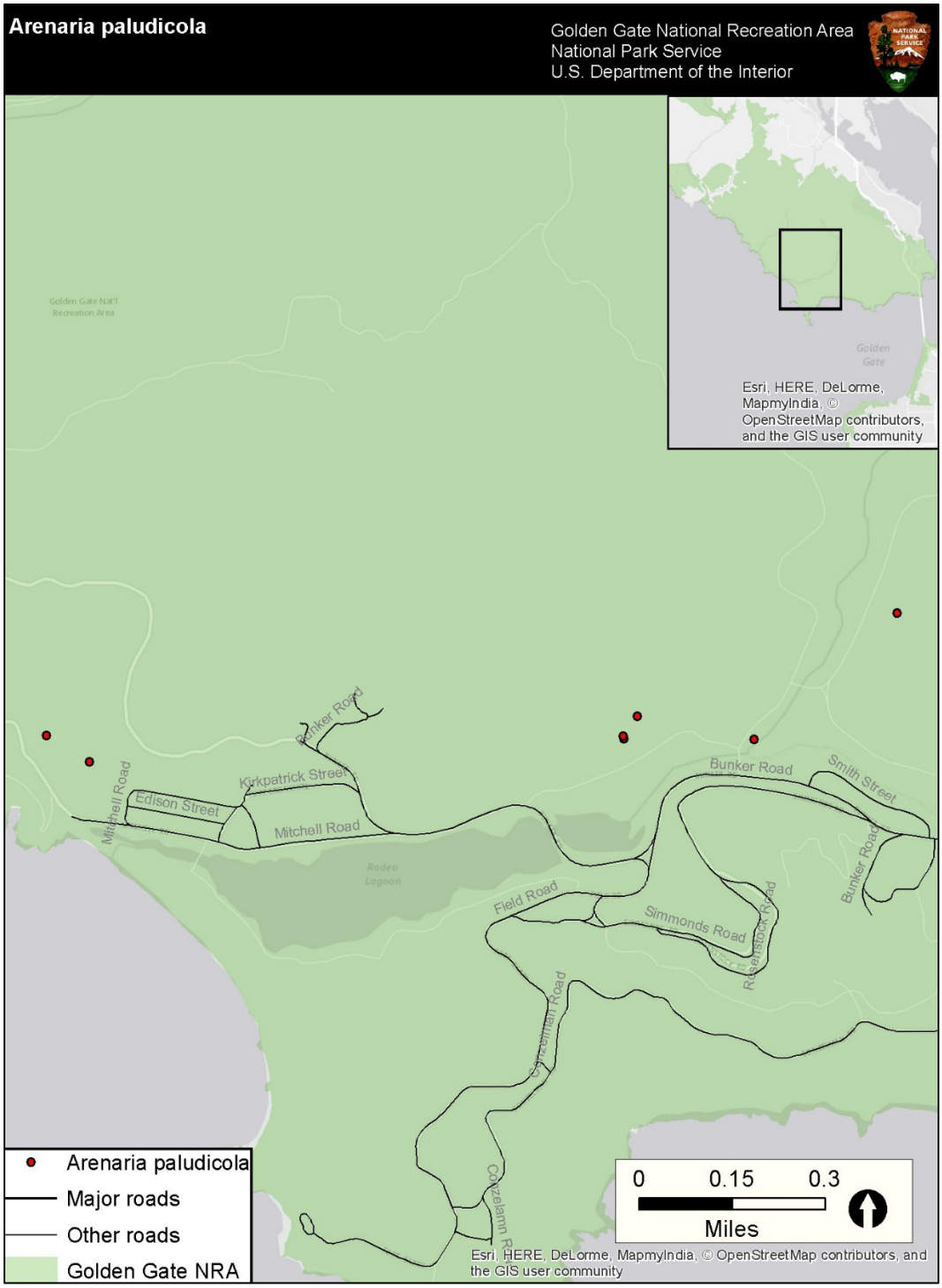


Figure 4.6.3. Distribution of Marsh Sandwort (NPS).

Stressors

Anthropogenic Influence

The GOGA populations are protected from development and other similar pressures. Although the planted populations are not immediately accessible, trampling by humans or pets could be a threat if the populations expand (Chassé and Forrestel 2014).

Wildlife Interactions

Little is known about the reproductive biology of marsh sandwort. Potential for pollination appeared limited according to two initial field studies in 1993 and 1994 of the Oso Flaco population: only one or two flowers were open at a time, no pollination activity was observed, and the population flowered and fruited minimally (USFWS 1998). No mention of pollination was made in the most recent 5-year Review (USFWS 2008) or by Bontranger et al. in their discussion of marsh sandwort introductions (2014). However, self-pollination of *Arenaria uniflora* has been observed as a potential niche development due to competition for pollinators with *Arenaria glabra* (Wyatt 1986). Also, herbivory of flowers could reduce the potential for the population to expand (USFWS 2008).

Plant Interactions

Competition with native coastal plants and non-native grasses for water, nutrients, light, and space could limit the viability of the marsh sandwort (USFWS 1998). However, neighboring plant interactions are complex and context-dependent, as shown in a study of marsh sandwort introductions in coastal lagoons of Santa Cruz, California (Bontrager et al. 2014). This study examined the effect of removing surrounding vegetation at transplant sites. Marsh sandwort exhibited lowered survival in plots that had sheet water flow or ponding, but were positively associated with areas with constant soil moisture. Although removal of surrounding vegetation was generally associated with higher survival rates, the study found cases where survival was lower after vegetation removal due to an interaction with presence of sheet flow and standing water. The authors indicate that this complex response should inform site-specific management decisions that incorporate vegetation, edaphic and climate variables (Bontrager et al. 2014).

Similarly, the GOGA populations had a complex response to vegetation clearing: plant removal at the Rodeo Beach site increased survival, but decreased survival and plant health at the Miwok site. The Miwok site was identified as more wet, which corresponds to the Bontrager et al. results (2014). Overall, the researchers of the GOGA populations concluded that removing surrounding vegetation did not produce a consistently measurable positive result that would support the additional time and cost (Acierto et al 2012). On the other hand, GOGA staff have found that both native (e.g. giant coastal vetch; *Vicia gigantea*) and non-native (e.g. common Cape-ivy; *Delairea odorata*) plants are outcompeting marsh sandwort and require active management to protect the sandwort from potential extirpation (A. Forrestel personal communication 2015). The complex nature of these interspecific plant interactions warrant further research and consideration in management actions.

Physical Factors

Natural or human-enhanced sedimentation into wetland habitat could alter the water table regime and degrade habitat for marsh sandwort (USFWS 1998). Marsh sandwort individuals were able to

withstand varying salinity levels in a greenhouse setting; this may improve the species' resilience to changing water chemistry (Bontrager et al 2014).

Reduced Gene Pool and Population Size

Small populations can have significantly lower germination rates than larger populations of the same species due to high levels of homozygosity, where the offspring receives two copies of the same gene from both parents (Menges 1991). The two wild populations, Oso Flaco and Black Lake Canyon, were found to be genetically distinct, with further genetic segregation between potentially clonal groups in Oso Flaco Lake (Mazer 2000). This level of genetic divergence may call for maintaining distinct clonal lineages in future recovery efforts (USFWS 2008). Unpredicted random events that damage one or more of these populations is more significant due to the small size and isolation of the reintroduced populations (USFWS 1998).

Climate Change

Changing climate conditions could render the chosen reintroduction sites unsuitable to current marsh sandwort populations. Drought, in combination with groundwater pumping and aquifer recharging with pesticide and fertilizer, altered the water table in natural habitat of marsh sandwort in non-GOGA populations (USFWS 1998). Although the human influence is reduced in GOGA property, water tables could diminish in climate scenarios with frequent drought. The limited gene pool from the natural population could reduce the species' resilience to a changing climate (USFWS 2008).

Level of confidence in assessment

The condition and trend of the marsh sandwort summarized in this report have been based primarily on conclusions found in the most recent GOGA monitoring report (Chassé and Forrestel 2014), USFWS 5-year Review (USFWS 2008), and the USFWS Recovery Plan (USFWS 1998). The USFWS reports are comprehensive reviews of the species and supersede conclusions made in this document. The 2011 population planted within GOGA lands was not described in the 2008 5-year Review or the 1998 Recovery Plan. However, the USFWS is due to produce another 5-year Review for the species that will contain up-to-date information regarding the status and trend of marsh sandwort in all wild and introduced populations. Additional reports and studies were incorporated as needed to fully depict the status of marsh sandwort.

Gaps in understanding

General declines in wild population numbers in Oso Flaco Lake and Black Lake Canyon are not fully understood. Anthropogenic biostimulation and alteration of hydrologic regimes may have played an important role in making previously suitable habitat unsuitable (USFWS 2008). The failure of these populations to maintain self-sustaining populations would inform management of planted populations.

Historic occurrences identified in herbaria specimens contain limited information on habitat requirements of marsh sandwort when collected (USFWS 2008). Studies of the genetic variation of marsh sandwort across its known range would inform the recovery strategy for the species (USFWS 2008). The Recovery Plan recommends non-destructive research into the following areas: genetic intra- and inter-population relationships; the tolerance of the species to withstand the effects of

human, physical, or biological variables on survivorship of the species; and main factors in population growth (USFWS 1998).

The most recent USFWS 5-year Review of marsh sandwort concluded that the species had a low potential of recovery due to lack of understanding of threats and limiting factors, necessity of active management (removal of competitive species) and unknown probability of the species success (USFWS 2008). Establishing new populations in the historic range of marsh sandwort was recommended in the recovery actions of the 5-year Review and the preliminary downlisting criteria in the Recovery Plan (USFWS 2008 and 1998). The two populations planted within the Marin Headlands in 2011 have not been evaluated by any published USFWS review. Initial monitoring indicates that after initial loss of individuals observed in 2012 (25–35% at Miwok site and 45–65% at Rodeo site), 2013 monitoring showed an increase over the previous year: 39 and 64%, respectively (Chassé and Forrestel 2014).

Tiburon paintbrush (*Castilleja affinis* ssp. *neglecta*) Condition Assessment

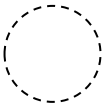
Tiburon paintbrush (*Castilleja affinis* ssp. *neglecta*) is a hemiparasitic perennial herb found associated with various host plants on north to west facing slopes in serpentine bunchgrass and valley and foothill grassland (USFWS 1998, CNPS 2014, USFWS 2012b). GOGA staff have only found Tiburon Indian paintbrush populations in patches of Nicasio ceanothus (*Ceanothus decornutus;* Chassé and Forrestel 2014). This California endemic herb blooms from April to June and occurs at 60 to 400 meters of elevation. It is currently listed as federally endangered and California threatened, and is also listed by the California Native Plant Society (CNPS) as Rare Plant Rank 1B.2, which is defined as "fairly endangered in California" (CNPS 2014).

Condition and Trend

The Tiburon paintbrush is limited to Marin, Napa and Santa Clara counties (USFWS 2012b). The Tiburon paintbrush is considered extant in five locations in Marin County (three on the Tiburon Peninsula and two on GOGA property west of Sir Francis Drake Blvd.), one in Napa County (near American Canyon), and two in Santa Clara County (Paintbrush Hill and North Canyon; USFWS 2012b). An additional occurrence was noted at Stinson Beach in Marin County, but this was last observed in 1965 and is considered extirpated (USFWS 2012b).

The Nicasio Ridge population occurs on GOGA land (managed by Point Reyes National Seashore) and on the adjacent private property, which includes the majority of individuals. (Chassé and Forrestel 2014; Figure 4.6.4). All populations noted in the USFWS 5-year Review have shown high fluctuations in numbers of individuals (USFWS 2012b). However, the results from the Nicasio Ridge population monitoring have shown overall consistent gains in individuals since monitoring began in 2003 (Table 4.6.5; Chassé and Forrestel 2014). Two additional outlier patches near the main Nicasio Ridge population were recorded in 2012: Outlier Patch 1 showed a decrease the second monitoring year, while Outlier Patch 2 showed an increase (Chassé and Forrestel 2014).

Table 4.6.5. Condition summary for Tiburon paintbrush (*Castilleja affinis* ssp. *neglecta*).

Indicators of Condition	Specific Measures	Condition Status	Rationale
How many of the natural populations observed since GOGA management began are still extant?	Proportion of natural populations with > 0 individuals in 2012 and 2013		Two outlier patches have been observed since 2012 and show fluctuations in population size. GOGA annual monitoring of the population has been consistent since first monitored in 2003 (Chassé and Forrestel 2014)
Are introduction efforts successful?	Proportion of successful expansions and/or introductions into new sites		No planted populations have been attempted at GOGA
Have the USFWS Recovery Plan goals been fulfilled for populations within GOGA lands?	Proportion of interim and long-term goals realized, partially-met or in progress. Goals carried out by other entities will not be counted toward score		Of the four recovery criteria reviewed in the USFWS 5 year status report, two are completed or in progress for the GOGA population (habitat secure, 20 year monitoring) one has not been met (management plan creation), and one is coordinated by other entities (seed storage). Downlisting criteria are not calculated for this indicator as all downlisting criteria overlap recovery goals

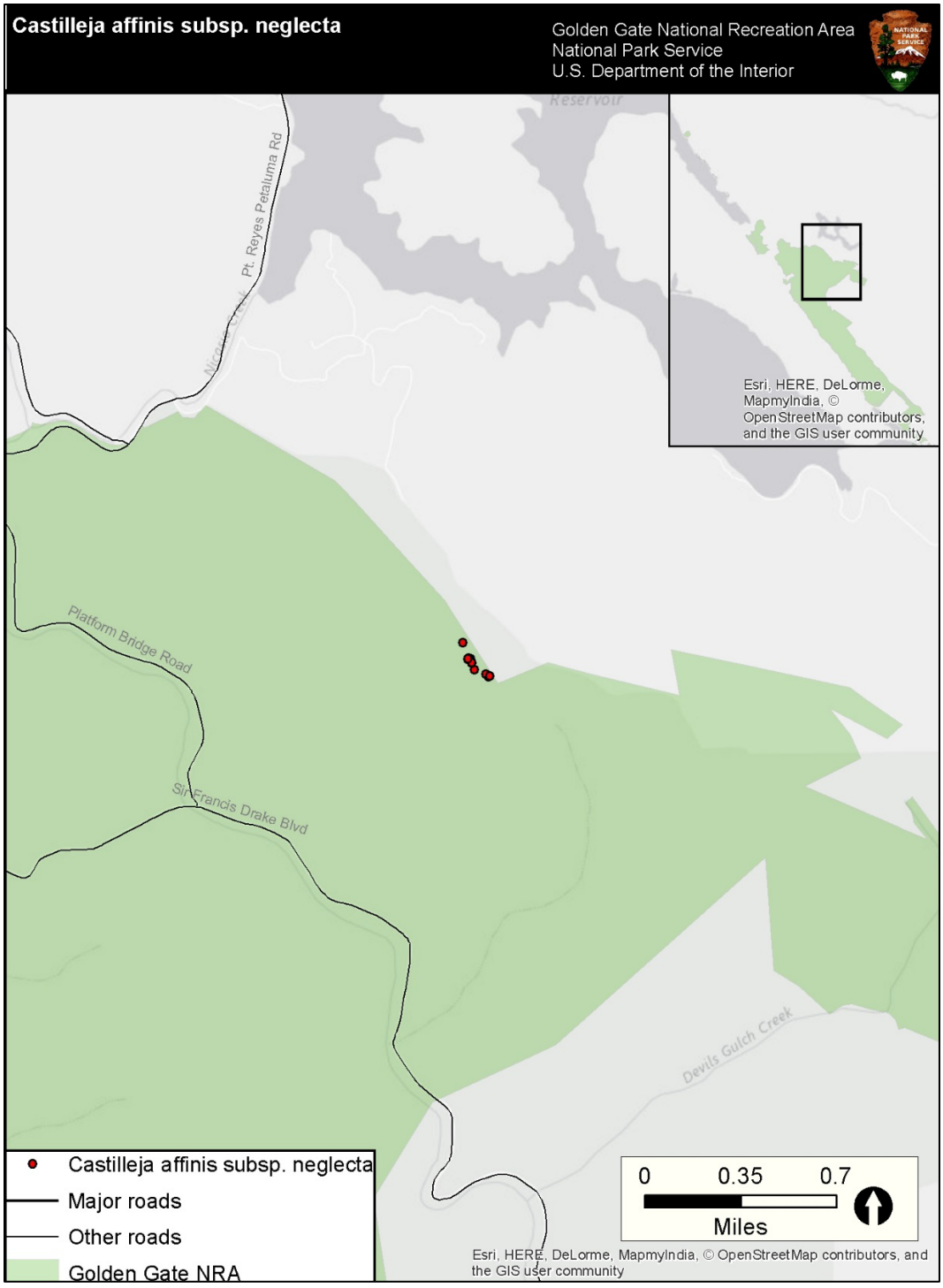


Figure 4.6.4. Distribution of Tiburon paintbrush (NPS).

Stressors

Anthropogenic influence

Tiburon paintbrush individuals within GOGA are not subject to development pressures present in other occurrence areas (USFWS 1998). However, incidental foot traffic or pet activity could pose a

threat to the GOGA individuals (Hunter 1989). The proximity to developed areas increases the likelihood of fire or vandalism of plants (USFWS 2012b).

Plant Interactions

Invasion of non-native species into naturally nutrient-poor serpentine habitats may be facilitated by nitrogen deposition from vehicular traffic and industrial output prevalent in the Bay Area (Weiss 1999). Invasion by non-natives, such as distaff thistle (*Carthamus* sp.) and tocalote (*Centaurea melitensis*), could threaten Tiburon paintbrush populations (Chassé and Forrestel 2014). Point Reyes National Seashore has been working to remove tocolote near the Nicasio Ridge occurrence (USFWS 2012b).

Animal Interactions

Herbivory by native small and large mammals of Tiburon paintbrush plants could pose a threat to individuals (USFWS 2012b). Feral pig (*Sus scrofa*) rooting was considered a threat to Santa Clara occurrence (County of Santa Clara et al. 2010). Cattle grazing is considered instrumental in reducing non-native grass species in Santa Clara County (County of Santa Clara et al. 2010). Grazing effects have not been evaluated for the Nicasio Ridge population. GOGA staff anecdotally note that paintbrush populations may be limited to chaparral areas due to grazing pressures in grasslands (Chassé and Forrestel 2014).

Climate Change

Due to its limited distribution and dependence on serpentine habitats, Tiburon paintbrush populations may be limited in naturally relocating to more suitable habitats in an era of climate change. Furthermore, the lack of genetic diversity due to small populations also decreases the populations' survival in changing climatic conditions (USFWS 2012b).

Level of confidence in assessment

The condition and trend of the Tiburon paintbrush summarized in this report have been based primarily on conclusions found in the most recent GOGA monitoring report (Chassé and Forrestel 2014), USFWS 5-year Review (USFWS 2012b), and the USFWS Recovery Plan for Serpentine Soil Species of the San Francisco Bay Area (USFWS 1998). The USFWS reports are comprehensive reviews of the species and supersede conclusions made in this document. Additional reports and studies were incorporated as needed to fully depict the status of Tiburon paintbrush.

Gaps in understanding

The USFWS 5-year Review noted a second occurrence of 50 individuals was surveyed once in 1991 within GOGA, but this occurrence was not described in the GOGA Rare Plant Report (USFWS 2012b, Chassé and Forrestel 2014).

The role of grazing is not fully understood or quantified. Experimental manipulation of grazing, fire, and propagation were identified in the recovery strategies of the Rare Plant Report with an unknown status (Chassé and Forrestel 2014). The 1998 USFWS Recovery Plan suggested the use of burn boxes as a way to integrate small-scale burning onto the landscape, with reduced risk of unintended adverse effects to the population. If the adjacent land owner is willing, GOGA could take advantage

of the opportunity for natural studies examining the distribution of paintbrush individuals within the two properties of different land management strategies.

The Recovery Plan also recommends demography, genetic, pollination, and taxonomic studies of Tiburon paintbrush (USFWS 1998). A 1968 study of *Castilleja* chromosome numbers and polyploidy conducted by Heckard (as cited in USFWS 2012b) found that inbreeding was possible between species with various ploidy levels. No additional studies, genetic or otherwise, had been conducted specific to Tiburon paintbrush by the 5-year Review (USFWS 2012b).

The GOGA Tiburon paintbrush population has increased steadily and substantially since monitoring efforts noted in 2003. Initial population numbers were limited to 4 individuals in 2003 and 2004, but have since reached over 140 individuals in 2013. The 2012 and 2013 numbers include two additional outlier patches in the vicinity of the original main patch (Chassé and Forrestel 2014). However, these numbers are far below the 2,000 individuals per recovering population recommended in the Recovery Plan (USFWS 1998b). This population is protected and annually monitored by NPS staff. Carefully-applied research could target the benefits or drawbacks of management-related disturbance agents such as grazing and fire, as well as demographic, taxonomic and pollinator studies (USFWS 2012b).

Presidio clarkia (*Clarkia franciscana*) Condition Assessment

Presidio clarkia (*Clarkia franciscana*) is an annual herb found in coastal shrub and grasslands in valleys and on foothills, often on serpentinite substrate. This California endemic herb blooms from May to July and occurs at 25 to 335 meters of elevation. It is currently listed as federally endangered and California endangered, and is also listed by the California Native Plant Society (CNPS) as Rare Plant Rank 1B.1, which is defined as “seriously endangered in California” (CNPS 2014).

Condition and Trend

The San Francisco Presidio population was discovered in 1958, and was the only known population of Presidio clarkia until discovery of the Oakland Hills population in 1980 (USFWS 2012b). This species is currently known from two locations: San Francisco Presidio and Oakland Hills, which includes six subpopulations within 0.5 miles of the Redwood Park population (CNPS 2014). The Presidio population includes one natural occurrence at Inspiration Point on serpentine grasslands (Table 4.6.6; Figure 4.6.5). Three introduced subpopulations in the Presidio include the World War II Memorial (introduced in 1972), West Crissy Bluffs (a.k.a. McDowell Avenue; 2011), and Presidio Coastal Bluffs (2011; Chassé and Forrestel 2014).

Table 4.6.6. Condition summary for Presidio clarkia (*Clarkia franciscana*) Condition Assessment.

Indicators of Condition	Specific Measures	Condition Status	Rationale
How many of the natural populations observed since GOGA management began are still extant?	Proportion of natural populations with > 0 individuals in 2012 and 2013.		Consistent monitoring of the main macroplot at Inspiration point have shown high levels of variation in population size.
Are introduction efforts successful?	Proportion of successful expansions and/or introductions into new sites		Three populations have been introduced GOGA lands. Two sites initiated in 2011 have not been monitored yet, and one population was extant in recent surveys.
Have the USFWS Recovery Plan goals been fulfilled for populations within GOGA lands?	Proportion of interim and long-term goals realized, partially-met or in progress. Goals carried out by other entities will not be counted toward score.		For the populations within GOGA management areas, three delisting criteria are met or partially fulfilled (protection of populations, minimum population size and population stability), and two are fulfilled by other entities (research and seed storage).

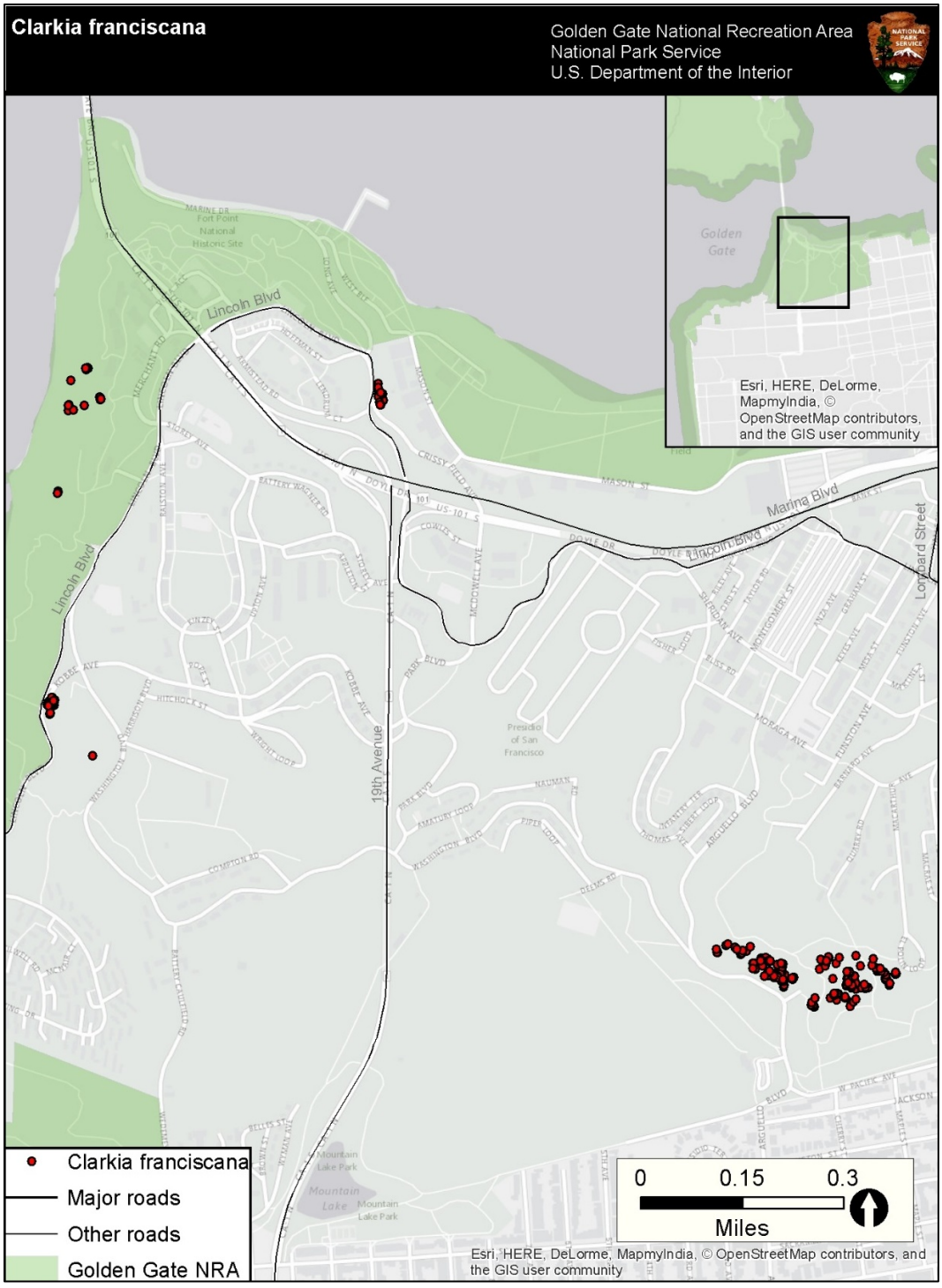


Figure 4.6.5. Distribution of *Presidio clarkia* (NPS).

The 2013 Inspiration Point population was estimated to include between 39,448 to 52,752 individuals (Chassé and Forrestel 2014). The World War II Memorial site consisted of approximately 48 individuals in 2013; and the Presidio Coastal Bluffs population was not surveyed in 2013 (Chassé and Forrestel 2014). Major variation in population size has been observed in both the Inspiration

Point (approximately 1,000 to 110,000 individuals in 2005–2013) and World War II (approximately 4 to 973 individuals in 1998–2013) sites. In the Inspiration Point population, the lowest number of individuals occurred in 2008 (approximately 10,000) and 2012 (20,000); in the World War II population, lowest numbers were in 2008 (4), 2009 (29) and 2013 (48). The 5-year Review notes that the low abundance years generally co-occur with drought or recovery from drought years (USFWS 2010).

Population estimates of the Inspiration Point population were analyzed for relationship to specific climate factors for this report. Of the models tested, the model with the best fit and lowest AIC value was the "March/April Mean Minimum Temp and Annual Precipitation with Interaction" model. The model with second lowest AIC value was within 2 units of the model with the best fit, and its level of fit is considered indistinguishable from the model of best fit (Table 4.6.7). The model with the second lowest AIC value was the very similar "March, April and May Mean Minimum Temp and Annual Precipitation." Both models are tested below for significance of individual parameters.

Table 4.6.7. Akaike Information Criterion Values for Presidio Clarkia Models (NPS unpub. Data).

Models (Clarkia)	AIC Value	Δ AIC
March/April Mean Minimum Temp and Annual Precipitation with Interaction	199.1500	0.000
March, April and May Mean Minimum Temp and Annual Precipitation	200.7180	1.5675
April/May Mean Minimum Temp and Annual Precipitation with Interaction	205.0910	5.9403
April/May Mean Maximum Temp and Annual Precipitation with Interaction	210.3490	11.1990
Spring Mean Minimum Temperature	213.6059	14.4555
Spring Extreme Minimum Temperature	215.1324	15.9820
Spring Extreme Maximum Temperature	218.1037	18.9533
March/April Mean Maximum Temp and Annual Precipitation with Interaction	219.1740	20.0238
Seasonal Precipitation	219.2963	20.1459
March, April and May Mean Maximum Temp and Annual Precipitation	221.1060	21.9551
Spring Mean Maximum Temperature	222.9847	23.8343

The parameters within the two models were tested for significance (see Table 4.6.8 and 4.6.9 below). In the model with the lowest AIC value, "March/April Mean Minimum Temperature and Annual Precipitation with Interaction," the only parameter with statistical significance (p= 0.0385) was the interaction between March/April MMNT and annual precipitation. In the second lowest model, "March, April and May Mean Minimum Temp and Annual Precipitation," two parameters were statistically significant: March Mean Minimum Temperature (p-value = 0.00452) and annual precipitation (p = 0.02204).

In the model with March/April MMNT, annual precipitation and an interaction term, the interaction is statistically significant (p=0.0385). The main effects: annual precipitation and March/April MMNT are not individually statistically significant. However, this may reflect the extra model parameters and the small sample size. The significant interaction term means that the effect of the explanatory variables are contingent on one another. In the second model, the positive effect that the March

MMNT has on population values indicates that warmer March temperatures may predict or facilitate larger clarkia population sizes. Similarly, the positive effect of annual precipitation indicates that increasing precipitation in the year before flowering is correlated with increasing population numbers. Presidio clarkia generally would be at a vegetative or pre-blooming development stage in March (CNPS 2014).

Table 4.6.8. Summary Statistics of March/April Mean Minimum Temperature and Annual Precipitation with Interaction for Presidio Clarkia.

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
Intercept	-125600.000	159600.000	-0.787	0.4670
Annual precipitation	-96.500	387.800	-2.488	0.0553
March/April MMNT[1]	1083.000	1752.000	0.618	0.5635
Interaction	1.220	0.437	2.788	0.0385[2]

[1] MMNT= Mean Minimum Temperature

[2] Statistically significant (p<0.05)

Table 4.6.9. Summary Statistics of March, April and May Mean Minimum Temp and Annual Precipitation for Presidio Clarkia.

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
Intercept	-402200.00	109800.000	-3.664	0.02151*
Annual precipitation	14.01	3.854	3.636	0.02204*
March MMNT	4259.00	740.000	5.755	0.00452*
April MMNT	1088.00	1222.000	0.891	0.42350
May MMNT	-980.10	1169.000	-0.838	0.44898

* Statistically significant (p<0.05)

It is important to recognize that the dataset is spatially limited to one site and temporally limited to the number of years the population was sampled, which limits any potential interpretation of data to the Inspiration Point population. A future study incorporating population data from other sites with different climate variables would bolster the findings of this analysis. This study also did not test all potential climate factors or combinations in order to avoid multiple testing, which would negate the significance of any findings.

Stressors

Plant Interactions

Non-native and native herbaceous plants, including weedy natives such as Himalayan blackberry (*Rubus ursinus*), blue blossom (*Ceanothus thyrsiflorus*), and poison-oak (*Toxicodendron diversilobum*), may outcompete Presidio clarkia for suitable microhabitat (Chassé and Forrestel 2014). Shading, litter accumulation, and increased soil moisture from native and introduced shrubs and trees could reduce habitat suitability for Presidio clarkia. Invasive plant species are controlled and removed by the Presidio Trust (Chassé and Forrestel 2014). Non-native trees have been removed

from the War Memorial and Inspiration Point sites. Although this has improved the habitat for Presidio clarkia, residual effects from litter accumulation may continue to alter the soil properties (USFWS 2010).

Anthropogenic Interactions

Many of the negative anthropogenic disturbances cited in the Recovery Plan have been eliminated by efforts of GOGA and the Presidio Trust. These managing entities have made efforts to fence populations, remove trees, and reduce the cover of non-native plants (USFWS 2010). Road maintenance and poorly-timed mowing no longer threaten extensions of the population (USFWS 2010). Trail erosion, storm drain runoff and other hydrologic issues were concerns cited in the 5-year Review and may still threaten the Presidio clarkia (USFWS 2010). Nitrogen deposition from industrial and automobile combustion can alter the chemical makeup of serpentine habitats to favor non-native plant invasion (USFWS 2010).

Niederer, Weiss and Stringer studied the potential benefits of anthropogenic disturbance and reintroduction of historically excluded natural disturbance to Presidio clarkia populations (2014). This study consisted of blocks with or without Presidio clarkia seed that each received one of the following treatments: “fall burning, fall flaming, fall mowing with thatch reduction, fall scraping, fall tarping, spring burning, and spring mowing with and without thatch reduction” (Niederer et al 2014). Application of scraping, flaming or tarping in late fall, after annual grass germination, proved to be the most effective at reducing annual grass germination and thatch. Fall scraping and flaming also showed increased numbers of Presidio clarkia in unseeded plots if seeds were initially present (Niederer et al 2014).

Habitat Restriction

Population expansion is limited by the lack of preserved areas that contain the required serpentine habitat preferred by the Presidio clarkia. Three additional areas were repatriated with Presidio Clarkia and are monitored every other year (Chassé and Forrestel 2014). Soil depth and solar insolation were not considered major limiting factors in Presidio clarkia distribution at Inspiration Point (USFWS 2010). However, Presidio clarkia was not found directly under tree canopies (Weiss and Neiderer 2009).

Genetic Bottleneck

Presidio clarkia habitat has been lost to development, and remaining populations are fragmented by roads and other development. Isolated populations with limited genetic variability are more subject to genetic drift and stochastic events, such as erosion, climate, fire, or disease (USFWS 2010). Early genetic work on Presidio clarkia concluded that the species self-pollinates and is monomorphic in most of its populations, but has enzymatic variation in lieu of genetic variation (Gottlieb and Edwards 1992). Gene flow of the generally self-pollinating species could be facilitated by pollinators that increase the genetic variability of isolated populations (Gottleib 1974, USFWS 2010).

Climate Change

Presidio clarkia was observed to be intolerant to variations in microclimate conditions at the War Memorial site. The limited distribution and climatic variation intolerance of Presidio clarkia could leave the isolated populations vulnerable to climatic variations. As shown in monitoring data,

drought years have shown the lowest population sizes observed (Chassé and Forrestel 2014, USFWS 2010), which could indicate declining populations in a drier climate regime.

Level of confidence in assessment

The condition and trend of the Presidio clarkia summarized in this report have been based primarily on conclusions found in the most recent GOGA monitoring report (Chassé and Forrestel 2014), USFWS 5-year Review (USFWS 2010), and the USFWS Recovery Plan for Serpentine Soil Species of the San Francisco Bay Area (USFWS 1998b). The USFWS reports are comprehensive reviews of the species and supersede conclusions made in this document. Multiple species-specific studies have been conducted to inform management of protected Presidio clarkia populations, most notably the work of Neiderer and Weiss (2009 and 2014). Additional reports and studies were incorporated as needed to fully depict the status of *Presidio clarkia*.

Gaps in understanding

The Recovery Plan recommends surveying historic locations for present individuals or potential suitable habitat for repatriation. One such area, the McDowell Avenue (West Crissy Bluffs) was seeded with Presidio clarkia in 2011. The 2014 Rare Plant report recommends increasing efforts to monitor introduced populations, and to begin monitoring the seeded population on the West Crissy Bluffs (Chassé and Forrestel 2014).

The dramatic fluctuations in population size are not fully understood and may be due to a combination of climate variables and management activities (USFWS 2010). The recently planted and infrequently monitored Bluff populations are located within a more coastal habitat than the more interior World War II Memorial and Inspiration Point sites. The Bluff site is subject to wind, increased precipitation and increased fog conditions (USFWS 2010). These coastal conditions were cited as less than ideal and potentially a major driver in determining the lower abundance of the World War II Memorial site (Chassé and Forrestel 2009, as cited in USFWS 2010).

The Presidio populations of Presidio clarkia are managed and monitored by the Presidio Trust and the National Park Service. Both the natural Inspiration Point population and the monitored introduced World War II Memorial population have shown great variation in population size since monitoring began (Chassé and Forrestel 2014). Results from applied management studies (Weiss and Neiderer 2009, Neiderer et al 2014) can be carefully incorporated into future management of Presidio clarkia to increase population sizes and resilience.

Marin dwarf flax (*Hesperolinon congestum*) Condition Assessment

Marin dwarf flax (*Hesperolinon congestum*) is an annual herb found with bunchgrasses, chaparral, and dry grasslands in valleys and foothills, mostly on serpentinite substrate (USFWS 2011). Recent classification work has placed Marin dwarf flax within the Hesperevaco sparsiflorae-Hemizonion congestae alliance, which is described as a serpentine annual grassland in sunny open areas with oceanic influence (Rodriguez-Rojo et al. 2001). This California endemic herb blooms from April to July and occurs at 5 to 370 meters of elevation. It is listed as federally threatened and state threatened, and is also listed by the California Native Plant Society (CNPS) as Rare Plant Rank 1B.1, which is defined as “seriously endangered in California.”

Condition and Trend

The historical range of Marin dwarf flax has not been established. However, it is likely that the historical range included all extant populations, and all populations listed in the original 1995 report, where 14 populations were listed but only 12 were discussed (USFWS 2011). The dwarf flax likely inhabited other areas of San Francisco and San Mateo counties that have been converted to urban land use but were at one point serpentine habitat (USFWS 2011). Specifically, confirmed voucher specimens were collected from both Laurel Hill and Masonic Cemeteries (M. Chassé personal communication 2015).

There are currently 23 extant occurrences recognized by CNPS and the most recent 5-year Review (USFWS 2014; CNPS 2014). Marin dwarf flax is currently limited to San Francisco, San Mateo and Marin Counties in California. Ten extant San Mateo occurrences are divided into two subgroups: Crystal Springs (6 extant), and Edgewood/Woodside (4 extant). Two extant San Francisco occurrences are noted in the 5-year Review: Presidio (CNDDB #16) and Inspiration Point restoration experiment (CNDDB #20). Eleven extant occurrences within Marin County include one unreliable occurrence and three major subgroups: Mount Burdell (2 extant, 1 additional non-CNDDB occurrence), Central Marin (5 extant), and Tiburon (3 extant, 1 additional non-CNDDB occurrence) (NPS unpublished data 2014).

GOGA boundaries encompass populations at Nicasio Ridge (Marin; managed by Point Reyes National Seashore), within the San Francisco Water District management unit (San Mateo; managed by the SFPUC), near the World War II Memorial (San Francisco), and an introduced population at Inspiration Point of limited success (San Francisco) (Figure 4.6.6; Chassé and Forrestel 2014. Chassé personal communication 2015). Populations vary in number, spatial distribution and extent between years (USFWS 2011). The overall Presidio population was considered unstable in the 2011, due to "20-fold increases and declines over the 1995–2010 survey period" (USFWS 2011).

In 2000, seeds from Ring Mountain in Tiburon, Marin County, were introduced to Inspiration Point, a previously-extirpated Marin dwarf flax site. Although initially successful, all individuals were removed in 2008 due to concerns about the genetic difference between the Tiburon seeds from the closer Presidio population (Chassé and Forrestel 2014). A new seeding effort was attempted in 2010 with Presidio seed stock, but few individuals were initially established from that effort (Table 4.6.10; Chassé and Forrestel 2014). Thirteen individuals were observed during May 2015 surveys (M. Chassé personal communication 2015).

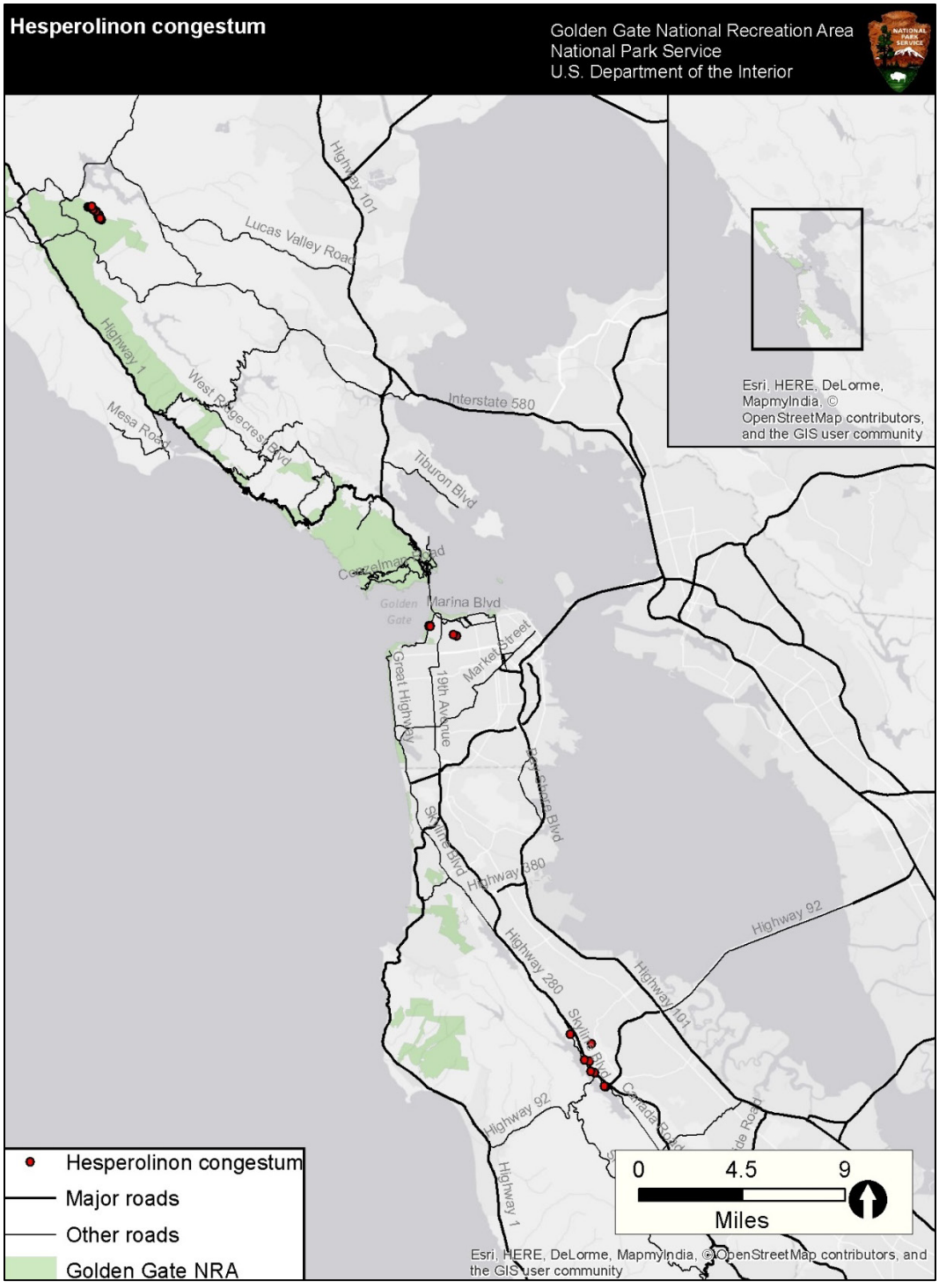
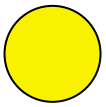


Figure 4.6.6. Distribution of Marin dwarf flax (NPS).

Table 4.6.10. Condition summary for Marin dwarf flax (*Hesperolinon congestum*).

Indicators of Condition	Specific Measures	Condition Status	Rationale
How many of the natural populations observed since GOGA management began are still extant?	Proportion of natural populations with > 0 individuals in 2012 and 2013. Populations not monitored in 2012, 2013, and 2014 will not be counted toward score		The Nicasio Ridge population is not consistently monitored. The two populations at the World War II Memorial have shown great variation over sampling years. All are extant.
Have introduction efforts been successful?	Proportion of successful expansions and/or introductions into new sites		In 2000, the reintroduction of the dwarf flax was attempted at Inspiration Point, but the plants were removed in 2008 under advisement because of the possibility of their genetic difference from other populations. A seeding operation was attempted at the Presidio in 2011 but has had limited success (less than 15 individuals after 4 years).
Have the USFWS Recovery Plan goals been fulfilled for populations within GOGA lands?	Proportion of interim and long-term goals realized		Three recovery criteria were established for the dwarf flax. Within GOGA-managed lands, one is fulfilled (land protection), and two are partially fulfilled (management plan and stable monitored population)

For this report, population estimates of two populations of Marin dwarf flax populations, Yerba Buena and Raven's Manzanita, were combined before being analyzed together for relationship to specific climate factors. Of five models tested, the model with the best fit and lowest AIC value was the Spring Mean Maximum Temperature model. The parameters within this model were then tested for significance (see Tables 4.6.11 and 4.6.12 below). Of all the parameters, the effect of March and May Mean Maximum Temperature (MMXT) parameters on the Marin dwarf flax population size were statistically significant (p-value < 0.05). The positive effect that the March MMXT has on population values indicates that warmer March temperatures might predict or facilitate larger Marin dwarf flax population sizes. The May MMXT had an opposite effect on population values: increasing MMXT correlated with decreasing population numbers.

Overall, the dataset is spatially limited, which limits any potential interpretation of the data to other populations. A future study incorporating population data from other sites with different climate variables would bolster the findings of this analysis. This study also did not test all potential climate factors or combinations in order to avoid multiple testing, which would negate the significance of any findings.

Table 4.6.11. Akaike Information Criterion Values for Marin Dwarf Flax Models.

Models	AIC Value	Δ AIC
Spring Mean Maximum Temperature	158.1992	0.0000
Seasonal Precipitation	161.4094	3.2102
March/April Mean Maximum Temp and Annual Precipitation with Interaction	162.0090	3.8100
February, March and April Mean Minimum Temp and Annual Precipitation	162.7930	4.5941
Spring Mean Minimum Temperature	163.2705	5.0713
February, March and April Mean Maximum Temp and Annual Precipitation	163.5120	5.3129
Spring Extreme Maximum Temperature	164.0278	5.8286
March/April Mean Minimum Temp and Annual Precipitation with Interaction	164.4210	6.2215
February/March Mean Maximum Temp and Annual Precipitation with Interaction	164.5600	6.3607
February/March Mean Minimum Temp and Annual Precipitation with Interaction	165.4420	7.2431
Spring Extreme Minimum Temperature	165.7541	7.5549

Table 4.6.12. Summary Statistics of Spring Mean Maximum Temperature for Marin Dwarf Flax.

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
Intercept	27.9369	40.4799	0.690	0.5006
February MMXT[1]	-0.1394	0.2255	-0.618	0.5457
March MMXT	0.4705	0.1907	2.467	0.0261[2]
April MMXT	0.1003	0.2184	0.459	0.6527
May MMXT	-0.4308	0.1787	-2.411	0.0292*

[1] MMXT = Mean Maximum Temperature

[2] Statistically significant ($p<0.05$)

Stressors

Plant Interaction

Both non-native and native plant populations may threaten the populations of Marin dwarf flax by competition for resources. Several Monterey cypress trees (*Cupressus macrocarpa*) adjacent to a Marin dwarf flax population were removed prior to the 1998 Recovery Plan (USFWS 1998b). Chassé and Forrestel (2014) identified yellow star-thistle (*Centaurea solstitialis*), windmill pink (*Silene gallica*), fennel (*Foeniculum vulgare*), Italian thistle (*Carduus pycnocephalus*), and non-native grasses as species of particular competition concern. Invasion by non-native species into low-nutrient soil areas may be fostered by nitrogen deposition from industrial and motor vehicle combustion (USFWS 2011). Areas with increased nitrogen deposition and subsequent increases in non-native vegetation biomass can be restored with grazing, mowing, weeding, and selective herbicide (USFWS 2011).

Wildlife Interaction

Gopher activity may disturb soil associated with Marin dwarf flax populations. Effects from cattle grazing are unknown but of research interest (Chassé and Forrestel 2014).

Anthropogenic Disturbance

Casual recreational use and unleashed dogs were considered a threat to Marin dwarf flax during the initial listing, but the population has since been fenced. Although not managed by GOGA, the SFPUC populations may be affected by trail development, increased visitor access, and improvements to Crystal Springs Reservoir (USFWS 2011). Salvage of Marin dwarf flax is not considered a viable avoidance measure as recommended by the Native Plant Protection Act, as transplants often fail at the reintroduction site (USFWS 2011).

Climate Change

Although the specific effects of climate change on a population-size scale are not well defined, alterations of the current climate regime could render current habitat unsuitable (USFWS 2011). Harrison et al. (2002) identified Marin dwarf flax as a rare species that has persisted despite historical climate change due to its occurrence in areas with more benign climates and within larger areas with the required special habitat features (2008). These findings indicate that these species could persist through regional climate change in certain microhabitats.

Level of confidence in assessment

The condition and trend of the Marin dwarf flax summarized in this report have been based primarily on conclusions found in the most recent GOGA monitoring report (Chassé and Forrestel 2014), USFWS 5-year Review (USFWS 2011), and the USFWS Recovery Plan for Serpentine Soil Species of the San Francisco Bay Area (USFWS 1998b). The USFWS reports are comprehensive reviews of the species and supersede conclusions made in this document. Additional reports and studies were incorporated as needed to fully depict the status of Marin dwarf flax.

Gaps in understanding

The 5-year Review describes a discrepancy between the CNDDB and original populations in the 1995 listing (USFWS 2011). Only extant populations recognized by GOGA Rare Plant Report are considered in this document. Lack of surveys with consistent monitoring methodology precluded the USFWS from making conclusions on many of the Marin dwarf flax populations (USFWS 2011).

Although grazing, mowing, herbicides, weeding and fire have been suggested as management options to reduce increased competition from non-native species in nutrient-poor soil types, these management options have not been specifically tested on improving Marin dwarf flax populations (USFWS 2011). Research needs of Marin dwarf flax demography include soil seed bank, pollination and reproductive strategy studies (USFWS 2011). Surveys of potentially suitable habitat would increase presence/absence data, increase potential for re-introduction efforts, and help direct conservation planning.

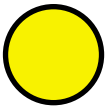
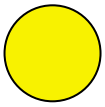
Great levels of variability in population numbers occur in all monitored populations of Marin dwarf flax, and were attributed to variation in annual precipitation, although the results of the preliminary climate-population models presented in this report indicate that mean maximum temperature may be

of greater importance (USFWS 2011). The Presidio population was considered unstable in the 5-year Review; all other GOGA-related populations were not monitored often enough to conclude population trends (USFWS 2011).

San Francisco lessingia (*Lessingia germanorum*) Condition Assessment

San Francisco lessingia (*Lessingia germanorum*) is an annual herb found on remnant dunes of coastal scrub. This California endemic herb blooms from June to November and occurs at 25 to 110 meters of elevation. It is currently listed as federally endangered and California endangered, and is also listed by the California Native Plant Society (CNPS) as Rare Plant Rank 1B.1, which is defined as "seriously endangered in California." This species is known from only four native occurrences at the Presidio in San Francisco and one on San Bruno Mountain (Table 4.6.13; Figure 4.6.7; CNPS 2014).

Table 4.6.13. Condition summary for San Francisco lessingia (*Lessingia germanorum*).

Indicators of Condition	Specific Measures	Condition Status	Rationale
How many of the natural populations observed since GOGA management began are still extant?	Proportion of natural populations with > 0 individuals in 2012 and 2013. Populations not monitored in 2012, 2013, and 2014 will not be counted toward score		Of the four GOGA populations, two are above their respective recovery threshold population sizes. These thresholds are specific to each site, and were set by the USFWS. All natural populations are extant
Are introduction efforts successful?	Proportion of successful introductions into new sites. This does not include natural populations. Lack of introduction efforts is not counted toward score		North Baker Beach reintroduction has been successful, but a Crissy Field introduction effort was unsuccessful. Monitoring methodology was consistent across years
Have the USFWS Recovery Plan goals been fulfilled for populations within GOGA lands?	Proportion of interim and long-term goals realized		Recovery criteria are set out by recovery unit. The GOGA lands fall within the Presidio Recovery Unit. The Interim Recovery Criteria have been met for four of five areas within the Presidio Recovery Unit (USFWS 2012a, b, c). None of the three sites within the Presidio Recovery Unit have met the specifics of the long term recovery criteria.

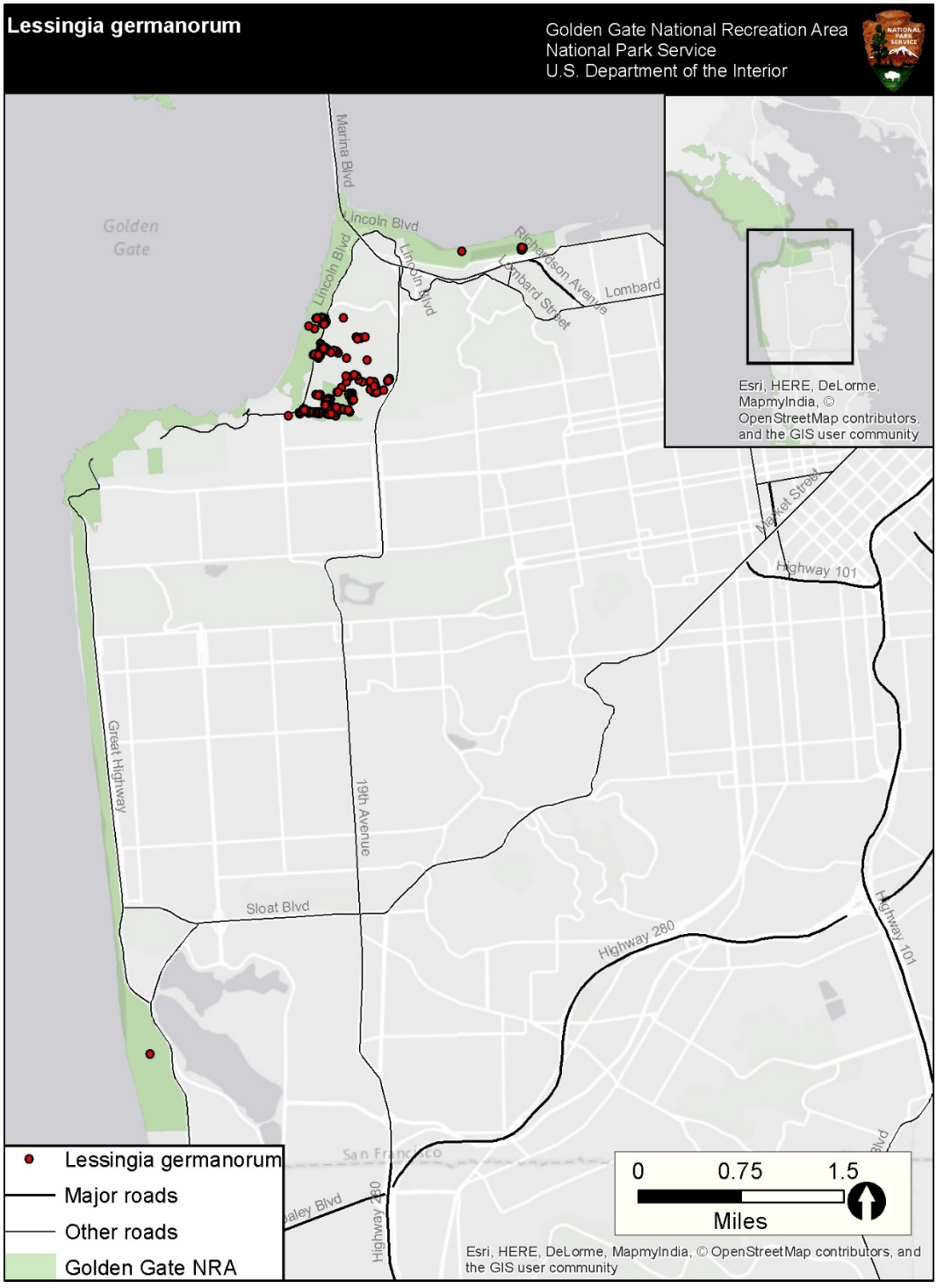


Figure 4.6.7. Distribution of San Francisco lessingia (NPS).

Condition and Trend

This species is found only in the San Francisco Presidio and near San Bruno Mountain in San Mateo Counties of California. Its historic range included all suitable central dune scrub habitat throughout the San Francisco peninsula (USFWS 2012c). Historically, the species occurred throughout the San

Francisco peninsula in central dune scrub habitats, but it is now restricted to the San Francisco Presidio and Hillside Park in Daly City (USFWS 2012c). The Daly City population occurs near the base of San Bruno Mountain on privately-owned land (USFWS 2012c). GOGA manages multiple populations within the Presidio Recovery Unit of San Francisco: Lobos Dunes Reserve, Battery Caulfield Roadside Reserve, Wherry Dunes Reserve, Rob Hill Reserve, Public Health Services Hospital Reserve (includes Golf Course site), and an introduced population at North Baker Beach (Chassé and Forrestel 2014). An additional population was accidentally introduced to Crissy Field during seeding of another native annual species. This population was surveyed annually until no longer extant (M. Chassé personal communication 2015).

Overall population numbers had increased from 1994 to 2011, and were likely maintained by acts of stewardship: weeding, protection and seeding (USFWS 2012c). Of the five populations managed by GOGA, the US Fish and Wildlife Service recognizes population sizes will fluctuate, but should not decline below these minimum recommended population sizes: Lobos Creek (50,000), Battery Caulfield (1,000), Wherry (5,000), Rob Hill (5,000), and Public Health Services Hospital sites (5,000) (USFWS 2003). However, the report also states that "fixed population size targets have limited applicability for San Francisco lessingia" (USFWS 2003).

The 2014 USFWS Rare Plant Report (Chassé and Forrestel 2014) summarizes the population statistics of the Presidio populations:

- "The core population of L. germanorum at the Lobos Dunes macroplot is below the recovery threshold of 50,000 individuals. The 80% confidence level for the 2013 population estimate within the macroplot at Lobos Creek Valley is between 18,940 and 25,925.
- The Rob Hill Reserve population is over twice the recovery threshold of 5,000 individuals with 10,546 individuals.
- The Public Health Services Hospital Reserve population (combined total of Presidio Hills and Golf Course Lessingia Site) is above the recovery threshold of 5,000 individuals.
- The Wherry Dunes Reserve population (combined total of Wherry Dunes, North Pershing Dunes, and Baker Beach Housing areas) is above the recovery threshold of 5,000 individuals.
- The Battery Caulfield Reserve population, with 268 individuals, is below the recovery threshold of 5,000 individuals.
- A previously introduced population of L. germanorum at the Shellmound area of Crissy Field has not persisted.
- New subpopulations of L. germanorum have been established in the North Baker Beach area and currently number 2,041 individuals."

More specific habitat goals were expressed in the most recent 5-year Review, including non-native plant cover, bare ground cover, and substrate conditions (USFWS 2012c). These habitat characteristics were not monitored quantitatively and are not considered in this report.

Population estimates of the Lobos Dunes San Francisco lessingia was analyzed for any relationship with specific climate factors. Of models tested, the model with the best fit and lowest AIC value was the Spring Extreme Minimum Temperature model. The parameters within this model were then tested for significance (see Tables 4.6.14 and 4.6.15 below). Of all the parameters, the effect of February and March Extreme Minimum Temperature (EMNT) parameters on the San Francisco lessingia population numbers were statistically significant (p-value < 0.05). San Francisco lessingia is a late season annual that generally blooms in July to November (CNPS 2014). The positive effect that the February EMNT had on population values indicates that warmer extreme temperatures during germination or early development in February correlates with larger lessingia population sizes. The negative estimate of March EMNT indicates that increasing extreme minimum temperatures in early to mid-development stages decreases final population sizes.

Table 4.6.14. Akaike Information Criterion Values for San Francisco Lessingia Models.

Models	AIC Value	Δ AIC
Spring Extreme Minimum Temperature	216.7997	0.0000
April, May and June Mean Maximum Temp and Annual Precipitation	219.075	2.2749
Spring Mean Minimum Temperature	221.8216	5.0219
April, May and June Mean Minimum Temp and Annual Precipitation	223.0070	6.2071
April/May Mean Minimum Temp and Annual Precipitation with Interaction	224.5620	7.7627
April/May Mean Maximum Temp and Annual Precipitation with Interaction	224.5860	7.7863
May/June Mean Minimum Temp and Annual Precipitation with Interaction	224.8500	8.0505
Spring Mean Maximum Temperature	225.5623	8.7626
May/June Mean Maximum Temp and Annual Precipitation with Interaction	225.8480	9.0482
Seasonal Precipitation	228.3924	11.5927
Spring Extreme Maximum Temperature	229.3415	12.5418

Table 4.6.15. Summary Statistics of Spring Mean Maximum Temperature for San Francisco Lessingia.

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	179928	148614.2	1.211	0.2926
February EMNT[1]	2500.5	880.2	2.841	0.0468[2]
March EMNT	-5761.7	1531.6	-3.762	0.0197*
April EMNT	5160.5	2635.6	1.958	0.1218
May EMNT	-2469.1	1644.9	-1.501	0.2077

[1] EMNT = Extreme Minimum Temperature

[2] Statistically significant (p<0.05)

Overall, the dataset is spatially limited to one site and limited in number of year surveyed, which limits any potential interpretation of data to the Lobos Dunes populations. A future study incorporating population data from other sites with different climate variables would bolster the

findings of this analysis. This study also did not test all potential climate factors or combinations in order to avoid multiple testing, which would negate the significance of any findings.

Stressors

Plant Interactions

The artificial lack of disturbance of dunes has caused gradual shrub encroachment (e.g. *Lupinus chamissonis*) into the remnant coastal dune system, which can cause succession to stable shrub habitat (Chassé and Forrestel 2014). Development and vegetation change have altered natural processes that would allow dune habitat to persist by blocking wind patterns, stabilizing sandy slopes and fragmenting dunes (USFWS 2003). Non-native grasses, such as *Bromus diandrus, Briza maxima, Avena fatua,* and *Lagurus ovatus*, may also outcompete San Francisco lessingia for resources. Non-native grasses and forbs are currently managed by GOGA in order to maintain and improve habitat quality. Topsoil inversion, where soil from >0.75 meter deep replaces the topsoil of dunes, could be an effective tool in reducing invasive herbaceous cover recruitment (Chassé and Forrestel 2014).

Non-native historical forests alter the ecology of historic dune habitat by increasing litter, stabilizing sandy soil, reducing wind effect and increasing soil moisture (USFWS 2003). The 2003 Recovery Plan (USFWS 2003) long-term recovery criteria include desired structural habitat features, which include restoration of dune fields with active wind disturbance and reduced shrub and non-native plant cover (USFWS 2012c).

Anthropogenic Disturbance

Pedestrian, pet, and horse trampling can directly destroy individuals and/or degrade habitat quality by introducing non-native competitive species (USFWS 2012c). Habitat fragmentation due to urban development limits the species capacity for dispersal and extent of potential habitat. Further development and introduction of competitive landscape plants may occur under management of Presidio lands by the Presidio Trust. The Presidio Trust is also allowed to dispose of Presidio lands to non-federal ownership in order to meet financial success criteria, which would reduce the protection of federal listing (USFWS 2003). Existing populations that expand into unprotected landscaped or historic forest areas can be impacted by visitor use and park operations (Chassé and Forrestel 2014). Existing habitat has been expanded by three large-scale dune restoration projects near the Wherry Reserve and Public Health Reserve (Chassé and Forrestel 2014).

Genetic Bottleneck

The San Bruno and Presidio populations of San Francisco lessingia are as genetically distinct from each other as each genotype is from other species of the genus, although the two populations are morphologically identical. San Francisco lessingia is generally self-incompatible, requiring pollination for successful reproduction. Subpopulations limited in extent are vulnerable to stochastic events such as erosion, landslides and loss of pollinators (USFWS 2012c).

Climate Change

Predictions of climate change at a small-scale are variable and not suitable for management decisions at this time. However, even slight alterations in climate regime could render currently suitable habitat

within GOGA managed lands to be unsuitable in the future. Variations in extreme minimum temperatures could significantly alter population dynamics, as shown in climate models in this report. Populations are currently limited by natural and anthropogenic barriers to dispersal, and would be vulnerable to climatic shifts (USFWS 2012c).

Level of confidence in assessment

The condition and trend of the San Francisco lessingia summarized in this report have been based primarily on conclusions found in the most recent GOGA monitoring report (Chassé and Forrestel 2014), USFWS 5-year Review (USFWS 2012c), and the USFWS Recovery Plan for Coastal Plants of the Northern San Francisco Peninsula (USFWS 2003). The USFWS reports are comprehensive reviews of the species and supersede conclusions made in this document. Additional reports and studies were incorporated as needed to fully depict the status of San Francisco lessingia.

Gaps in understanding

Habitat conditions of existing populations should be monitored in order to assess whether success criteria for recovery has been achieved. Species-specific research of current pollinator status in current and planned reintroduction sites could improve management of San Francisco lessingia populations (USFWS 2012c).

GOGA and the Presidio Trust monitor and manage all extant populations of San Francisco lessingia excluding one Daly City occurrence (USFWS 2012c). Of the managed populations, three populations (Rob Hill, Public Health Services Hospital, and Wherry Dunes) are above target population levels from the initial Recovery Plan, two populations (Lobos Dunes and Battery Caulfield) are below target population levels and one introduced population (Crissy Field) has not persisted (Chassé and Forrestel 2014). Two new subpopulations, totaling over 2,000 individuals, were established in North Baker Beach (Chassé and Forrestel 2014). All of the Presidio populations have been bolstered by habitat restoration and regular maintenance activities (USFWS 2012c).

Hickman's cinquefoil (*Potentilla hickmanii*) Condition Assessment

Hickman's cinquefoil (*Potentilla hickmanii*) is a perennial herb found in variety of habitats, including coastal terrace, coastal bluff scrub, closed-cone coniferous forest, vernally mesic meadows and seeps, and freshwater marshes and swamps. This California endemic herb generally blooms from April to August, although GOGA staff observed blooming in February 2015 during a multi-year drought (S. Bennett personal communication 2015). Hickman’s cinquefoil occurs at 10 to 149 meters of elevation. The Rancho Corral de Tierra population occurs on shallows, well-drained, and weathered granitic-derived soils (Vanfleet-Brown 2015). This cinquefoil is currently listed as federally endangered and California endangered, and is also listed by the California Native Plant Society (CNPS) as Rare Plant Rank 1B.1, which is defined as “seriously endangered in California” (CNPS 2015).

Condition and Trend

Hickman's cinquefoil was originally described by Alice Eastwood in 1902 on the Monterey Peninsula. The species was collected in 1905 by Katherine Brandegee from Moss Beach in San Mateo County, and in a nearby location in 1933. Later collections came from the Monterey Peninsula

during the 1930s, but specific details about locations is lacking. The species is considered extirpated from both of these sites, due to development and other changes in land use (USFWS 2009).

There are currently 5 total known occurrences. Only two remnant populations and one introduced population are presently extant (CNPS 2014). At the time of the 5-year Review, this species was known from two remnant native populations: one occurs near Pebble Beach in Monterey County with fewer than 20 individuals, and the second occurs near the town of Montara with 3000 individuals USFWS has attempted multiple reintroductions at sites in Monterey County with very limited success (USFWS 2009).

One stable population of Hickman's cinquefoil, first found in 2005, occurs at Rancho Corral de Tierra, a GOGA parcel north of the city of Montara (Figure 4.6.8). In 2011, the parcel was acquired by GOGA from the Peninsula Open Space Trust. The GOGA population has been monitored in 2008, 2013, and 2015 and appears to be relatively stable. In large patches (greater than 20) there are representatives from a variety of size classes. Patches with smaller numbers of individuals appear to be waning, with fewer young plants per adult. GOGA has focused on controlling invasive species threatening the larger isolated patches and has determined that seed collection and outplanting is not necessary to preserve this species at this site at this time (Table 4.6.16; M. Chassé and S. Bennett, personal communication, 2015). A 2015 census indicated a total of 5274 individuals. However, this increase probably reflects the change in monitoring method to a more detailed counting technique, rather than an actual increase in the number of individuals (S. Bennett personal communication 2015).

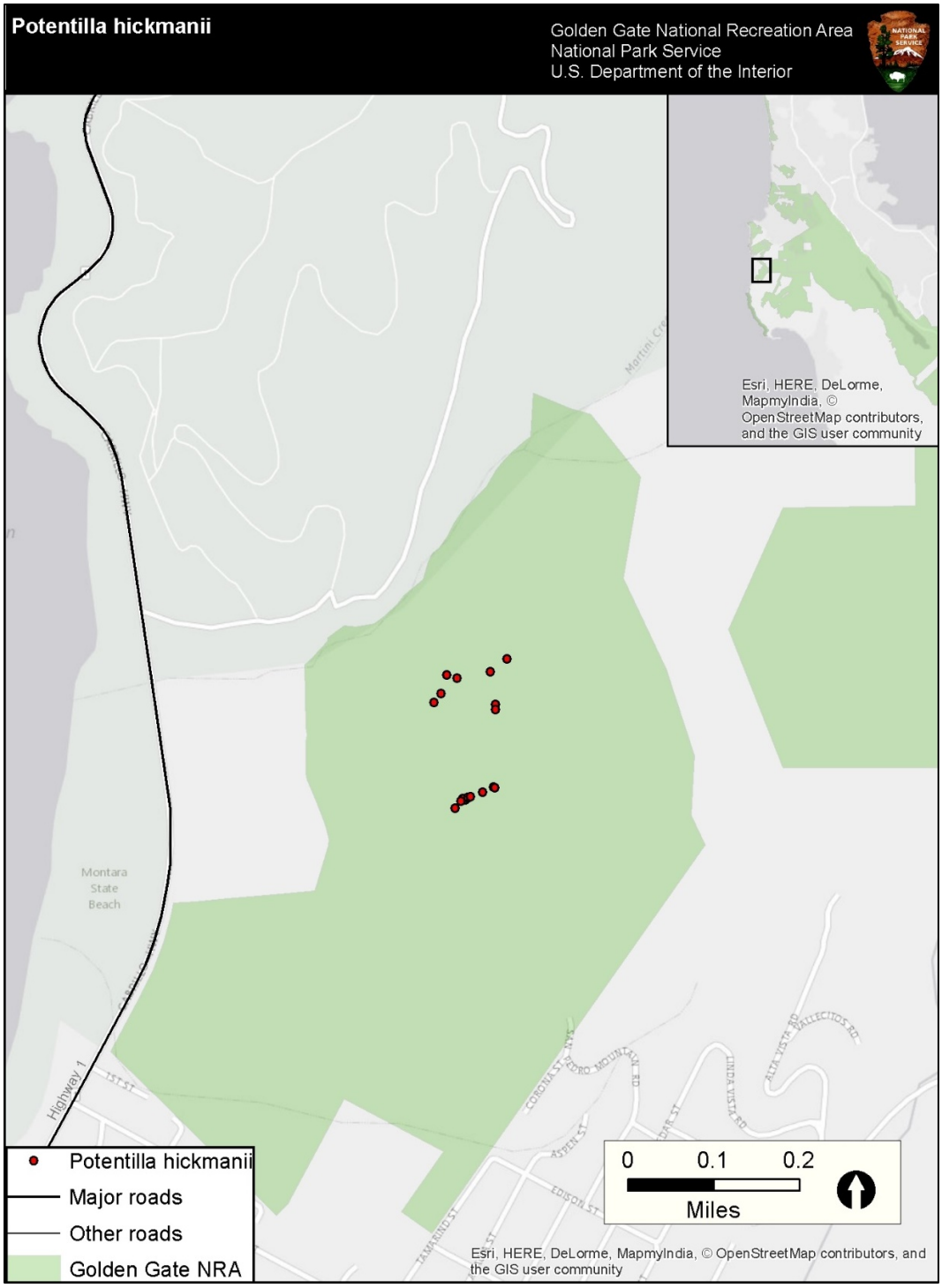
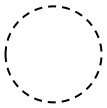
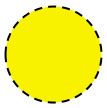


Figure 4.6.8. Distribution of Hickman's cinquefoil (NPS).

Table 4.6.16. Condition summary for Hickman's cinquefoil (*Potentilla hickmanii*).

Indicators of Condition	Specific Measures	Condition Status	Rationale
How many of the natural populations observed since GOGA management began are still extant?	Proportion of natural populations with > 0 individuals in 2012 and 2013. Populations not monitored in 2012, 2013, and 2014 will not be counted toward score.		The existing population is extant, and is being actively managed. (Chassé and Bennett pers. com. 2015).
Are introduction efforts successful?	Proportion of successful expansions and/or introductions into new sites		No introduced populations within GOGA-managed lands were noted (Chassé and Forrestel 2014).
Have the USFWS Recovery Plan goals been fulfilled for populations within GOGA lands?	Proportion of interim and long-term goals realized		Of the five criteria for downlisting, the GOGA population has met two criteria (viable population, management of encroaching vegetation), and the status of the other three remains unknown (long-term management funding, monitoring, and seed bank storage)

Stressors

Plant Interactions

Hickman's cinquefoil is very low growing and dies back annually, making it vulnerable to encroachment by a variety of plants, particularly fast-growing and thatch-producing plants. Artificially increased year-round water availability at the Pebble Beach population has caused an increase in competitive invasive species, such as Harding grass (*Phalaris aquaticus*), velvet grass (*Holcus lanatus*) and tall fescue (*Festuca arundinacea*), that favor the increase in water availability (USFWS 2004). The GOGA population is currently threatened by annual invasive grasses, perennial invasive grasses, and encroachment by conifers and native shrubs (Vanfleet-Brown 2015). These non-native invasive threats are being actively managed by NPS staff to preserve the isolated patches, in order to convert the non-native grasslands between isolated patches of cinquefoil into a native coastal prairie to encourage genetic flow between patches. Based on analysis of historical aerial photography starting in 1943, the populations that appear very small and isolated today were previously connected by grasslands in the 1940s (Vanfleet-Brown 2015). Management activities, including agricultural use, have since changed and the encroachment of native scrub has severely isolated several populations. In the smaller patches of cinquefoil, abundance appears to be decreasing since 2008 surveys. Future management efforts may require the removal of scrub and riparian vegetation to reconnect satellite populations in order to encourage genetic flow and resilience (S. Bennett, personal communication 2015).

Animal Interactions

The Pebble Beach populations have been predated by various herbivores, including mule deer (*Odocoileus hemonius*), gophers (*Thomomys* sp.), mice (various species), voles (*Microtus* spp.), snails (various species), and slugs (various species) (USFWS 2009). The GOGA population has been negatively impacted by gopher/burrowing mammal activity, which appear to destroy the roots of the plants. The impact appears minimal in the larger patches. Cattle grazing has been observed as both beneficial (reducing the cover of competitive species) and harmful (by trampling or predation) to Hickman's cinquefoil populations (USFWS 2009).

The role of pollinators for this species is not completely understood. The GOGA population seems to support a variety of insect orders who are potential pollinators, but throughout the rest of its range, insect visitations (and natural seed production) appear uncommon (S. Bennet personal communication 2015).

Anthropogenic Disturbance

The population at Pebble Beach currently sits in a former horseshoe ring and picnic area, and since that population has been fenced off, numbers appear to be reducing. The GOGA population is distributed along hillsides with the densest populations supporting a variety of size classes. These dense populations occur on or within 10 feet of trails, typically along hill crests where soil is thinnest. Based on the observed distribution, GOGA staff has suggested that foot traffic may either exclude the invasion of non-native grasses or scarify seeds and encourage germination for this species, though the coexistence of anthropogenic disturbance and remnant cinquefoil plants may be due to other abiotic factors. One dense population occurring along a social trail also receives additional surface water during winter storms (Vanfleet-Brown 2015). The interaction effect on the population of the trail use disturbance, increased water during storm events, occurrence of thin soils, and other variables warrants further study (S. Bennett personal communication, 2015).

Genetic Bottleneck

Significant habitat reduction by development and its secondary impacts have reduced the populations from estimated previous population levels. Such small populations have increased homozygosity and can have reduced germination rates as compared to healthy populations of the same species (USFWS 2009). The two small populations are also susceptible to stochastic events that could remove or significantly decrease the population. One instance occurred when a severe storm deposited beach cobble and significantly reduced the Pebble Beach population (USFWS 2009). Comparison of reproductive success as measured by size class distribution among patches suggests that the threat of genetic homozygosity is exacerbated when patches become isolated by grassland conversion and numbers reach fewer than 20 individuals in a patch (S. Bennett personal communication 2015).

Level of confidence in assessment

The condition and trend of the Hickman's cinquefoil summarized in this report have been based primarily on conclusions found in the most recent USFWS 5-year Review (USFWS 2009), the USFWS Recovery Plan for Five Plants from Monterey County, California (USFWS 2004), and personal communication with NPS staff. The USFWS reports are comprehensive reviews of the species and supersede conclusions made in this document. No data on Hickman's cinquefoil were

included in the 2011–2013 Rare Plant Report compiled by GOGA (Chassé and Forrestel 2014). Michael Chassé provided basic information on the GOGA Hickman's cinquefoil occurrence in Rancho Corral de Tierra and Susie Bennett provided more detailed information during final review stages.

Gaps in understanding

At the time of data compilation for this report, spatial and census information about the GOGA population was not provided due to the recent addition of this site into the park and the on-going development of a monitoring protocol. Since that time, a monitoring technique has been developed and will be repeated annually to allow for adaptive management of this species. To assist with species conservation throughout the potentilla's range, managers recommend identifying pollinators at GOGA. Additionally, the relationship between scrub encroachment and patch size should be monitored and mediated if deemed necessary.

As a whole, the Rancho Corral de Tierra population of Hickman's cinquefoil is considered stable by GOGA staff (M. Chassé personal communication 2015). However, this population was not described in the most recent USFWS 5-year Review (2009) or Recovery Plan (2005).

4.6.4. Density and Distribution of Rare Plants in GOGA Lands

Critical Question 4 was addressed by mapping the density of rare plants per hectare within GOGA-managed lands (Figures 4.6.9, 4.6.10 and 4.6.11). This mapping effort includes 54 threatened, endangered, and rare plant species of interest to GOGA management, not just the species of interest discussed above. The maps and associated spatial data will support management decisions regarding known rare plant occurrences.

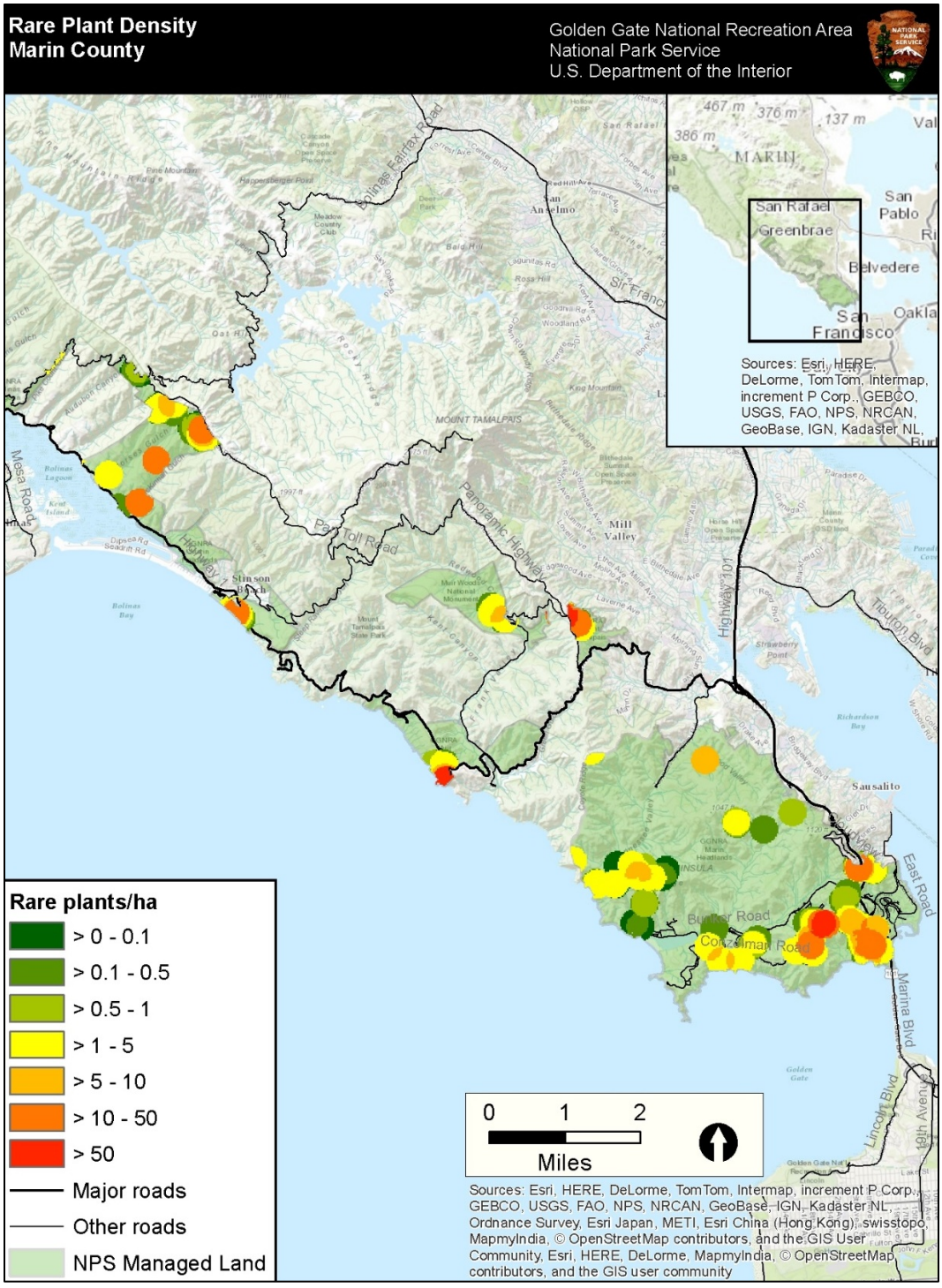


Figure 4.6.9. Density of Rare Plants in Marin County (NPS).

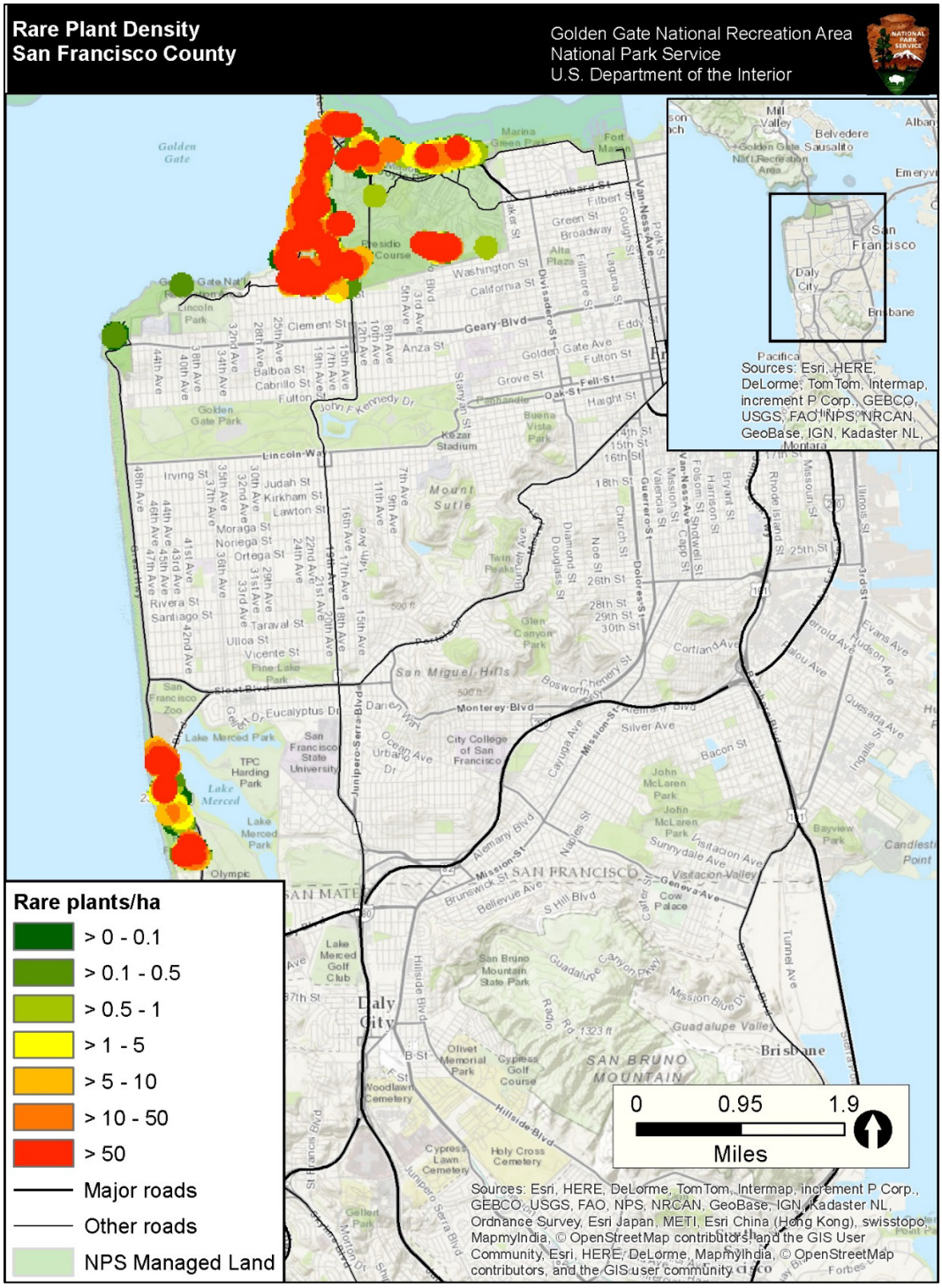


Figure 4.6.10. Density of Rare Plants in San Francisco County (NPS).

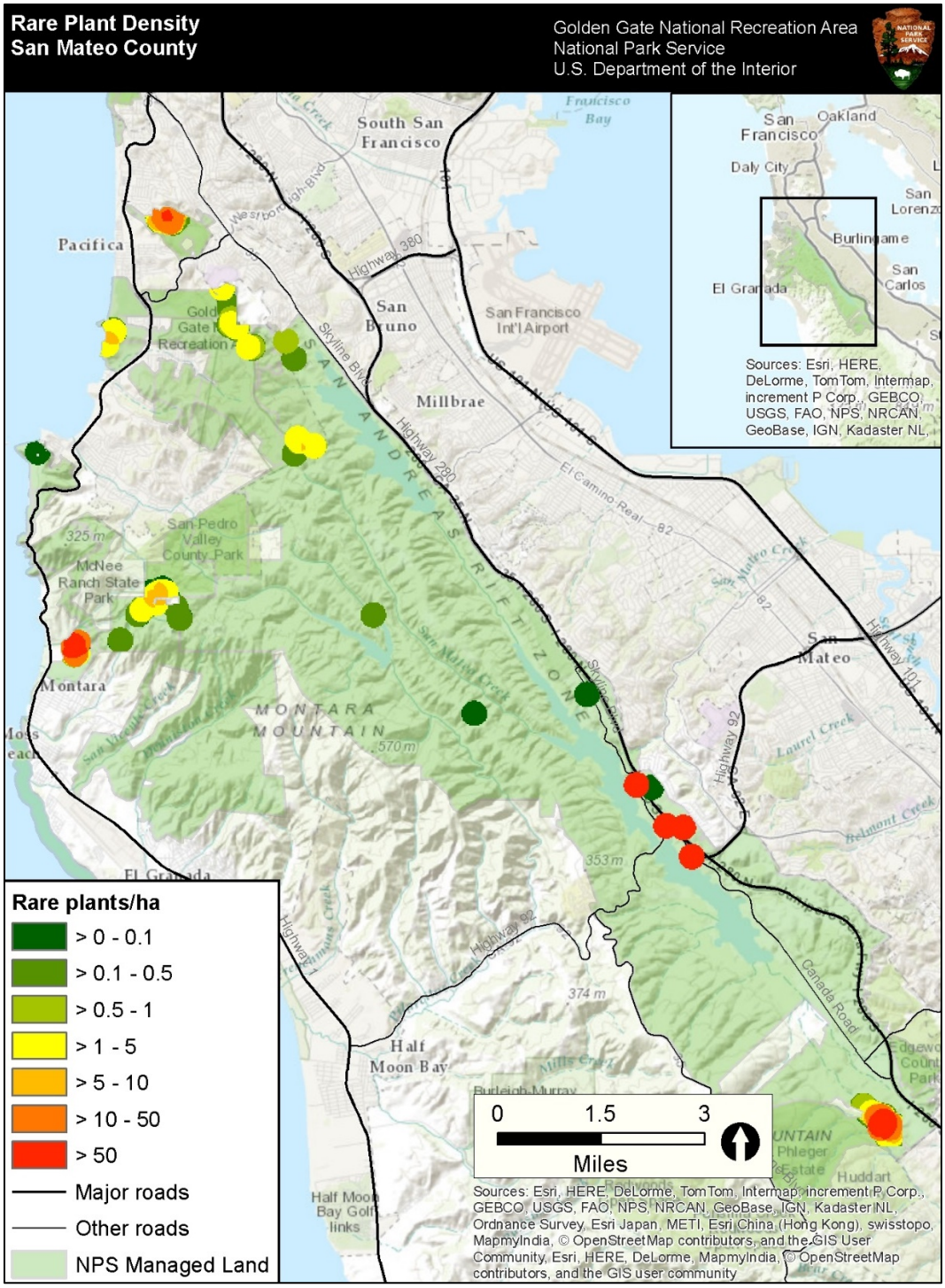


Figure 4.6.11. Density of Rare Plants in San Mateo County (NPS).

4.6.5. Summary of Resource Condition

The Critical Questions posed for rare plant resource at GOGA were the following:

1. What is the current status and distribution of threatened and endangered species of interest within GOGA?
2. What are significant stressors for threatened and endangered species of interest within GOGA?
3. Has climate influenced population trends for Presidio clarkia (Clarkia franciscana), Marin dwarf flax (Hesperolinon congestum), or San Francisco lessingia (Lessingia germanorum)?
4. What areas within GOGA have high numbers of threatened, endangered and rare plant species of interest?

The first three Critical Questions were addressed in Section 4.6.3 for each of the eight species of interest: Franciscan manzanita (*Arctostaphylos franciscana*), Presidio manzanita (*Arctostaphylos montana* ssp. *ravenii*), marsh sandwort (*Arenaria paludicola*), Tiburon paintbrush (*Castilleja affinis* ssp. *neglecta*), Presidio clarkia (*Clarkia franciscana*), Marin dwarf flax (*Hesperolinon congestum*), San Francisco lessingia (*Lessingia germanorum*), and Hickman's cinquefoil (*Potentilla hickmanii*). The condition of eight species was examined through USFWS documentation and NPS monitoring reports. The conditions were also summarized by management unit in order to identify regions where rare plant condition may warrant concern. The condition and confidence in assessment for each of the three indicators are summarized below and in Figure 4.6.12.

In general, the natural populations that had been observed within GOGA lands (excluding historical observations) continued to persist under GOGA management and monitoring. The condition of the natural population of marsh sandwort was not applicable for this analysis because the GOGA population was introduced. Overall, confidence ratings were high for the condition status rates given the consistent annual monitoring conducted by GOGA. The condition of Marin dwarf flax was considered moderately confident because the Nicasio Ridge population was not consistently monitored.

The success of introduction efforts ranged in degrees of successful depending on species and site. Two species, Tiburon paintbrush and Hickman’s cinquefoil, had not had any documented introduction efforts by GOGA. Marin dwarf flax, San Francisco lessingia and Presido clarkia introduction efforts had both successes and failures, warranting moderate concern. Confidence levels ranged from high to low in condition statuses that were assessed. Low and moderate confidence levels occurred where monitoring protocols were unknown or had been modified for some or all populations.

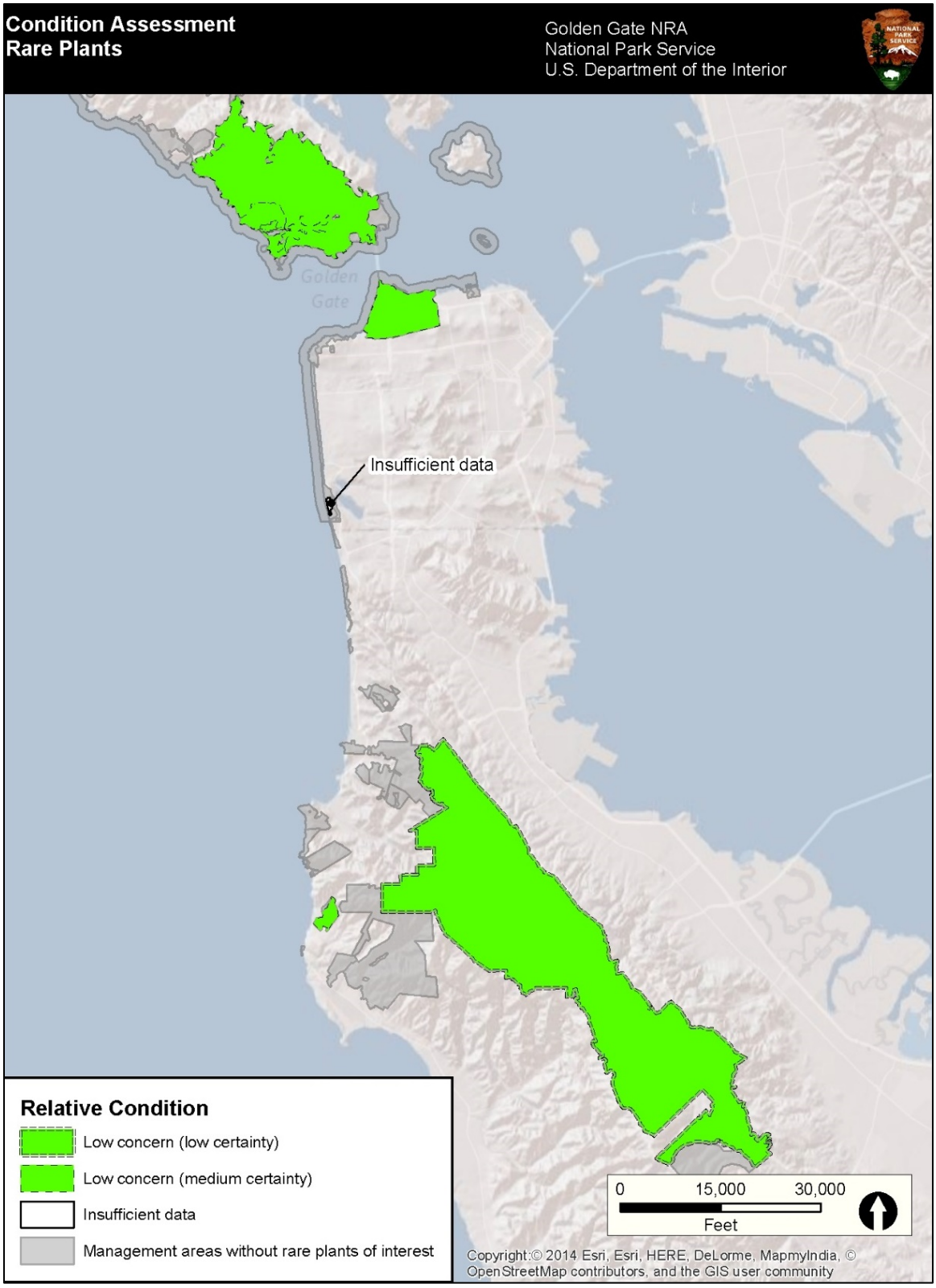


Figure 4.6.12. Condition Summary Map for GOGA (NPS).

Many of the recovery criteria outlined in Recovery Plans for the species of interest were in progress, partially met, or fully met for GOGA-managed populations. Most criteria involved preservation of habitat, management of threats, and introduction of new populations. However, long-term criteria were often not met. Downlisting criteria were not considered in this analysis where the criteria overlapped the recovery criteria. No analysis of recovery criteria was conducted for Franciscan manzanita because no Recovery Plan had been completed for the species.

The overall condition of rare plant populations managed by GOGA is warrants low concern, as calculated by the suggested set of rules for Natural Resource Condition Assessments. The map similarly reflects the overall low concern level and moderate certainty in findings. The Marin dwarf flax occurring in the San Mateo unit is not monitored by GOGA, and thus had low certainty.

This overall score does not include a trend analysis because the population data for the rare plants of interest were not robust enough (Table 4.6.17). Furthermore, the first indicator is limited to assessing populations as extant or potentially extirpated. This does not include any assessment of viable population levels or threshold population levels determined by the USFWS or another entity. Continued monitoring and management of the rare plants within GOGA is most important to sustain populations in a changing climate and with increasing urban population.

Table 4.6.17. Overall Condition summary for Rare Plants.

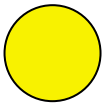
Indicators of Condition	Specific Measures	Condition Status	Rationale
How many of the natural populations observed since GOGA management began are still extant?	Proportion of extant natural populations with > 0 individuals in 2012 and 2013. Populations not monitored will not be counted toward score.		Of the eight species of interest, seven were in good condition. Five conditions had high confidence in the rating and two had moderate confidence. Marsh sandwort only exists as introduced populations in GOGA lands, and was thus omitted from this summary category.
Have introduction efforts been successful?	Proportion of successful introductions into new sites. This does not include natural populations.		Of the eight species of interest, three were in good condition and the condition of three warranted moderate concern. Two condition had high confidence in the rating. Three conditions had moderate confidence, and one had low confidence. Tiburon paintbrush and Hickman's potentilla do not have introduced populations on GOGA lands, and were omitted from this summary category.
Have the USFWS Recovery Plan goals been fulfilled for populations within GOGA lands?	Proportion of interim and long-term goals realized or in progress. Goals carried out by other entities will not be counted toward score.		Of the eight species of interest, four were in good condition, and three warranted moderate concern. Five conditions had moderate confidence in the rating and two had low confidence. Franciscan manzanita did not have a Recovery Plan and was omitted from this summary category.

Table 4.6.17 (continued). Overall Condition summary for Rare Plants.

Indicators of Condition	Specific Measures	Condition Status	Rationale
Overall Condition Status for Rare Plants			**Managed rare plant populations extant; introduction efforts somewhat successful; USFWS Recovery Criteria generally in progress or completed. Data gaps warrant moderate confidence in findings and fail to support trend analysis**

4.6.6. Information Sources

Sources of Expertise

This review incorporates data reported in the most recent USFWS Recovery Plans, USFWS 5-year Reviews, NPS reports submitted to USFWS and data collected by NPS. Selection of indicator conditions and specific measures were chosen in consultation with GOGA staff in order to represent the condition of the designated species of interest.

Literature Cited

Allendorf, F., G. Luikart. 2007. Conservation and the Genetics of Populations. Blackwell Publishing.

Acierto, K., R. Hendricks, M. Bontrager, and I. Parker. 2012. "Transplant Success for the Endangered Herb Arenaria Paludicola at Golden Gate National Recreation Area: Effect of Site, Propagation Type, and Competition; Prepared for the U.S. Fish and Wildlife Service and California Department of Fish and Game." Department of Ecology and Evolutionary Biology, University of California, Santa Cruz. http://www.sfnps.org/download_product/3077/0.

Bontrager, M., K. Webster, M. Elvin and I.M. Parker. 2014. The Effects of Habitat and Competitive/facilitative Interactions on Reintroduction Success of the Endangered Wetland Herb, *Arenaria paludicola*. *Plant Ecology* 215 (4): 467–78. doi:10.1007/s11258-014-0317-z.

Boykin, L.M., M.C. Vasey, and V.T. Parker. 2005. Two Lineages of Arctostaphylos (Ericaceae) identified Using the Internal Transcribed Spacer (ITS) Region of the Nuclear Genome. *Madroño*, no. 52: 139–47.

California Native Plants Society (CNPS), Rare Plant Program. 2015. Inventory of Rare and Endangered Plants (online Edition, v8-02). Sacramento, CA: California Native Plants Society.http://www.rareplants.cnps.org.

Chassé. M. 2015. *Potentilla hickmanii*, February 19.

Chassé, M.R. 2013. San Francisco's Rare Endemic Manzanitas : Prospects for Recovery through Restoration. Thesis, San Francisco State University. http://sfsu-dspace.calstate.edu.

Chassé, M.C., M. Frey, M. Vasey B. Young, and V. T. Parker. 2009.*Conservation Plan for Arctostaphylos Franciscana in the Presidio*.

Chassé, M., and A. Forrestel. 2014. 2011–2013 Monitoring Report for Federally Listed Plants: Within the Golden Gate National Recreation Area. Golden Gate National Recreation Area: National Park Service.

County of Santa Clara, et al. 2010. Draft Santa Clara Valley Habitat Plan. Santa Clara, CA.

Gluesenkamp, D. 2010. "Lessons from the Rediscovery of the Franciscan Manzanita: Loss and Redemption." The Ardeid (Conservation Science and Habitat Protection at Audubon Canyon Ranch). http://egret.org/sites/default/files/publicpdfs/ardeid_2010_0.pdf.

Gottlieb, L.D. and S.W. Edwards. 1992. An Electrophoretic Test Ofthe Genetic Independence of a Newly Discovered Population of *Clarkia franciscana*. Madrono, no. 39: 1–7.

Gambel, J. 2012. Raven's Manzanita (*Arctostaphylos montana* ssp. *Ravenii*) and Franciscan Manzanita (*Arctostaphylos franciscana*): A Study of Their Flowering Periods and the Pollinators They Attract. San Francisco, CA: US Fish and Wildlife Service/ The Presidio Trust.file:

Mazer, SJ. 2000. *Arenaria Paludicola* (marsh Sandwort: Caryophyllaceae) and *Rorippa Gambelii* (Gambel's Watercress: Brassicaceae) in Black Lake Canyon and the Oso Flaco Lake Region. Sacramento: California Department of Fish and Game.

Menges, E.S. 1991. Seed Germination Percentage Increases with Population Size in a Fragmented Prairie Species. Conservation Biology 5: 158–64.

National Oceanic and Atmospheric Administration (NOAA). 2015. Data Tools: Find a Station. National Centers for Environmental Information. http://www.ncdc.noaa.gov/cdo-web/datatools/findstation.

Neiderer, C., S.B. Weiss, and L. Stringer. 2014. Identifying practical, small-scale disturbance to restore habitat for an endangered annual forb. California Fish and Game 100 (1): 61–78.

Parker, T., M. Frey. 2010. Management of *Arctostaphylos montana* Subsp. *ravenii* in the Presidio of San Francisco. Presidio Trust.

Rodriguez-Rojo, M.P., D. Sanchez-Mata, R.G. Gavilan, S. Rivas-Martinez and M.G. Barbour. 2001. Typology and Ecology of Californian Serpentine Annual Grasslands. Journal of Vegetative Science 12 (5): 687–98.

US Fish and Wildlife Service (USFWS). 1998a. Recovery Plan for Marsh Sandwort (*Arenaria paludicolus*) and Gambel's Watercress (*Rorippa gambelii*). Portland, OR: US Fish and Wildlife Service. http://ecos.fws.gov/docs/recovery_plan/980928b.pdf.

US Fish and Wildlife Service (USFWS). 1998b. Recovery Plan for Serpentine Soil Species of the San Francisco Bay Area. Portland, OR: US Fish and Wildlife Service.http://ecos.fws.gov/docs/recovery_plan/980930c_v2.pdf.

US Fish and Wildlife Service (USFWS). 1998c. Recovery Plan for Seven Coastal Plants and the Myrtle's Silverspot Butterfly. Recovery plan. Sacramento, CA: US Fish and Wildlife Service. http://ecos.fws.gov/docs/recovery_plan/980930d.pdf.

US Fish and Wildlife Service (USFWS). 2003. Recovery Plan for Coastal Plants of the Northern San Francisco Peninsula. Portland, OR: US Fish and Wildlife Service. http://ecos.fws.gov/docs/federal_register/fr4187.pdf.

US Fish and Wildlife Service (USFWS). 2004. Recovery Plan for Five Plants from Monterey County, California. Portland, OR: US Fish and Wildlife Service. http://ecos.fws.gov/docs/recovery_plan/050617a.pdf.

US Fish and Wildlife Service (USFWS). 2008. *Arenaria paludicola* (Marsh Sandwort) 5-Year Review: Summary and Evaluation Ventura, CA: US Fish and Wildlife Service. http://ecos.fws.gov/docs/five_year_review/doc1932.pdf.

US Fish and Wildlife Service (USFWS). 2009. *Potentilla hickmanii* (Hickman's potentilla) 5-Year Review: Summary and Evaluation. Ventura, CA: US Fish and Wildlife Service. http://ecos.fws.gov/docs/five_year_review/doc2386.pdf.

US Fish and Wildlife Service (USFWS). 2010. *Clarkia franciscana* (Presidio clarkia) 5-Year Review: Summary and Evaluation. Sacramento, California: Sacramento Fish and Wildlife Office. http://ecos.fws.gov/docs/five_year_review/doc3590.pdf.

US Fish and Wildlife Service (USFWS). 2011. *Hesperolinon congestum* (Marin Dwarf-flax) 5-Year Review: Summary and Evaluation. Sacramento, CA: US Fish and Wildlife Service. http://ecos.fws.gov/docs/five_year_review/doc3961.pdf.

US Fish and Wildlife Service (USFWS). 2012a. *Arctostaphylos montana* ssp. *ravenii* (Presidio Manzanita, 5-Year Review: Summary and Evaluation. Sacramento, CA: US Fish and Wildlife Service. http://ecos.fws.gov/docs/five_year_review/doc4014.pdf.

US Fish and Wildlife Service (USFWS). 2012b. *Castilleja affinis* spp. *neglecta* (Tiburon Paintbrush) 5-Year Review: Summary and Evaluation. Sacramento, CA: US Fish and Wildlife Service. http://ecos.fws.gov/docs/five_year_review/doc4019.pdf.

US Fish and Wildlife Service (USFWS). 2012c. *Lessingia germanorum* (San Francisco lessingia) 5-Year Review: Summary and Evaluation. Sacramento, CA: US Fish and Wildlife Service. http://ecos.fws.gov/docs/five_year_review/doc4017.pdf.

US Fish and Wildlife Service (USFWS). 2013. Recovery Outline for the *Arctostaphylos franciscana* (Franciscan Manzanita). Sacramento, CA: United States Fish and Wildlife Service. http://ecos.fws.gov/docs/recovery_plan/Franciscan%20manzanita_Recovery%20Outline.pdf.

Van Den Berg, J., C. Quock, and J. Hafernik. 2010. Comparative Study of Bee Diversity in Restored Habitats in the Presidio San Francisco. San Francisco: Presidio Trust.

Vanfleet-Brown, J. 2015. Plant Dynamics and Soils Influencing Ecological Restoration of *Potentilla hickmanii* at Rancho Corral de Tierra, San Mateo County, California. Senior Integrative Exercise, Northfield, Minnesota: Carleton College.

Wahlert, G., V.T. Parker, and M.C. Vasey. 2009. A Phylogeny of *Arctostaphylos* (Ericaceae) Inferred from ITS Sequence Data. Journal of the Botanical Research Institute of Texas 3 (2): 673–82. http://ecos.fws.gov/docs/five_year_review/doc4014.pdf.

Waltert, B., V. Wiemken, H. Rusterholz, T. Boller, and B. Baur. 2002. Disturbance of Forest by Trampling: Effects on Mycorrhizal Roots of Seedlings and Mature Trees of Fagus Sylvatica. Plant and Soil, no. 243: 143–54.

Weiss, Stuart B. 1999. Cars, Cows, and Checkerspot Butterflies: Nitrogen Deposition and Management of Nutrient-Poor Grasslands for a Threatened Species. Conservation Biology 13 (6): 1476–86. Doi:10.1046/j.1523-1739.1999.98468.x.

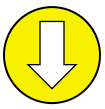
Weiss, S.B. and C. Niederer. 2009. Presidio clarkia (*Clarkia franciscana*) habitat restoration project at Inspiration Point. Final Report. January 2009. Creekside Center for Earth Observation, Menlo Park, California.

Wood, H., V. Moore, M. Culpepper C. Fenter, and J. Hafernik J. Nicolloff. 2005. Bee Diversity in Restored Habitats in the Presidio San Francisco. San Francisco, CA: Presidio Trust.

Wyatt, R. 1986. Ecology and Evolution of Self-Pollination in Arenaria Uniflora (Caryophyllaceae). Journal of Ecology 74 (2): 403–18. Doi: 10.2307/2260264.

4.7. Salmonids/Steelhead

Steelhead in the focal region currently warrant moderate concern and have experienced declines in many streams in the region. Fish passage has been improved for some streams; however, numerous barriers remain. Additionally, other stressors that were not assessed pose a significant threat to populations within (and beyond) the focal region.



Steelhead trout are the anadromous (marine migratory) form of *Oncorhynchus mykiss* (the resident form being 'rainbow trout'). The native range of steelhead trout spans from Baja California to southwestern Alaska along the North American continent and continues along the Aleutian Islands to the Kamchatka Peninsula in eastern Russia (Quinn and Myers 2004). Unlike Pacific salmon, steelhead are iteroparous (characterized by multiple reproductive events over the lifetime of an individual) and may undertake multiple migrations between freshwater breeding grounds and marine feeding grounds across the course of their lives. Steelhead often exhibit considerable life history diversity (Shapovalov and Taft 1954, Quinn and Myers 2004), which likely confers some degree of resilience to variation in freshwater and marine conditions (Moyle et al. 2008). Despite this, steelhead populations at the southern end of their range in California are in decline. In 1998, steelhead populations within the central coast region of California were listed under the United States Endangered Species Act as a federally threatened species (NMFS 2011). In 2006, the National Marine Fisheries Service (NMFS) applied the distinct population segments (DPS) policy rather than the former Evolutionary Significant Unit (ESU) policy (NMFS 2011) to distinguish populations of steelhead that occur in California, Oregon, and Washington. A DPS is defined as a population or a group of populations of vertebrates that is discrete from other populations within the species (NMFS 2011).

This report focuses on steelhead trout found within streams of Point Reyes National Seashore (PORE) and Golden Gate National Recreation Area (GOGA). PORE is located entirely within Marin County, whereas GOGA lands occur within Marin, San Francisco, and San Mateo counties. Steelhead that occur in PORE and GOGA lands are part of the Central California Coast (CCC) DPS, which extends from the Russian River (Sonoma County, CA) to Aptos Creek (Santa Cruz County, CA), and includes the San Francisco Bay drainages. The CCC DPS excludes the Sacramento and San Joaquin drainages; however, some lands within the GOGA boundary extend ¼ mile from shore in the San Francisco Bay and thus are likely used as a migratory corridor by the Central Valley steelhead DPS. As such, management and conservation efforts within GOGA may influence steelhead from the neighboring Central Valley DPS.

Within the CCC region, steelhead typically spend 1–3 years in their natal stream before undergoing smoltification and migrating downstream to the ocean (Shapovalov and Taft 1954). During their stream residency, young-of-year steelhead tend to occupy riffle habitat and grow rapidly while feeding on drifting invertebrates (Shapovalov and Taft 1954). In this region, steelhead smolts spend days to months in estuaries before migrating to the ocean. Adults spend 1–4 years in the ocean

feeding on the abundant food resources before returning to their natal stream to spawn, typically between December and April (Moyle et al. 2008). Spawning usually occurs in streams with fast-moving, cool and clear water, dense canopy cover, and gravel free of fine silt.

4.7.1. Why Focal Resource Was Assessed

Description

Central California Coast DPS steelhead are federally threatened, thus effective management efforts are needed to prevent further declines. The National Park Service (NPS) has identified multiple potential factors leading to the decline of steelhead in the PORE and GOGA regions (NPS 2012b). Specifically, dam and culvert construction in the focal regions have acted as migration barriers to steelhead, influencing spawning migrations and in some cases restricting steelhead to lower sections of watersheds. Furthermore, historic logging has resulted in increased fine sediment delivery, fewer inputs of large woody debris, and decreases in vegetation along riparian areas, all of which can result in poor rearing conditions for steelhead (NPS 2012b). We expect that such declines or local extirpations of CCC steelhead would have ecological consequences. For example, juvenile steelhead are often the top predators in small streams, and can have strong top-down effects on river food webs (Power 1990). Although steelhead are philopatric (i.e., return to their natal sites to breed), a small percentage of individuals stray (i.e., disperse) to streams other than their natal stream, which can result in increased genetic diversity (Shapovalov and Taft 1954). Steelhead populations in California have higher genetic diversity compared to steelhead in northern regions (McCusker et al. 2000). As such, the loss of CCC steelhead would likely lead to the loss of genetic diversity that might be advantageous in nearby northerly regions as physical conditions to the north become more variable with climate change (Katz et al. 2013).

The overall goal of this project was to assess the presence and abundance of steelhead within streams in the PORE and GOGA regions. Such information could be useful to natural resource managers when desiging future steelhead surveys, land management decisions, and restoration efforts. Our report also provides information on potential barriers for steelhead—both natural and unnatural—which can be used for estimating potential steelhead habitat and for prioritizing future barrier removals to expand steelhead habitat.

Critical questions

- What contemporary (defined here as 1993-present) and historical (defined as pre-1993) literature exists on the distribution of steelhead within the PORE and GOGA boundaries?
- What does this information reveal about current steelhead status in PORE and GOGA boundaries, and which regions have been under sampled?
- Under current conditions, where are the potential barriers that limit steelhead distributions—both natural and unnatural barriers—located within PORE and GOGA streams? Unnatural barriers, in particular, have potential population-level consequences by limiting the upstream distribution of steelhead, thereby reducing total habitat available and overall carrying capacity.

4.7.2. How Focal Resource Was Assessed

Measures

We used a combination of steelhead presence/absence and abundance data from contemporary (defined here as 1993-present) and historical literature (pre-1993) to determine the known occurrence of steelhead in streams within the focal region. These data were used to evaluate the current trends in steelhead occurrence and abundance. Additionally, we used data obtained from a literature search and an online database to document the presence of potential barriers to steelhead migration. While we compiled information on both natural barriers (e.g., waterfalls) and unnatural barriers (e.g., culverts, dams), we were especially interested in unnatural barriers because of their potential population-level consequences for steelhead via reductions in overall habitat available and carrying capacity.

Data Sources and Methods

Data sources

We performed an exhaustive search for reports, surveys, published articles, theses, and literature pertaining to the abundance and/or the location of steelhead trout within the PORE and GOGA boundaries. Because GOGA lands were administered in different counties (Marin, San Francisco, and San Mateo), we provide a breakdown of our findings by county.

We used the following online resources to search for information on steelhead occurrence in the focal region: Google, Web of Science, government agency websites (National Park Service, California Department of Fish and Wildlife (CDFW), National Marine Fisheries Service/National Oceanic and Atmospheric Association, Marin Municipal Water District), ProQuest thesis search, California Water Resources Center, and library catalogs of local colleges and universities (UC Berkeley, Stanford, San Jose State, Marin City College, San Francisco State, University of San Francisco, Sonoma State, Humboldt State). For these online sources, we searched the following biological and geographic search terms (in multiple combinations): steelhead, trout, coho, salmonid, fish, *Oncorhynchus*, red-legged frog, salamander, freshwater shrimp, Marin, San Francisco, San Mateo, Golden Gate, Point Reyes, Lagunitas, Olema, Redwood, Pine Gulch, Muir Woods, Bolinas, Tomales, Tennessee Valley, Pilarcitos, San Pedro, and Arroyo Leon. We included non-steelhead taxa in our search terms in an attempt to identify those instances where observations on steelhead were reported in surveys that focused on other taxa.

We also downloaded numerous reports from the KRIS Web website, an online resource for salmonid literature in the region (http://www.krisweb.com/biblio/biblio_wms_online.htm). Additionally, we contacted resource agencies (e.g., NPS, CDFW, Marin Resource Conservation District), non-profit groups (e.g., SPAWN), and consulting firms that had performed surveys or studies in the region to obtain reports or leads on other sources. We also used the California Academy of Science specimen database to obtain additional date and site location information of steelhead trout. Finally, we met with current NPS biologists (Darren Fong and Michael Reichmuth) to incorporate their personal knowledge of locations where steelhead occur that were not already identified through our searches.

Steelhead occurrence – data collection and methods

From each data source, we extracted information on the authors and/or agencies that prepared the reports, the date of publication, date of field surveys, geographic location (see below), estimates of fish abundance or density, and evidence that indicated the presence or absence of steelhead within the creek. If fish age was not reported, we assigned fish ≥ 100mm as age-1+ and fish < 100mm as age-0. While extracting information from the reports, we attempted to include as much detail as possible, so this resulted in a majority of the reports having multiple entries within our spreadsheet. For example, if surveys took place at different locations within the same watershed, we included an entry for each location, or if surveys within a report occurred on different sampling dates, we included an entry for each date. Additionally, if there were multiple age classes reported, we included an entry for each age class encountered during that survey.

We divided the literature into two groups: reports that documented historic surveys (pre-1993) and reports that documented contemporary surveys (1993-present). For purposes of this report, we consider the contemporary period as beginning in 1993, which corresponds with the start of annual surveys conducted by the NPS. Both contemporary and historic data sources included reports by local, state, and federal agencies (Marin Municipal Water District (MMWD), CDFW, and NPS), reports by consulting firms (e.g., Stillwater Science, D.W. Kelley and Associates, Philip Williams and Associates), and reports or theses published by universities in Northern California (e.g., San Francisco State, San Jose State, University of San Francisco, and UC Berkeley). Please note that because the annual NPS reports focus on large watersheds where steelhead occurrence is well-documented, we did not include those data in our analysis. The annual reports documenting these NPS surveys can be found here: http://www.sfnps.org/coho/reports.

Using the location information we collected, we georeferenced the survey locations, which allowed us to create maps to highlight steelhead locations within PORE and GOGA boundaries. Most sources did not include precise location coordinates; however, in most cases we were able to georeference site locations using site descriptions (e.g., distance from known landmark). In some cases, information on steelhead occurrence was provided for discrete sample sites, and thus we assigned known point locations for these surveys. In other cases, information was provided on upstream and downstream points to indicate stream reaches where steelhead were found. For these data, we delineated stream lines to represent steelhead presence in the focal reach. We also encountered reports that did not provide any location information beyond the name of the stream. For these data, we marked the mouth of the stream as the site's "location." Finally, we denoted sample sites where sources noted the *absence* of steelhead during stream surveys.

We report a broad summary of the steelhead data that we compiled in Appendix 4.7.1 along with watershed/creek characteristics. We also provide a more detailed account of each survey location and corresponding fish data in Appendix 4.7.2. Reports that provide information on a single point can be found on the "Known point location" worksheet, reports that provide upstream and downstream location information can be found on the "Reach location" worksheet, reports that only provide the name of the stream can be found on the "Unknown point location" worksheet. Finally, reports that

noted that no fish were present during a survey can be found on the "No fish point location" worksheet.

For each entry we included information pertaining to spatial location including: watershed, creek, creek number (which corresponds to the map labels), location notes, certainty of accuracy of location (0= no information provided on within stream location, 1 = uncertain, 2 = fairly certain, 3 = certain), and GPS coordinates (see Appendix 4.7.2 for detailed description of extracted information).

Barriers – data collection and methods

To estimate the location of potential anthropogenic and natural barriers restricting the upstream distribution of steelhead trout, we compiled information on putative barriers highlighted in the literature described above (see Appendix 4.7.3 for description of barrier classification). For example, if a report indicated the presence of a barrier, we included it in Appendix 4.7.3 on the "Barriers report" worksheet. However, it is important to note that we often could not make a judgment on barrier passability from these sources. We also included existing barrier information from the regularly updated California Fish Passage Assessment Database (CFPAD; obtained October 2014; http://www.calfish.org/), which includes current information on possible fish barriers such as road crossings, dams, and log jams.

We created two GIS layers with potential barriers—one layer consisting of information obtained from our literature search (GIS layer "Barriers reports") and a second layer consisting of information from CFPAD (GIS layer "Barriers. CFPAD"). Barriers that were identified through our literature search were classified as natural/permanent, natural/temporary, culverts, or dams. Barriers identified in the CFPAD were classified as dams, fish passage facilities, log jams, non-structural, road crossings, and unknown types. Additionally, CFPAD classified the degree of passability of each barrier, including natural total barriers, artificial total barriers, partial barriers, remediated barriers that have not been examined to determine passability, and barriers where passability is unknown. CFPAD barrier data can be found in Appendix 4.7.3 on the worksheet entitled "CFPAD barrier."

Products

The main products of this report include seven different components, including three appendices, maps, and GIS shapefiles. Appendix 4.7.1, found at the end of this document (starting on page 26), provides a detailed description of each stream where steelhead were documented together with associated survey notes as well as a list of streams within the focal region for which we were unable to find data pertaining to steelhead occurrence. Appendix 4.7.2 is a detailed spreadsheet that includes all of the information we extracted on fish surveys and the authors and titles of the associated source of information. Appendix 4.7.3 is a detailed spreadsheet that includes information we extracted on barriers to steelhead from information sources and CFPAD. Also included are eight non-interactive maps within this document that show the location of fish surveys in Marin (Figures 4.7.1 and 4.7.2) and San Mateo counties (Figure 4.7.3 and 4.7.4) and maps that show the location of barriers in Marin (Figures 4.7.5 and 4.7.6) and San Mateo (Figure 4.7.7 and 4.7.8) counties.

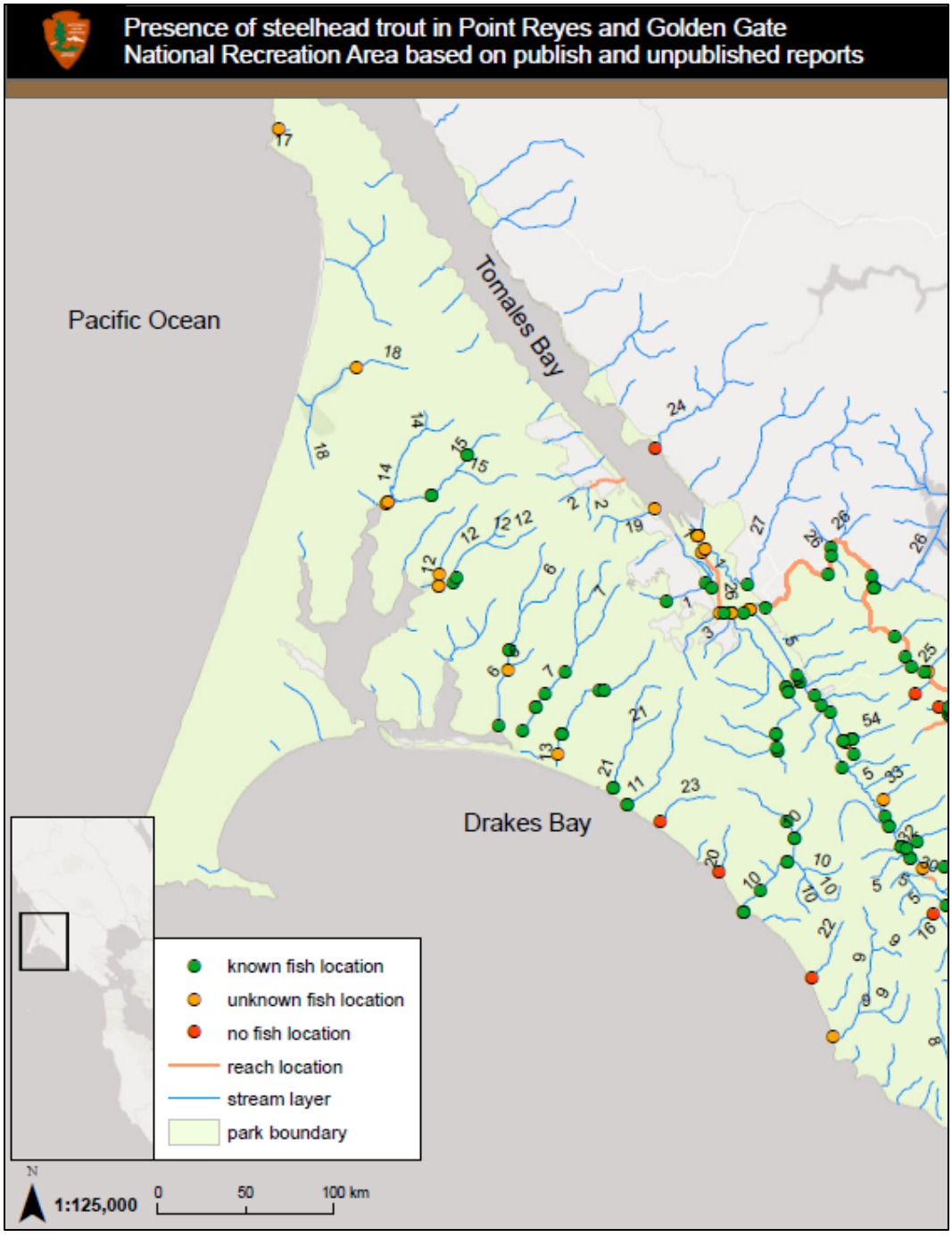


Figure 4.7.1. Map showing location of steelhead survey data for sites in northern Marin County. “Known fish location” represents survey data taken at a specified site within a stream. “Unknown fish location” represents survey data from a specific stream, but where no finer-scale information was provided on steelhead locations within the stream. For this subset of data, we situated the points at the mouth of the focal creek. “No fish location” points represent locations on a stream where surveying occurred, but where steelhead were not observed. When data on steelhead occurrence were collected across a specified reach of stream (as opposed to a single site), we noted this as a “reach location” (see Appendix 4.7.1).

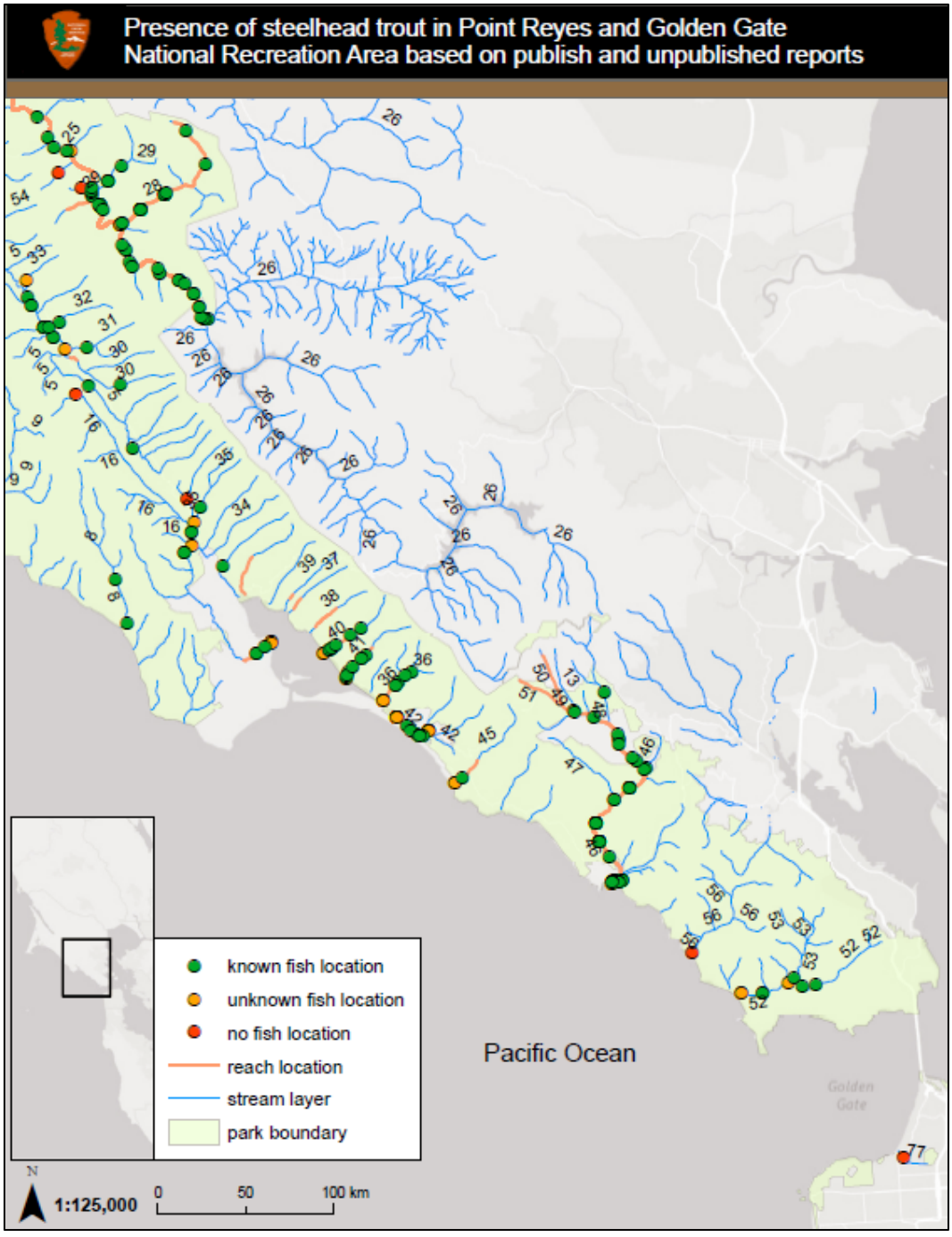


Figure 4.7.2. Map showing location of steelhead survey data for sites in southern Marin County. “Known fish location” represents survey data taken at a specified site within a stream. “Unknown fish location” represents survey data from a specific stream, but where no finer-scale information was provided on steelhead locations within the stream. For this subset of data, we situated the points at the mouth of the focal creek. “No fish location” points represent locations on a stream where surveying occurred, but where steelhead were not observed. When data on steelhead occurrence were collected across a specified reach of stream (as opposed to a single site), we noted this as a “reach location” (see Appendix 4.7.1).

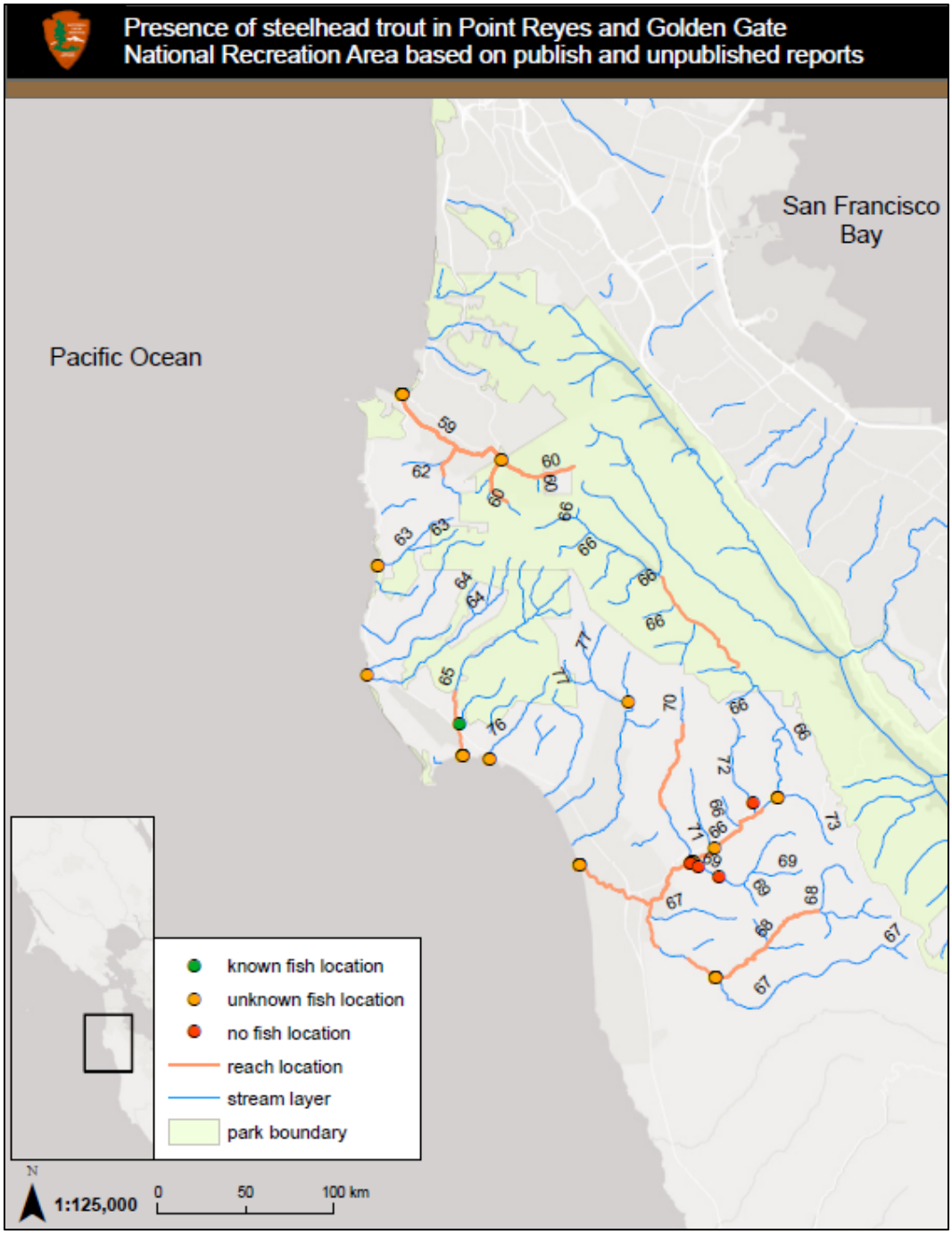


Figure 4.7.3. Map showing location of steelhead survey data for sites in northern San Mateo County. "Known fish location" represents survey data taken at a specified site within a stream. "Unknown fish location" represents survey data from a specific stream, but where no finer-scale information was provided on steelhead locations within the stream. For this subset of data, we situated the points at the mouth of the focal creek. "No fish location" points represent locations on a stream where surveying occurred, but where steelhead were not observed. When data on steelhead occurrence were collected across a specified reach of stream (as opposed to a single site), we noted this as a "reach location" (see Appendix 4.7.1).

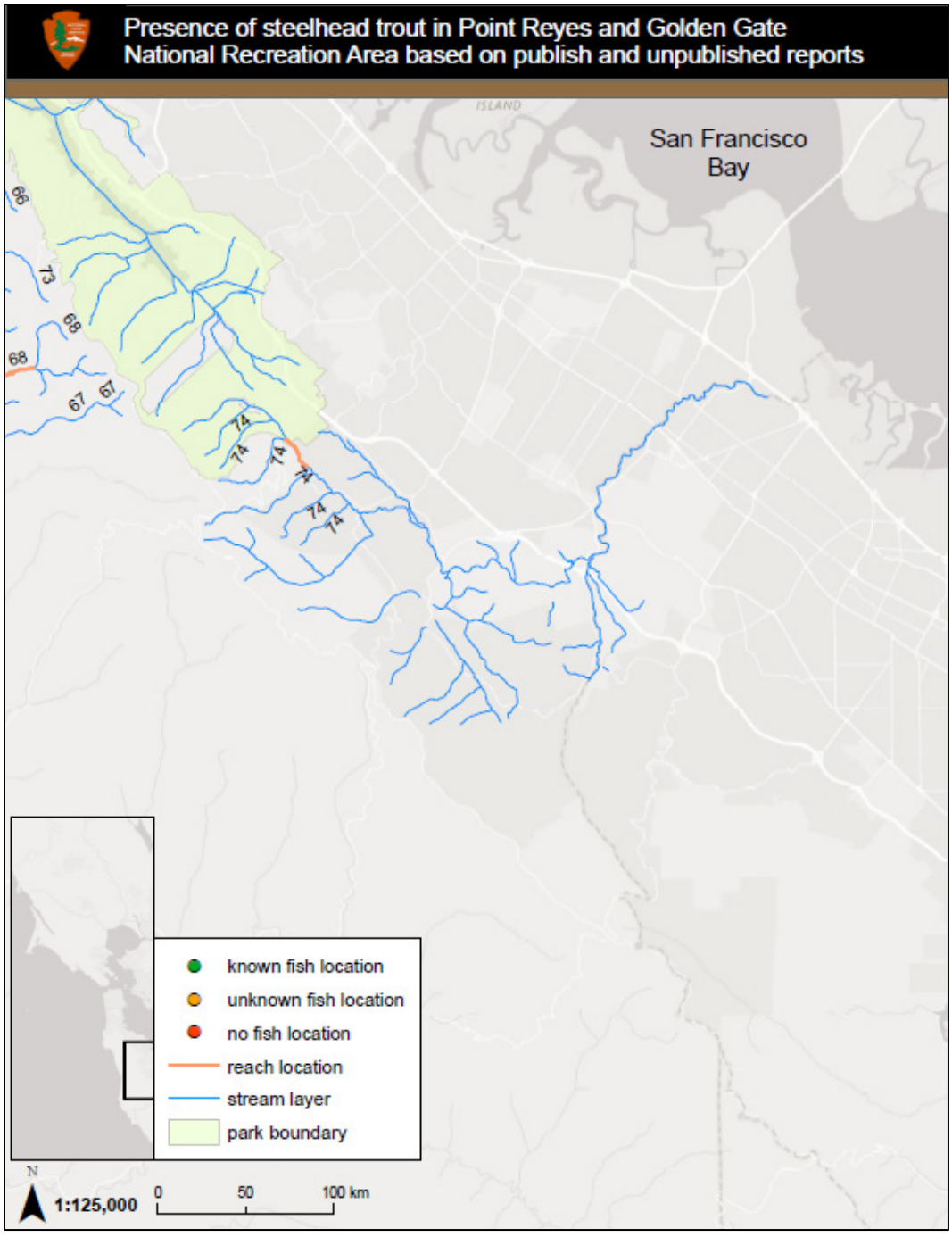


Figure 4.7.4. Map showing location of steelhead survey data for sites in southern San Mateo County. "Known fish location" represents survey data taken at a specified site within a stream. "Unknown fish location" represents survey data from a specific stream, but where no finer-scale information was provided on steelhead locations within the stream. For this subset of data, we situated the points at the mouth of the focal creek. "No fish location" points represent locations on a stream where surveying occurred, but where steelhead were not observed. When data on steelhead occurrence were collected across a specified reach of stream (as opposed to a single site), we noted this as a "reach location" (See Appendix 4.7.1).

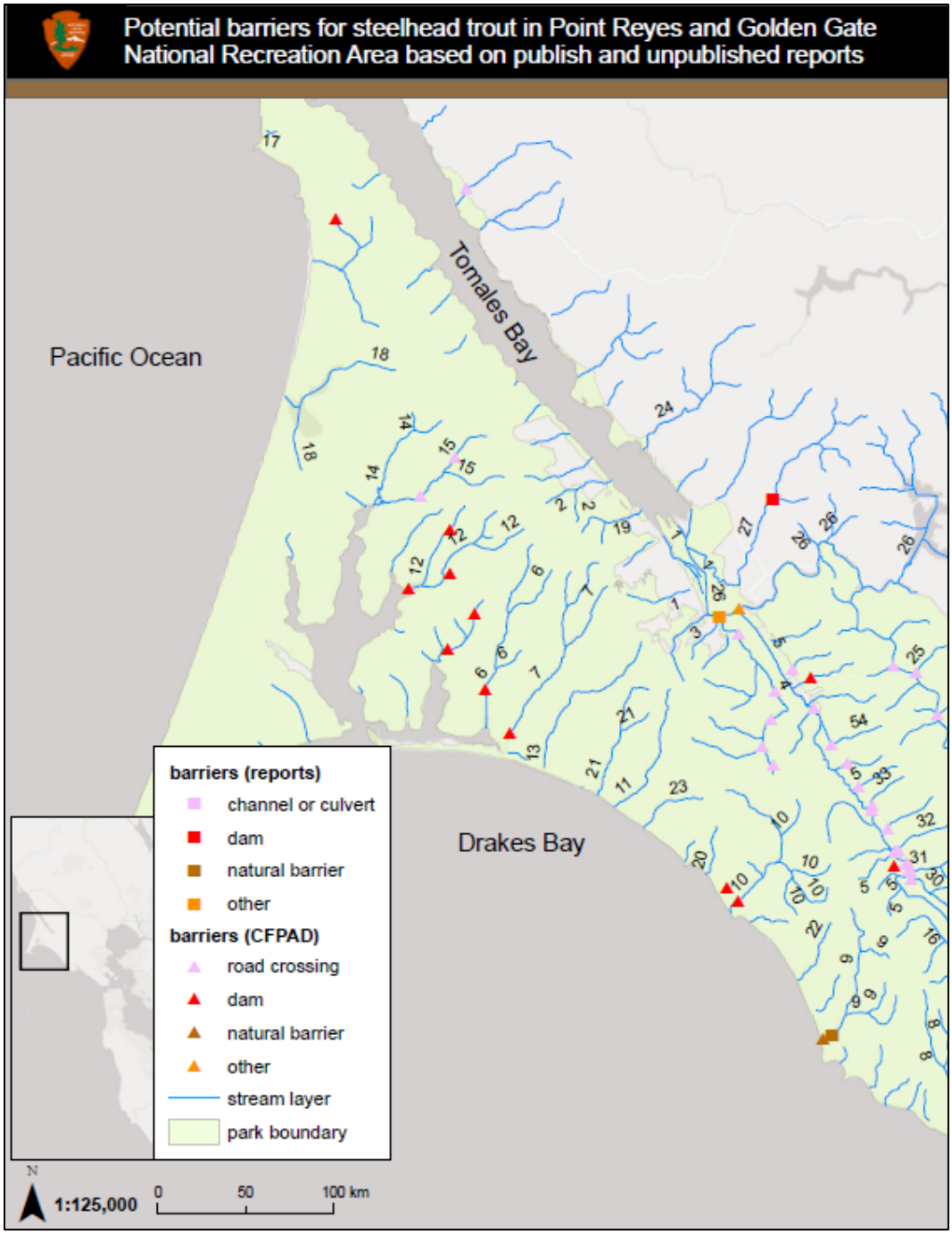


Figure 4.7.5. Map showing barrier data for sites in northern Marin County. Squares represent barrier data obtained through a literature search and via personal communications. Triangles represent data collected from the California Fish Passage Assessment Database (CFPAD). Colors represent different barrier types.

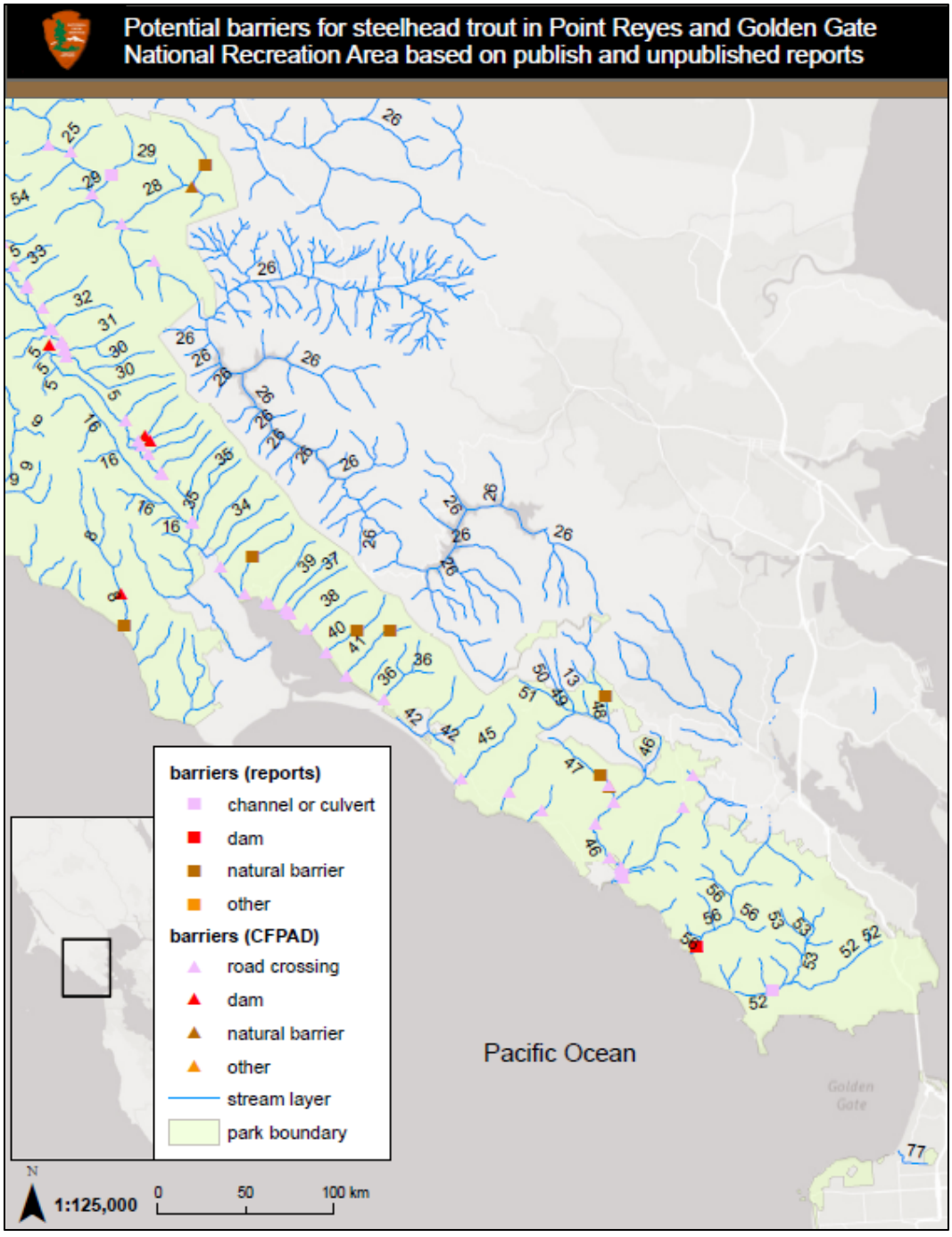


Figure 4.7.6. Map showing barrier data for sites in the southernmost region of Marin County. Squares represent barrier data obtained through a literature search and via personal communications. Triangles represent data collected from the California Fish Passage Assessment Database (CFPAD). Colors represent different barrier types.

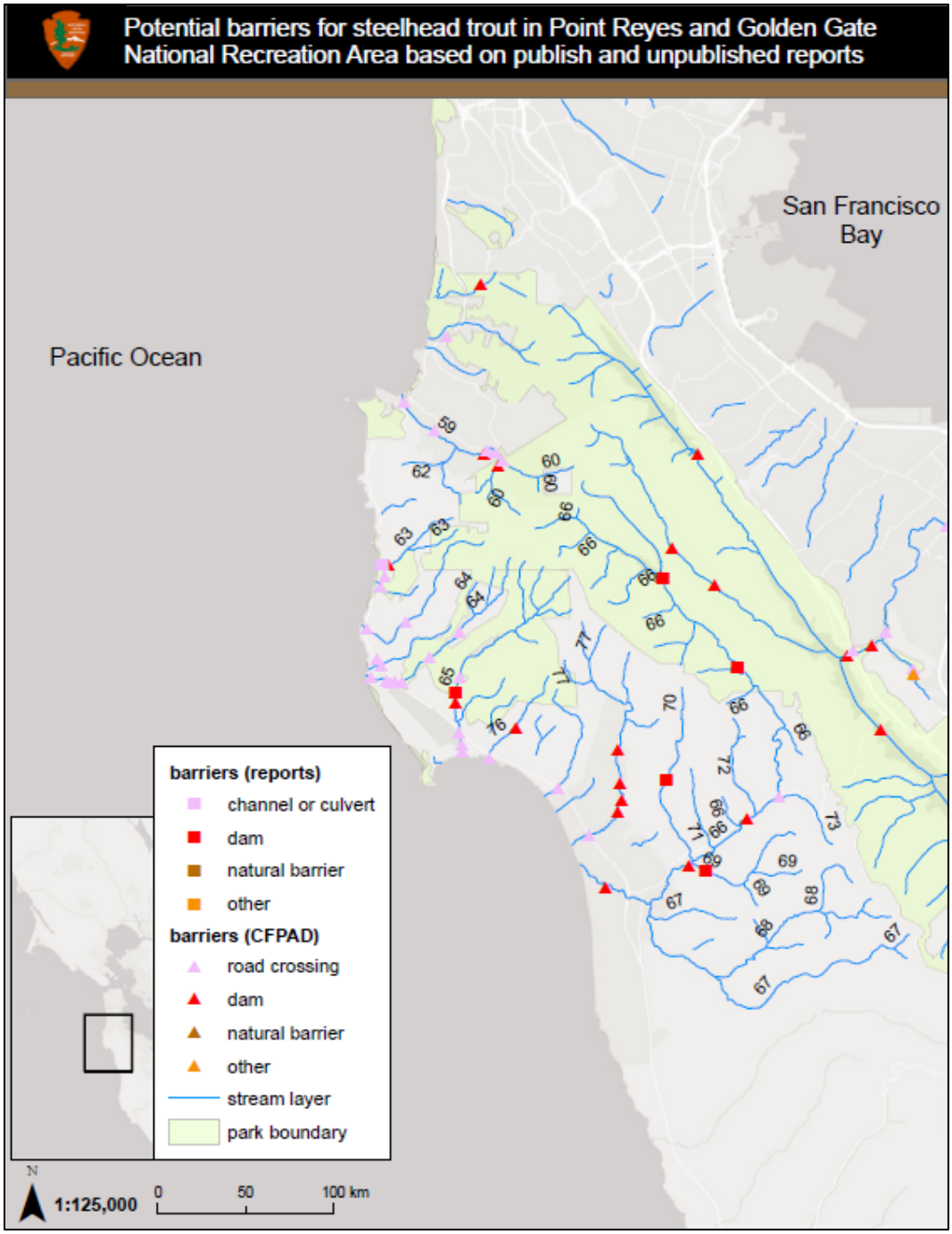


Figure 4.7.7. Map showing barrier data for sites in the northernmost region of San Mateo County. Squares represent barrier data obtained through a literature search and via personal communications. Triangles represent data collected from the California Fish Passage Assessment Database (CFPAD). Colors represent different barrier types.

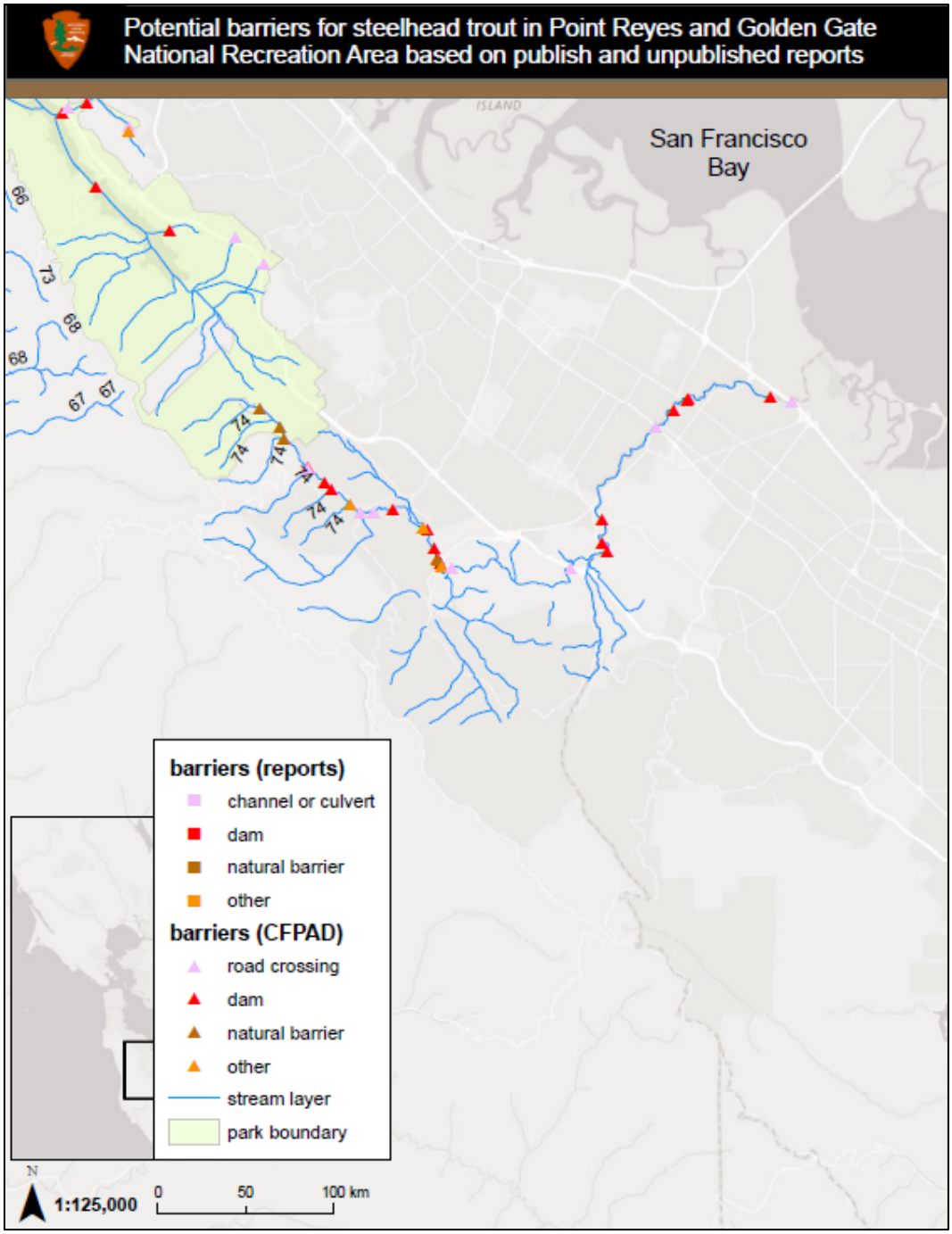


Figure 4.7.8. Map showing barrier data for sites in the southernmost region of San Mateo County. Squares represent barrier data obtained through a literature search and via personal communications. Triangles represent data collected from the California Fish Passage Assessment Database (CFPAD). Colors represent different barrier types.

Additionally, we created seven GIS shapefiles for stream, fish, and barrier data that can be used for further analysis and can be obtained from NPS. The final product consists of a folder containing electronic versions of all of the reports used in this analysis, which can also be obtained from NPS.

We also provide a reference list for all of the information presented in this report (see Literature Cited).

Reference Conditions/Values

For this report, we were unable to obtain sufficient data on reference conditions for many streams within the focal region. For some streams, we were able to document reference conditions using information obtained from interviews of local residents by NPS staff or the historical literature (e.g., newspaper articles, reports from government agencies or consulting firms). These sources indicate that steelhead historically occurred in many of the streams within the focal region and in large abundances.

4.7.3. Condition Assessment

Condition and Trend

Summary of data sources

In total, we found 281 sources of information (reports, articles, and personal communications) pertaining to steelhead in the PORE and GOGA regions. Only 103 of these documented the occurrence and or provided abundance/density estimates of steelhead and provided at least coarse-level geographic information (i.e., watershed-level). Because many sources reported data from multiple sites, survey dates, and age classes, these 103 sources resulted in 634 entries (i.e., rows) in our table that documented the presence or absence of steelhead within GOGA and PORE streams (see Appendix 4.7.2). In addition to the sources that we were able to locate, we identified an additional 31 sources that seemed likely to include relevant information, but which we were unable to access. The information detailed below provides a summary of our findings. Detailed information on individual streams, including information on survey dates and findings of steelhead occurrence can be found in Appendix 4.7.1.

Steelhead occurrence in PORE and GOGA streams

In total, we determined that there were approximately 140 streams in PORE and GOGA administered lands in Marin County (large streams and their major tributaries and smaller streams that were not part of a larger watershed). We were able to find steelhead occurrence information on 60 of these streams (Figures 4.7.1 and 4.7.2). In San Mateo County, we estimated that there were approximately 13 streams, and we were able to find information on 12 of these (Figure 4.7.3 and 4.7.4). Much of the GOGA land in San Mateo County are located in the upper watersheds of coastal streams. The lower sections of these streams are not located within GOGA boundaries, however we included steelhead data in our analysis from the downstream regions as they might imply steelhead presence in the upper portions of these watersheds. These streams included Arroyo Leon, Mills Creek, Madonna Creek, Apanolio Creek, Corinda Los Trancos, and Nuff Creek. For San Francisco County, we determined that Lobos Creek was the only creek in GOGA-administered lands. The addition of these creeks increased the number of San Mateo County streams we were able to locate information on from 12 to 18.

Of the 60 creeks we were able to obtain information on in Marin County, 50 were reported as having steelhead present at the time they were surveyed, whereas steelhead were absent during surveys for

the remaining ten. Of the 18 creeks for which we found information on steelhead occurrence in San Mateo County, 16 were reported as having steelhead present and two were documented as having no steelhead present. The lone creek in San Francisco that flows through GOGA land, Lobos Creek, was noted as not having steelhead present.

Breakdown of reports by county

Of the 103 total sources reporting on steelhead occurrence, 93 of these included information on Marin County streams, 9 of these contained information pertaining to San Mateo County streams, and one report contained information on Lobos Creek in San Francisco County. Most of the reports in Marin County were focused on the large streams of the region. Forty-three percent were focused on Lagunitas Creek, 24% were from Redwood Creek, and 11% were from Pine Gulch. In San Mateo County, six of the nine reports included information on the San Pedro Creek Watershed, four included information on the Pilarcitos Creek Watershed, three included information on the Denniston Creek Watershed, and two contained information on the Martini Creek Watershed.

Of our 634 individual entries (i.e., individual rows within the spreadsheet in Appendix 4.7.2) documenting steelhead occurrence, 530 were entries for Marin County streams, 103 were for San Mateo County streams, and one of these was for a San Francisco County stream. Of the 530 entries for Marin County streams, 149 only provided the name of the creek that was surveyed and did not provide detailed location information. In San Mateo County, 52 of 103 entries did not provide detailed location information. We located one report for San Francisco County and this report included detailed information on survey locations.

Stressors

Of the various potential stressors influencing steelhead in the focal regions, NPS biologists were interested to learn more about the influence of barriers in limiting the upstream distribution of steelhead within PORE and GOGA watersheds. Culvert construction on many of the streams throughout the focal regions has posed a significant threat to populations of anadromous salmonids. Many of these act as migration barriers (temporal, partial, or complete barriers) to migratory fishes and can limit access to upstream reaches (Ross Taylor and Associates 2003), thereby reducing breeding and rearing habitat and generally lowering carrying capacity. To improve accessibility to historic steelhead habitat, several restoration projects have been implemented to improve fish passage through culverts (NPS 2004b).

Data extracted from our literature search provided information on 22 barriers (15 in Marin County and 7 in San Mateo County). Of the 15 barriers in Marin County, nine were identified as natural/permanent barriers, one was a natural/temporary barrier, two were culverts, and three were other structural barriers (e.g., dams). Of the seven barriers in San Mateo County, one was identified as a natural/permanent barrier, one was a culvert, and one was a dam.

In total, we identified 122 potential barriers within the focal regions using information from CFPAD (95 in Marin County and 27 in San Mateo County). Of the 95 potential barriers in Marin County (Figures 4.7.5 and 4.7.6), 73 of these were structures associated with road crossings, 17 were dams, two were non-structural barriers, two were fish passage facilities, and one was a log jam. In terms of

passability, ten of them were manmade total barriers , 13 were partial barriers, five were remediated barriers although the fish response has yet to be assessed at the time we were writing this report, 59 had an unknown passage status, and eight of these were not likely to be barriers.

For the 27 CFPAD barriers in San Mateo County (Figure 4.7.7), 11 were classified as dams, one was a log jam, two were non-structural, 12 were road crossings, and one was an unknown barrier. In terms of passability, one was a natural total barrier, seven were manmade total barriers, four were partial barriers, one was a remediated barrier although the fish response has not yet been assessed, 13 of these had an unknown passage status, and one of these was not likely to be a barrier. In Marin County, we observed many road crossings in the lower reaches of many Olema tributaries that might not completely restrict movement, but could limit movement during certain conditions. In San Mateo County, most of the potential barriers within the focal region were dams that were located in upper portions of watersheds; however, we encountered an additional 90 potential barriers that were in downstream portions of watersheds that were outside of the focal region. We included these in our barrier map for San Mateo County streams (Figure 4.7.8) because their downstream location could potentially restrict access by migratory fish to upstream sites located within GOGA boundaries.

In recent years, there have been efforts within PORE and GOGA to restore stream habitat and improve fish passage. For example, in the Drakes Estero Watershed in Marin County, improvements to road crossings have allowed for better access by migratory fish to upstream sections of several streams (NPS 2004b). Additionally, fish passage has been further improved by the removal of several dams (e.g., Glenbrook dam, Muddy Hollow Dam, and Limantour Beach Pond Dam) since the mid-2000s (NPS 2009a, NPS 2009b).

Based on previous studies, another important factor limiting the success of steelhead in PORE and GOGA lands is a lack of suitable habitat in accessible portions of watersheds. For example, a limiting factors analysis conducted by Stillwater Science determined that a lack of complex habitat during the winter months limits steelhead populations in the Lagunitas watershed (Stillwater Science 2008). Their analysis concluded that high flows during winter storm events resulted in high mortality of juvenile steelhead. As such, they proposed that steelhead populations would benefit from increasing the complexity of instream habitat via the addition of woody debris.

Level of confidence in assessment

Field sampling efforts in the PORE and GOGA region were not consistent in terms of effort or frequency across all watersheds. Moreover, the level of detail on steelhead locations and abundance varied considerably among the different sources of information. Additionally, it is worth highlighting that some surveys made by CDFW staff only occurred in an exceptional drought year (1976) when steelhead abundances would likely have been lower than normal. Consequently, it is difficult to draw conclusions regarding temporal trends in steelhead presence and abundance from the data we have amassed.

With these limitations in mind, however, we do note that many of the historical documents indicate that steelhead abundance was much higher in the past. Moreover, several of the historical documents include references to declines, absences, and impediments to steelhead migration or survival. Based

largely on newspaper articles dating back to 1865, we believe that steelhead populations in the study regions have declined considerably over the past century and a half. For example, a now defunct local newspaper, The Marin County Journal, published several articles noting that the Lagunitas Creek Watershed was very productive and attracted sport fishermen in the late 1800s (Van Kirk 2000). Newspaper articles from the early 1900s also report the planting of hundreds of thousands of hatchery-produced trout fry in several creeks in Marin (Van Kirk 2000).

Interviews of local residents by CDFW and NPS staff have also highlighted the decline of steelhead in some of the creeks in our study region. For example, an interviewee noted that McKinnan Gulch and Stinson Gulch, both of which drain into the southern end of Bolinas Lagoon, had large numbers of steelhead in the mid-1950s (NPS 2002b). Surveys that estimated the density of Stinson Gulch around the time of the interview (1997), estimated that the density of age-0+ steelhead in the creek was 1.2 fish per meter and age-1+ fish was 0.2 fish per meter. Although densities were not reported for the mid-1950s, the report implied that populations within the creek have declined in recent decades. A similar account by a local fisherman indicated that a sizable number of steelhead were present in Easkoot Creek (near Stinson Beach) through the 1970s (NPS 2002b). More generally, the high abundances of steelhead that were observed historically within the focal region have not been documented in recent times, providing another line of evidence that this organism has declined across the last century and a half.

Gaps in understanding

The majority of sources that we identified were focused on large watersheds that were surveyed on multiple occasions. For example, the information pertaining to the Lagunitas Creek Watershed comprised almost half of all sources in Marin County. The more consistent and thorough monitoring efforts of steelhead by NPS staff of large watersheds in recent years undoubtedly provides great information on long-term trends for these large watersheds; however, we found that information on smaller watersheds is generally lacking. For example, we were unable to locate any information on 80 of the streams in Marin County (57% of streams in PORE and GOGA lands within Marin). Interestingly, of the small watersheds that have been surveyed, most of these surveys occurred prior to 1993, suggesting a shift in emphasis to the larger systems in recent years. Moreover, some large regions were undersampled. For example, we found very little information on the small watersheds that drained into the Pacific Ocean on the western side of PORE. To help guide future monitoring efforts by highlighting gaps in survey data, we included a list of streams that lack information on steelhead occurrence at the end of Appendix 4.7.1.

Another gap in understanding relates to precise location data. Although we were able to determine detailed location data for many entries in our database (371 in Marin County and 48 in San Mateo County, see Appendix 4.7.2), there were a surprisingly large number of sources that failed to report detailed location data (149 in Marin County and 52 in San Mateo County). Detailed location information is important in helping to understand the geographic distribution of steelhead within a watershed as well as the influence of any potential migration barriers in the system. For these reasons, we encourage future investigators to provide detailed site description and location data (including GPS coordinates) with their survey results.

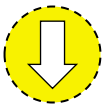
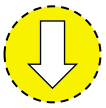
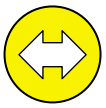
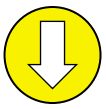
For future research, we also recommend that sampling efforts be expanded to include small watersheds, at least occasionally. While occasional surveys provide only a "snapshot" of steelhead occurrence and abundance, they may be particularly important for documenting the effects of large scale disturbances, such as the current multi-year drought that California is experiencing. For example, we encountered a report for Millerton Gulch that documented the surveying of the creek in 1976, an exceptionally dry year, and the authors of the report noted that "the stream has a past history of steelhead runs during wet winters" (CDFW 1976b). Unfortunately, this stream has not been surveyed since that time, leaving it unclear whether steelhead have recovered at this site. In light of the current multi-year drought in California (2012-present) and potential extinction risk of salmonids in California with increased aridity (Katz et al. 2013), expanded sampling to document steelhead presence, including after the drought breaks, will be important for understanding the trajectory of steelhead in PORE and GOGA lands.

We also recommend that a more in-depth analysis be performed on potential barriers limiting steelhead movement. While we are confident that most of the man-made structures were included in the CFPAD, there were likely many natural elevational barriers that were not documented. We suggest that efforts be made to locate areas where elevational jumps (knick-points) along creek corridors would exceed the jumping capabilities of adult steelhead. This could be done using high resolution remote sensing imagery (e.g., LiDAR) and GIS software. Understanding these natural barriers will undoubtedly help resource managers understand and map potential steelhead habitat and focus their conservation efforts on regions accessible to steelhead.

Condition summary

Annual reports by NPS (beginning in 1993) have not shown any clear trends in population size of steelhead through time over the last ~ 20 years. This is likely due to the strong interannual variability in climate conditions characteristic of California's Mediterranean-type climate, resulting in better survival conditions for steelhead in some years compared to others (NPS 2012b) and the relatively short time frame (20 years represents ~5 steelhead generations). From anecdotal evidence based on interviews with local residents as well as the distribution and abundance data that we compiled as part of this effort, it appears as though steelhead populations have declined in some streams within the focal regions across the last century. Moreover, the presence of numerous unnatural barriers within PORE and GOGA boundaries likely have population-level consequences by limiting the upper extent of steelhead in some streams, thereby reducing available habitat and carrying capacity. Based on these different lines of evidence, our opinion is that steelhead populations are widespread throughout the focal region, but at reduced abundances compared to the past, making these populations vulnerable to large-scale disturbance events, such as multi-year drought (Table 4.7.1).

Table 4.7.1. Condition summary for Steelhead Salmon.

Indicators of Condition	Specific Measures	Condition Status	Rationale
Population size and distribution	Abundance data		Steelhead populations are widespread throughout the focal region, but at reduced abundances; making these populations vulnerable to large-scale disturbance events
	Presence/Absence data		Steelhead populations are widespread throughout the focal region, but at reduced abundances; making these populations vulnerable to large-scale disturbance events
Migration barriers	Number of invasive species		Improved fish passage in some streams; many barriers remain
Overall Condition Status and Trend for Steelhead			**Steelhead in the focal region currently warrant moderate concern and have experienced declines in many streams in the region. Fish passage has been improved for some streams; however, numerous barriers remain. Additionally, other stressors that were not assessed pose a significant threat to populations within (and beyond) the focal region**

4.7.4. Information Sources

Sources of expertise

Field surveys conducted by NPS, consulting firms, and university researchers provided the bulk of the information on current distributional information and population estimates of steelhead in the study regions. NPS biologists, Darren Fong and Michael Reichmuth, also provided additional information on steelhead populations in several watersheds based on their own experiences at these sites. Older sources of information allowed us to compare steelhead distributions through time. These sources included reports from CDFW, consulting firms, and articles from local newspapers. Additionally, interviews of local residents by NPS and CDFW staff provided anecdotal information on the historic status of steelhead in some watersheds.

Personal Communications

- Bogan, Michael. University of California, Berkely. E-mail conversation.
- Fong, Darren. National Park Service. Unpublished data sent in Excel spreadsheet via e-mail.
- Hwan, Jason. University of California, Berkeley. Unpublished data from one of the authors of this report.
- Reichmuth, Michael. National Park Service. E-mail conversation.

Literature Cited

Department of Fish and Game (CDFW). 1976b. Millerton Gulch Stream Survey. Report by Maureen Cogger and Ron Curtis.

Katz, J.K., Moyle, P.B., Quiñones, R.M., Israel, J., and S. Purdy. 2013. Impending extinction of salmon, steelhead, and trout (salmonidae) in California. Environmental Biology of Fishes. 96(10–11): 1169–1186.

McCusker, M.R., Parkinson, E., and E.B. Taylor. 2000. Mitochondrial variation in rainbow trout (*Oncorhynchus mykiss*) across its native range: testing biogeographical hypotheses and their relevance to conservation. Molecular Ecology. 9: 2089–2108.

Marin Municipal Water District (MMWD). 2013. Smolt monitoring in the Lagunitas Creek Watershed – 2013. Report by Eric Ettlinger, Ariana Chiapella, Mike Paccassi, and Gregory Andrews.

Moyle, P.B., Israel, J.A., and S.E. Purdy. 2008. Salmon, steelhead, and trout in California. Status of an emblematic fauna. UC Davis Center for Watershed Sciences.

National Park Service (NPS). 2002b. Fisheries assessment for Bolinas Lagoon tributaries within the Golden Gate National Recreation Area, 1995–2000. Report by Darren Fong.

National Park Service (NPS). 2004a. Summer stream habitat and fish surveys for Upper West Union Creek, 1996–2001, Golden Gate National Recreation Area. Report by Darren Fong.

National Park Service (NPS). 2004b. Coastal watershed assessment--Drakes Estero road crossing improvements.

National Park Service (NPS). 2009a. Glenbrook Quarry Restoration and dam removal: Restoring natural process in the Phillip Burton Wilderness slideshow.

National Park Service (NPS). 2009b. Coastal watershed restoration project: Restoring tides in Estero de Limantour. Prepared by Alison Williams.

National Park Service (NPS). 2012b. Long-term monitoring of coho salmon and steelhead trout during freshwater life stages in coastal Marin County. Report by Sarah Carlisle, Michael Reichmuth, Katelyn Jordan, and Kelly Church.

Power, M.E. 1990. Effects of fish in river food webs. Science. 250: 811–814.

Quinn, T.P. and K.W, Myers. 2004. Anadromy and the migrations of Pacific salmon and trout: Rounsefell revisited. Reviews in Fish Biology and Fisheries. 14: 421–442.

Shapovalov, L. and A.C. Taft. 1954. The life histories of rainbow trout (*Salmo gairdneri gairdneri*) and silver salmon (*Oncorhynchus kisutch*). California Fish Bulletin no. 98.

Stillwater Science. 2008. Lagunitas limiting factos analysis: Limiting factors for coho salmon and steelhead. Final report. Prepared by Stillwater Sciences, Berkeley, California for Marin Resource Conservation District, Point Reyes Station, California.

Van Kirk, S. 2000. Marin County fish newspaper references.

4.8. Shorebirds

Shorebird condition warrants moderate concern and shows a declining trend overall the beaches. This assessment should be treated with caution because it is based on one metric from only four shorebird species.



4.8.1. Why Focal Resource Was Assessed

Description

The San Francisco Bay and surrounding shoreline area provide important habitat for large populations of migrating and wintering shorebirds along the Pacific Flyway (Page et al. 1999). The Golden Gate National Recreation Area (GOGA) manages an important piece of protected shoreline within the Bay and outer Pacific Coast beaches that includes excellent foraging habitat for wintering shorebirds. Shorebird monitoring for GOGA is conducted through a non-profit research and education program, Beach Watch, which utilizes volunteers to conduct research in the Greater Farallons National Marine Sanctuary. Beach Watch measures shorebird abundance using encounter rate (birds/km), a standardized measure calculated by dividing the number of individuals observed by kilometers of beach surveyed. Initial analysis of this dataset was done for the years 1993–2006 for the segments of eight GOGA beaches: Muir Beach, Rodeo Beach, Baker Beach, China Beach, Ocean Beach North, Ocean Beach Central, Ocean Beach South, and Thornton Beach North (Beach Watch 2006).

The shorebird chapter of the Natural Resource Condition Assessment provides an update and evaluation of shorebird population trends on GOGA beaches and shorelines. Beach Watch provided data for 1994-present for four common, wintering shorebird species: Marbled Godwit (*Limosa fedoa)*, Sanderling (*Calidris alba)*, Whimbrel (*Numenius phaeopus)*, and Willet (*Tringa semipalmata)*. These species were chosen because they are abundant enough to allow for robust statistical analysis, they are easily identified, they represent a variety of foraging habits and they had different seasonal activity patterns in the Beach Watch data. The rare species are important, but to sufficiently analyze trends for these species would require a more focused sampling and analysis effort. Future analysis could address trends for these species, and is recommended.

This chapter includes an analysis showing population trends over twenty years of Beach Watch observations for the four shorebird species within GOGA management zones. Population of each species is not compared to an external benchmark or to population in a given year. The analysis instead tries to identify trends within the 20 years of data in relation to time (year), season and location.

Critical questions

- What is the current condition of the shorebird focal resource in GOGA based on the last two decades of surveys, 1994–2013?
- What population trends exist (if any) for the focal shorebird species?

- How does disturbance from human activity affect the shorebird distribution?
- What are the critical data and knowledge gaps necessary to indicate the condition of shorebirds in GOGA?
- How does the fragmentation of GOGA's parkland affect the condition of the shorebird focal resource in each specified NRCA condition assessment zone?

4.8.2. How Focal Resource Was Assessed

Measures

1. The spatial and temporal distribution of the BeachWatch data collection.
2. Species trend analysis using BeachWatch data from 1994–2013 is used to measure the condition of the GOGA shorebird focal resource.
3. The decision was made by GOGA to limit the assessment to a trend analysis and not include human activity disturbance or spatial fragmentation. Human activity disturbance is not quantitatively measured with the same spatial and/or temporal scale as the BeachWatch shorebird surveys. Spatial fragmentation metrics were not available at the time of the trend analysis.

Data Sources and Methods

Measure 1: BeachWatch data is used to measure the spatial and temporal distribution of the shorebird surveys. The ongoing annual BeachWatch surveys are conducted throughout the four seasons of the year.

Measure 2: The species trend analysis used data from BeachWatch from 1994–2013 for four species: Marbled Godwit, Sanderling, Whimbrel and Willet.

Methods

The dataset was restricted to beaches within GOGA jurisdiction; including beaches that are partially in GOGA jurisdiction (e.g. Seadrift). Analysis was performed on the four most common and easily identifiable shorebird species: Marbled Godwit, Sanderling, Whimbrel, and Willet, in R using the MASS package (R Core Team 2014, Venables and Ripley 2002).

Generalized linear models (GLM) were created independently for each shorebird species to look at the effect of independent variables Year, Beach and Season on abundance. GLMs are linear regression models that can be used to analyze data that do not follow a normal distribution. In each modelling technique, the response variable was number of individuals of a species encountered per kilometer on any given survey. In the case where multiple surveys occurred within one year, on a given beach, within the same season, the results of those surveys were averaged within the season. For example, if three surveys occurred on Rodeo Beach in the summer of 2002, the response variable used in the model would have been the average of those survey results rather than three individual observations. The response variable was then rounded to the nearest integer to approximate count data.

The negative binomial distribution was chosen for the GLM because it is a useful way of modeling data with lots of zeros. Data containing many observations of zero individuals can be

"overdispersed" (having variance greater than the mean), causing the data to fail to meet the assumption of Poisson models of equal variance and mean. While the average number of individuals observed per kilometer varied greatly by species, in each case the variance in number of individuals observed per kilometer far exceeded the mean (Table 4.8.1).

Table 4.8.1. Comparing the mean and variance in individuals observed per kilometer (From the Greater Farallones National Marine Sanctuary Beach Watch Program).

Species	Mean Species/Km	Variance in Species/Km
Marbled Godwit	1.76	25.05
Sanderling	14.34	1648.92
Whimbrel	0.067	3.38
Willet	6.73	384.3

Eight models were created for each species. These sets included models with the following independent variables:

- Year only
- Beach only
- Season only
- Year + Beach
- Year + Season
- Beach + Season
- Year + Beach + Season
- Year * Beach + Season (Interaction between Year and Beach present)

AIC was used to select the best fitting model from the set of possible models. The glm.nb function used in the MASS package in R does not give factor-wide p-values. To assess significance of each factor likelihood ratio tests were performed using the anova.negbin() function in R which compares the full model to a model without the factor in question.

Linear trend models were fit using ordinary regression with a normal (Gaussian) distribution, which shows linear trends in abundance over the 20 year sampling window, because it can be difficult to interpret the effect sizes of factors from negative binomial regression. Since interactions between Beach and Year were found to be significant for all species, linear abundance trends were also calculated per beach to show how the annual trend varied per beach.

Reference Conditions/Values

Trends for the focal shorebird species are used to create a reference condition per beach (Tables 4.8.2 and 4.8.3). The management zone reference condition is the cumulative effect of the individual beach reference conditions within each zone.

Table 4.8.2. GOGA Shorebird Condition by Beach and Management Zone; summary of beach trends are from the four species in Table 4.8.1. Condition status refers to the number of focal species with negative population trends at each of the beaches: Red= beaches with 3 negative species trends, Yellow = beaches with 1–2 negative species trends, Green = beaches with 0 negative species trends.

Beach	Beach Trend (# species < -0.1)	Beach Watch segment number	Management Zone	Condition Status
Ocean Beach North	3	308	Diverse Opp for Visitors	Red
Thornton Beach North	3	311	Diverse Opp for Visitors	Red
Kirby Cove	0	230	Evolved Cultural Landscape	Green
Land's End	1	306	Evolved Cultural Landscape	Yellow
Rodeo Beach	1	223	Evolved Cultural Landscape	Yellow
Baker Beach	2	302	Natural	Yellow
Muir Beach	1	219	Natural	Yellow
Ocean Beach Central	2	309	Natural	Yellow
Ocean Beach South	1	310	Natural	Yellow
Tennessee Cove Beach	2	221	Natural	Yellow
Thornton Beach South	3	312	Natural	Red
Sharp Park	2	315	Natural (adjacent to GOGA)	Yellow
South Montara Beach	1	327	Natural (adjacent to GOGA)	Yellow
Seadrift	2	214	Scenic Corridor	Yellow

Table 4.8.3. GOGA Shorebird Condition by Management Zone; Condition status: based on cumulative beach condition (Table 4.8.2).

Management Zone	Shorebird Condition	Shorebird Trend
Diverse Opportunity for Visitors	Red	Condition Deteriorating
Evolved Cultural Landscape	Yellow	Condition Unchanging
Natural	Yellow	Condition Deteriorating
Scenic Corridor	Yellow	Condition Deteriorating

4.8.3. Condition Assessment

Trend 1994–2013 Results

Three of the four shorebirds were found to have a declining trend over all GOGA beach areas. Marbled Godwits, Sanderlings, and Willets show declines in abundance, although they range from quite close to a neutral or zero trend, -0.01 fewer individuals recorded per kilometer per year for Marbled Godwit to -0.38 for Willet and -0.74 for Sanderling. Whimbrels have a positive trend of

increasing +0.02 individuals per kilometer per year although this is also close to a neutral or zero trend (Table 4.8.4).

Table 4.8.4. Linear trend in individuals encountered per kilometer. The trend shows the difference in numbers of individuals observed per kilometer for every additional year. The last column shows the trend as a proportion of the overall mean from the 20 years of surveys. These trends were taken from linear regression estimates, and show a linear trend in abundance. The statistical significance of these trends is not reported here because it was tested using different statistical models which utilize a negative-binomial residual error distribution. Those results are reported in the focal species trend results below (From the Greater Farallones National Marine Sanctuary Beach Watch Program).

Species	Overall Linear Trend	1994 average per km	2013 average per km	1994–2013 Mean per km	Trend as proportion of mean
Marbled Godwit	-0.01	1.76	1.10	1.60	-0.006
Sanderling	-0.74	27.20	6.90	12.10	-0.060
Whimbrel	+0.02	0.50	1.12	0.67	+0.030
Willet	-0.38	5.44	1.00	6.73	-0.060

For all four species the specific beach surveyed played an important role with the effect size and whether this effect was a positive or negative trend (Table 4.8.5). Muir Beach had a decline for all four species although the effect size was very small, ranging from -0.01 to -0.13. Sanderlings have some of the largest declines at any one beach with the largest at -8.94 fewer individuals recorded per kilometer per year over the time period at Ocean Beach South. Sanderlings and Willets show a decline or negative effect for 12 out of 14 beaches. Marbled Godwits show a decline for half of the beaches, 7 out of 14.

Table 4.8.5. Linear trends and mean abundance (individuals per km) for GOGA beaches. Trend estimated from ordinary least squares regression with Gaussian distribution of individuals encountered per km per beach over the survey period (From the Greater Farallones National Marine Sanctuary Beach Watch Program).

	Marbled Godwit		Sanderling		Whimbrel		Willet	
Beach	**Trend**	**Mean**	**Trend**	**Mean**	**Trend**	**Mean**	**Trend**	**Mean**
Baker Beach[2]	-0.03	0.83	**-1.71[1]**	6.75	+0.01	0.25	-0.15	1.46
Kirby Cove	0.00	0.01	-0.02	0.55	0.00	0.11	0.00	0.38
Land's End	0.00	0.00	0.00	0.00	0.00	0.02	-0.14	0.73
Muir Beach[2]	-0.05	0.25	-0.13	0.31	-0.01	0.11	-0.05	0.28
Ocean Beach Central	+0.24	6.60	-0.04	57.6	+0.12	1.43	-0.40	8.86
Ocean Beach North[2]	-0.11	2.77	**-1.06[1]**	12.57	+0.04	0.42	**-1.23[1]**	5.08
Ocean Beach South	+0.24	4.74	**-8.94[1]**	39.84	-0.04	0.47	+0.50	27.78
Rodeo Beach[2]	-0.01	0.10	-0.14	0.93	0.00	0.10	-0.03	0.19
Seadrift	-0.13	2.82	+0.01	1.00	+0.22	2.38	-0.35	2.08
Sharp Park	0.00	0.05	**-1.03[1]**	8.56	0.00	0.88	-0.29	3.10
South Montara Beach	+0.01	0.07	-0.16	2.03	+0.03	0.49	-0.07	0.45
Tennessee Cove Beach[2]	+0.09	0.25	-0.37	1.93	-0.17	0.25	-0.01	0.06
Thornton Beach North[2]	-0.55	2.28	**-4.01[1]**	13.39	+0.09	0.56	-0.72	10.20
Thornton Beach South[2]	-0.63	3.73	**-3.51[1]**	31.56	+0.27	3.53	**-3.60[1]**	34.98

[1] Trend values for each species are strongly negative (greater than -1.0).

[2] Beaches with three or more species with a negative trend (also in bold font).

Seasonal differences were observed for all species when assessed over all GOGA beaches. Marbled Godwits and Whimbrels were most abundant during the Spring. Sanderlings were most abundant during the Fall, and Willets were most abundant during the Winter (Table 4.8.6).

Table 4.8.6. Average number of individuals recorded per km by season. Seasons were delineated by 3-month intervals (Winter = December-February; Spring = March-May, Summer = June-August, Fall = September-November) (From the Greater Farallones National Marine Sanctuary Beach Watch Program).

Species	**Winter**	**Spring**	**Summer**	**Fall**
Marbled Godwit	1.60	**2.40***	0.80	1.60
Sanderling	12.90	14.40	3.80	17.80
Whimbrel	0.15	**1.460***	0.84	0.23
Willet	**10.60***	5.10	0.30	7.20

* Values are the season with the highest average number of individuals (also in bold font).

Ocean Beach Central and Ocean Beach South were highlighted in the 2006 Annual Beach Watch Report as beaches with the highest encounter rates of shorebirds. They remain sites with high shorebird abundance, however since 2006, average encounter rates of all four shorebird species have been lower at these beaches than the during period between 1994–2006--with the exception of

Whimbrel and Marbled Godwit at Ocean Beach Central which have higher average encounter rates after 2006 (Table 4.8.7).

Table 4.8.7. Average number of individuals recorded per km per beach recorded between 1994–2013 (From the Greater Farallones National Marine Sanctuary Beach Watch Program).

Beach	Marbled Godwit	Sanderling	Whimberl	Willet
Baker Beach	0.83	6.75	0.25	1.46
Kirby Cove	0.01	0.55	0.11	0.38
Land's End	0.00	0.00	0.02	0.73
Muir Beach	0.25	0.31	0.11	0.28
Ocean Beach Central	6.60	57.61	1.43	8.86
Ocean Beach North	2.77	12.56	0.42	5.08
Ocean Beach South	4.74	39.84	0.47	27.78
Rodeo Beach	0.10	0.93	0.10	0.19
Seadrift	2.82	1.00	2.38	2.08
Sharp Park	0.05	8.56	0.88	3.10
South Montara Beach	0.07	2.03	0.49	0.45
Tennessee Cove Beach	0.25	1.93	0.25	0.06
Thornton Beach North	2.28	13.39	0.56	10.20
Thornton Beach South	3.73	31.56	3.53	34.98

Focal Species Individual Trend 1994–2013 Results

Generalized linear models using negative binomial distributions were fit for 20 years of survey data, 1994–2013, for each of the 4 species. Their results are summarized by species below. Effect sizes for Year represent log-transformed values used by the models. As such they cannot be interpreted as linear increases or decreases (like you get from normal linear regression). Instead estimated values can be calculated as:

$$\hat{p} = exp(b)^x \times exp(a)$$

In other words, the expected number of individuals observed per kilometer ($\hat{p}$) is equal to the exponentiated estimate ($exp(b)$) to the power of year (x) multiplied by the exponentiated intercept $exp(a)$. This is an exponential equation which yields a curve-linear regression line (see figures in Appendix 4.8).

The negative binomial models used for model selection and used to determine significance of the factors and interactions do not explicitly account for temporal autocorrelation. Correlated residual errors could lead to somewhat inaccurate p-values, however given the very large sample sizes involved and the *very* small p-values from the models, it is unlikely that the significance of these results would change if models accounting for autocorrelation were used. Still, this analysis could be refined to obtain more accurate p-values if it were done using models which accounted for such autocorrelation (such as moving average or autoregressive models).

Marbled Godwit

The negative binomial regression model showed that Marbled Godwits had a slight negative trend over the 20-year sampling period. Since there is a significant interaction between Year and Beach, care should be taken when interpreting these results, however the annual trend is statistically significant ($p<0.002$). This significance may be due in part to having a very large sample size since the effect size is very small. The overall annual trend from the linear model was a decrease of 0.01 individuals observed per kilometer surveyed. This is a proportional decrease of only -0.006 per year (Table 4.8.4).

The best-fitting model chosen by AIC was the full model with Year, Beach, and Season as independent variables, and an interaction between Year and Beach. Likelihood ratio tests of reduced models against the full model showed that each of the three explanatory variables was significant ($p<0.01$) (For details and AIC models see Appendix 4.8.1).

Because there was a significant interaction between Year and Beach, it is important to consider how the effect of Year varied by Beach. Table 4.8.5 above shows the linear trend of individuals encountered per kilometer at each beach over the survey period. Seven of the 14 beaches showed negative trends, three of the beaches showed a trend of zero, and four of the beaches showed positive trends. Two of these beaches (Ocean Beach South and Ocean Beach Central) showed strong positive trends (increase of +0.24 per year).

Sanderling

The negative binomial regression model showed that Sanderlings had an overall negative trend over the 20-year sampling period but that this trend varied per beach. Since there is an interaction between Year and Beach, care should be taken when interpreting these results, however the annual trend in abundance was statistically significant ($p<0.001$) and proportionally much larger than the Marbled Godwit trend. The overall annual trend from the linear model is a decrease of -0.74 individuals observed per kilometer surveyed. This is the largest absolute decrease of the four species, however because this species was also the most abundant it represents a proportional decrease of only -0.06 per year (Table 4.8.4).

The best-fitting model chosen by AIC was the full model with Year, Beach, and Season as independent variables, and an interaction between Year and Beach. Likelihood ratio tests of reduced models against the full model showed that each of the three explanatory variables was highly significant ($p<0.0001$) (Appendix 4.8.1).

Because there was a significant interaction between Year and Beach, it is important to consider how the effect of Year varied by Beach. Table 4.8.5 shows the linear trends of individuals encountered per kilometer at each beach over the survey period. Twelve of the 14 beaches showed negative trends, one beach showed a trend of zero, and one beach (Seadrift) showed a very small positive trend (+0.01). Ocean Beach South, and Thornton Beach North and South all showed very strong negative annual trends: -8.94, -4.01, and -3.51 fewer individuals encountered per kilometer annually respectively.

Whimbrel

The negative binomial regression model showed that Whimbrels had an overall positive trend over the 20-year sampling period but that this trend varied per beach. Because there is an interaction between Year and Beach, care should be taken when interpreting these results, however the annual trend is statistically significant ($p<0.001$). The overall annual trend from the linear model is an increase of +0.02 individuals observed per kilometer surveyed, representing a proportional increase of +0.03 (Table 4.8.4).

The best-fitting model chosen by AIC was the full model with Year, Beach, and Season as independent variables, and an interaction between Year and Beach. Likelihood ratio tests of reduced models against the full model showed that each of the three explanatory variables was highly significant ($p<0.0001$) (Appendix 4.8.1).

Because there was a significant interaction between Year and Beach, it is important to consider how the effect of Year varied by Beach. Table 4.8.5 shows the linear trends of species encountered per kilometer at each beach over the survey period. Seven of the 14 beaches had positive annual trends, four beaches had zero trend, and three beaches had negative trends.

Willet

The negative binomial regression model showed that Willets had a negative trend over the 20-year sampling period and that this trend varied per beach. Because there is an interaction between Year and Beach, care should be taken when interpreting these results, however the annual trend is statistically significant ($p<0.001$). The overall annual trend from the linear model is a decrease of -0.38 individuals observed per kilometer surveyed, representing a proportional decrease of -0.06 per year (Table 4.8.4).

The best-fitting model chosen by AIC was the full model with Year, Beach, and Season as independent variables, and an interaction between Year and Beach. Likelihood ratio tests of reduced models against the full model showed that each of the three explanatory variables was highly significant (Appendix 4.8.1).

Because there was a significant interaction between Year and Beach, it is important to consider how the effect of Year varied by Beach. Table 4.8.5 shows the linear trends of individuals encountered per kilometer at each beach over the survey period. Twelve of the 14 beaches showed negative trends, one beach showed a trend of zero (Kirby Cove), and one beach (Ocean Beach South) showed a moderate positive trend of +0.5. Ocean Beach North and Thornton Beach South both showed very strong negative trends: -1.23 and -3.60 fewer birds observed per kilometer annually respectively.

Stressors

Many theories have been proposed that could account for the observed shorebird decline on central Californian beaches within the last few decades including: increase in human activity, climate change, environmental contaminants, changes to breeding areas or migration corridors that result in lower recruitment or survivorship, and restoration or loss of regional habitat. An Audubon California review of 50 studies across North America investigating human activity disturbance on shorebirds

found significant negative effects of human and shorebird interactions (Borgmann 2010). Multiple studies investigating the foraging patterns of Sanderlings have found that human activity, specifically the presence of off-leash dogs, is potentially the most significant disturbance to Sanderling behavior (e.g. Colwell and Sundeen 2000, Thomas et al. 2003). However, a local study of shorebird use of beaches in central California found that physical characteristics of beaches, like flatness, were more important than human presence at predicting shorebird distribution (Neuman et al. 2008). It has been shown in many locations that humans can indirectly affect the behavior of shorebirds through increased noise in large groups and the activity of their accompanying dogs (Borgmann 2010). The Beach Watch tenth anniversary report has the most recent summary of dog and human occurrence on beaches. Further investigations are warranted for the physiological effects of these types of disturbance on shorebird longevity and health.

Many studies have investigated changes in abundance and frequency of shorebirds in California in relation to seasons and habitats. These studies reveal that there are distinct abundance patterns and seasonal preferences for each species observed (Colwell and Sundeen 2000, Dodd and Colwell 1996, Hubbard and Dugan 2003). Studies have also shown the importance of habitat characteristics to shorebirds. A study investigating winter shorebird communities in relation to tidal flat characteristics in Humboldt County, found Whimbrel presence correlated negatively with mudflat width and positively with standing water. Sanderlings were found in habitats characterized by coarse sediments and accordingly populated first areas of exposure when tides went down. The study concluded that tidal flats need protection in the face of potential changes in water quality and sediment size that could lead to disturbances in observed shorebird populations (Danufsky and Colwell 2003). Although none of these studies analyzed change over time, future research may indicate whether seasonal disturbance and tidal changes from climate change affect the physical characteristics of the preferred foraging areas for these species.

Climate change is a potential threat to shorebird communities across California, however it is difficult to predict how climate change will affect individual species. It is important to consider that many beaches in coastal California are constrained by development, and shorebirds will likely suffer habitat loss as sea levels rise and reduce beach size.

An interesting competing hypothesis suggests that what we interpret as a decline in shorebird population may simply be our observations of a drastic change of stopover duration and survival tactics in response to the increase in peregrine falcon populations since the ban of DDT. In an Australian study, comparing safer Fraser Island with the more predated Sidney Island, a study found that although Sandpiper body mass was about equal on both Fraser and Sidney Island in the mid-1980s, a present day study reveals that the mass of Sandpipers on Sidney Island has fallen by 2.5g relative to Fraser Island. Furthermore, the length of stay during migration declined by 68% between 1992 and 2001 for southbound sandpipers in both places. The study thus concluded that the recovery of peregrine populations is a possible causal factor on Sandpiper migration, and that there is little evidence to support a true population decline (Ydenberg et al. 2004). Another study at Sidney Island supports this hypothesis with the discovery that the migrating peregrine falcon front directly influences the pattern and speed of migrating Sandpipers based on temporal proximity. The earliest

sandpipers migrate slowly due to their head start on falcon predators while later migrants move quickly; the latest migrants directly under the falcon front precede more cautiously and slow again (Hope et al. 2011). Therefore, although their study does not address the effects of an increase in falcon numbers over time, Hope et al. (2011) do support the assertion that their presence directly influences the migrational patterns of Sandpipers. These studies suggest that the increase in peregrine populations over the last 20 years could also have an effect on central Californian shorebird behavior although local research is needed.

Environmental contaminants from ongoing beach contamination or catastrophic oil spill events have an effect on shorebird health and longevity (McConnell et al. 2015). Systematic shoreline surveys like Beach Watch are important sources of information on the effect of oil spills and their long-term consequences (Roletto et al. 2003). More research is needed on the effects of local oil spills and other contaminants in San Francisco Bay.

In conclusion, there are many supported theories that attempt to explain the observations of a decline in shorebird population on Central Californian beaches, but the exact cause of this phenomenon is still ambiguous and left to be answered by further research.

Level of confidence in assessment

Confidence in this condition assessment overall is medium due to use of only one measure (trend analysis) for four species of shorebirds. However, the restrictions used on the Beach Watch dataset and the number of years used in the trend analysis allow a robust trend assessment for these four species.

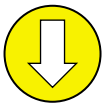
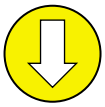
Gaps in understanding

- Continuing assessment is necessary of the level of human activity on GOGA beaches and its effect on shorebird populations.
- A measure of shorebird species diversity for GOGA beaches over time would add information to the condition assessment.

Condition Summary

Shorebirds found along the beaches of GOGA jurisdiction show a declining trend overall. This decline in the numbers of shorebirds is not particular to GOGA and mirrors a similar decline among shorebirds along the coast of California and North America (NABCI 2014). Certain beaches and management zones are more of a concern than other beaches within GOGA (Table 4.8.8).

Table 4.8.8. Overall Condition Summary for Shorebirds.

Indicators of Condition	Specific Measures	Condition Status	Rationale
Shorebird population trends	Marbled Godwit		Neutral trend
	Sanderling		Negative trend
	Whimbrel		Neutral trend
Shorebird population trends (cont'd)	Willet		Negative trend
Beach segment shorebird trends	Number of focal species with trend < -0.01		Majority of beach segments had 1–2 focal species with negative trend
Management zone shorebird trends	Cumulative beach segment condition by zone		Majority of beaches within each zone shorebird community is deteriorating
Overeall Condition Status and Trend for Shorebirds			**Shorebird condition warrants moderate concern and shows a declining trend overall the beaches. This assessment should be treated with caution because it is based on one metric from only four shorebird species**

4.8.4. Information Sources

Sources of Expertise

Beach Watch, Farallones Marine Sanctuary Association (FMSA), The Presidio, PO Box 29386, San Francisco, CA 94129, www.farallones.org

Literature Cited

Borgmann, K. L. 2010. A review of human disturbance impacts on waterbirds. Audubon California, 376. Retrieved from http://www.yourwetlands.org/pdf/A%20Review%20of%20Human%20Disturbance%20Impacts%20on%20Waterbirds.pdf

Colwell, M. A., and K.D. Sundeen. 2000. Shorebird distributions on ocean beaches of northern California. Journal of Field Ornithology, 71(1), 1–15. Retrieved from http://www.bioone.org/doi/abs/10.1648/0273-8570-71.1.1

Danufsky, T., and M.A. Colwell. 2003. Winter shorebird communities and tidal flat characteristics at Humboldt Bay, California. The Condor, 105(1), 117–129.

Dodd, S. L., and M.A. Colwell. 1996. Seasonal Variation in Diurnal and Nocturnal Distributions of Nonbreeding Shorebirds at North Humboldt Bay, California. The Condor, 98(2), 196–207.

Hope, D. D., D.B. Lank, B.D. Smith, and R.C. Ydenberg. 2011. Migration of two calidrid sandpiper species on the predator landscape: how stopover time and hence migration speed vary with geographical proximity to danger. Journal of Avian Biology, 42(6), 522–529.

Hubbard, D. M., and J.E. Dugan. 2003. Shorebird use of an exposed sandy beach in southern California. Estuarine, Coastal and Shelf Science, 58, Supplement, 41–54.

McConnell, H. M., B. D. Gartrell, B. L. Chilvers, S. T. Finlayson, P. C. E. Bridgen, and K. J. Morgan. 2015. Baseline hydrocarbon levels in New Zealand coastal and marine avifauna. Marine Pollution Bulletin 94:290–298.

North American Bird Conservation Initiative, U.S. Committee (NABCI). 2014. The State of the Birds 2014 Report. U.S. Department of Interior, Washington, D.C. 16 pages.

Neuman, K. K., L.A. Henkel, and G.W. Page. 2008. Shorebird Use of Sandy Beaches in Central California. Waterbirds, 31(1), 115–121.

Page, G. W., L. E. Stenzel, and J. E. Kjelmyr. 1999. Overview of shorebird abundance and distribution in wetlands of the Pacific coast of the contiguous United States. Condor 101:461–471.

R Core Team. 2014. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL: http://www.R-project.org/.

Roletto, J., J. Mortenson, I. Harrald, J. Hall and L. Grella. 2003. Beached Bird Surveys and Chronic Oil Pollution in Central California. Marine Ornithology 31: 21–28.

Thomas, K., R.G. Kvitek, and C. Bretz. 2003. Effects of human activity on the foraging behavior of sanderlings *Calidris alba*. Biological Conservation, 109(1), 67–71.

Venables, W. N. and B.D. Ripley. 2002. Modern Applied Statistics with S. Fourth Edition (MASS Package in R). Springer, New York.

Ydenberg, R. C., R.W. Butler, D.B. Lank, B.D. Smith, and J. Ireland. 2004. Western sandpipers have altered migration tactics as peregrine falcon populations have recovered. Proceedings of the Royal Society of London, Series B: Biological Sciences, 271(1545), 1263–1269. Retrieved from http://rspb.royalsocietypublishing.org/content/271/1545/1263.short

Chapter 5. Discussion

Chapter 5 provides an opportunity to summarize the overarching themes that have emerged from the assessment of the focal natural resources selected for Golden Gate National Recreation Area. Examination of these central themes can provide guidance regarding logical next-step activities that could be considered as a means to maintain or improve conditions for these important natural resources. The overall resource assessments and trends, the degree of confidence in the data for each resource, key stressors, and the most critical data gaps or research needs for each resource are summarized and discussed in this chapter.

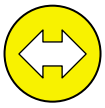
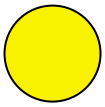
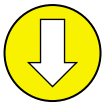
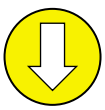
5.1. Resource Condition Summary

The NRCA assessment of each focal natural resource is based on a synthesis of data from the park's monitoring and management programs, as well as expert opinions and other credible scientific literature and/or programs. The overall condition and trend of each focal resource included in this NRCA framework is summarized in Table 5.1. These assessments were based on a combination of the status and trend of multiple indicators and specific measures of natural resource condition shown in the indicator level summary tables below. It is important to consider that these condition assessments were made with varying amounts of available data and with varying degrees of confidence. A more complete discussion and assessment of each indicator is provided in Chapter 4.

The majority of the focal natural resources at GOGA were determined to be in moderate condition (Table 5.1). Of the eight resources featured in this assessment, four were rated as being in moderate condition: forests, landscape context, shorebirds, and steelhead. Three resources; amphibians, breeding birds, and rare plants, were categorized as being in good condition. Only the condition of invasive plants was considered to be of significant concern. For the five resources with sufficient information to determine a trend in condition, two exhibited a declining trend (shorebirds and steelhead populations) and three were categorized as exhibiting a stable trend (amphibian populations, breeding bird diversity, and forest resources; Table 5.1). The confidence associated with each assessment was ranked as medium for all resources except for breeding bird diversity and invasive plants, which were ranked as having low confidence in the condition assessment due to data limitations.

When possible and useful for understanding the condition of the resource, the focal resource condition assessments were calculated for each GOGA management zone (i.e., Diverse Opportunities Zone, Scenic Corridor Zone, Evolved Cultural Landscape Zone, Historic Immersion Zone, Interpretive Corridor, Natural Zone, Sensitive Resources Zone, and Park Operations Zone; see Table 2.7 for descriptions and desired conditions in each zone).

Table 5.1. Resource-level summary of condition and trend for focal natural resources. Green circles indicate that the resource condition warrants low concern, yellow circles indicate moderate concern, and red circles indicate significant concern is warranted. Arrows signify trend; an upward arrow indicates an improving trend, a horizontal arrow a stable trend, and a downward arrow a declining trend.

Focal Resource	Condition Status/Trend	Rationale
Amphibians		Pond-breeding amphibians are widespread, but little is known about stream-breeding amphibians or terrestrial salamanders. California red-legged frogs are widespread in multiple habitats. American bullfrogs are present and negatively affect native species, but are limited to a small proportion of sites.
Breeding Landbird Diversity		Riparian species population trends in GOGA have greater stability compared to the larger, regional dataset of the California Breeding Bird Survey. Low confidence results from lack of data for assessing population trends in other habitats.
Forests		Tree decline associated with the progression of sudden oak death warrants concern. The trend in forest biomass suggests the capacity for recovery. Confidence in the assessment is constrained by the paucity of site-specific data.
Invasive Plants		The number of invasive plant species and the extent of area invaded are high and continue to increase. Confidence in existing data is limited by the non-systematic temporal and spatial coverage of past sampling efforts.
Landscape Context		GOGA land holdings provide relatively more intact wildlands with a substantial proportion of core area. However, small core areas in San Francisco County is cause for concern.
Rare Plants		Managed rare plant populations extant; introduction efforts somewhat successful; USFWS Recovery Criteria generally in progress or completed. Data gaps warrant moderate confidence in findings and fail to support trend analysis.
Steelhead		Steelhead in the focal region currently warrant moderate concern and are in decline throughout many streams in the region. Fish passage has been improved for some streams; however, numerous barriers still remain.
Shorebirds		Shorebird population trends suggest moderate concern is warranted and show a declining trend. This assessment should be treated with caution because it is based on one metric and is specific to individual beaches.

In the final assessment, only invasive plants, shorebirds, and rare plants were summarized at the management zone level due to limited availability of data, the spatial distribution of data, or the spatial distribution of the resources among management zones. This comparison of resource condition among management zones highlighted some areas of concern that could help guide next steps to take as part of ongoing efforts to protect and manage park natural resources. For instance, the invasive plant analysis found that the Park Operations Zone had the highest relative number of invasive species with 6 species recorded in 32 acres and the Evolved Cultural Landscape Zone had

the greatest percentage of invaded land area with invasive plants present in at least 70% of the acres in this zone. It was also determined that shorebird condition warranted the greatest concern in the diverse opportunity zone. However, few trends or big picture conclusions emerged from the management zone analyses, in part, due to lack of variation in condition assessment by zone. For instance, all but one of the management zones for the shorebird assessment were ranked as moderate concern and all but two of the management zones for the invasive plant assessment were ranked as warranting significant concern. Further, the wide variation in the percentage of land area surveyed for each resource within a given management zone reduced the value and accuracy of these comparisons among zones.

The resource condition assessments suggest that for the focal resources assessed, Golden Gate National Recreation Area is generally in moderate or good condition though there is wide variation in the assessed condition of the studied resources and within the indicators assessed for each resource. Determining an overall condition of GOGA at a park-wide scale is difficult due, in part, to data gaps and the limited spatial and temporal coverage of much of the current data. Further, the GOGA NRCA focused heavily on species or communities (i.e., little focus on air and climate, water quality, landscape, and human use categories). Seven of the eight natural resources selected for inclusion in the GOGA NRCA were focal species or communities classified in the biological integrity category of the NPS Ecological Monitoring Framework. Only the Land Use Context resource was in the landscapes category. Lastly, due to its ecological diversity, fragmented nature, and the variation in the extent of human use and impacts among areas within the park, it is expected that the condition and trend of individual resources will vary across the park.

The overall condition assessment for each resource was based on the combined valuation of individual indicators and measures. The condition and trend of each indicator included in the GOGA's NRCA framework is summarized in the tables and resource briefs below. The condition of these indicators varied within each resource assessment. Notably, the framework includes only the indicators and measures for which sufficient data was available. Further, this data was often spatially and temporally limited; information sufficient to estimate trends was lacking for 13 of the 30 indicators included in this assessment. Therefore, the condition and trend of the selected indicators may not fully represent the condition and trend of the larger ecosystem component or the entire park. It is also important to consider that condition assessments were made with varying amounts of available data and with varying degrees of confidence. A more complete discussion and assessment of each indicator and measure is available in Chapter 4.

5.1.1. Resource Brief: Amphibians

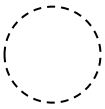
Amphibian declines are a nearly worldwide phenomenon (Blaustein and Wake 1990, Wake 1991, 2012, Stuart et al. 2004, Wake and Vredenburg 2008, Adams et al. 2003). In California, declines of several species, including California red-legged frogs (*Rana draytonii*), southern mountain yellow-legged frogs (*R. muscosa*), Sierra Nevada yellow-legged frogs (*R. sierrae*), and Yosemite toads (*Anaxyrus canorus*), have precipitated their listing as threatened or endangered by the U.S. Fish and Wildlife Service. Many factors have contributed to these declines, including loss of habitat or reduction in habitat quality (Lehtinen et al. 1999, Cushman 2006, Harper et al. 2008), introduced species (Adams et al. 2003, Vredenburg 2004, Knapp 2005, Knapp et al. 2007), diseases such as the amphibian chytrid fungus *Batracochytrium dendrobatidis* (*Bd*; Briggs et al. 2005, Vredenburg et al. 2010), and contaminants (Sparling et al. 2001, 2015, Davidson 2004, Sparling and Fellers 2007). Because of their sensitivity to these myriad threats, their biphasic life cycle that exposes them to stressors in both aquatic and terrestrial environments, and their permeable skin that further sensitizes them to environmental change, amphibians make excellent indicator species (Welsh and Ollivier 1998) that can serve as bellwethers for environmental changes. Amphibians also are an integral part of functional ecosystems, serving as primary consumers, predators at multiple trophic levels, and prey for a diversity of other organisms. The important role of amphibians in functioning ecosystems, combined with their sensitivity to environmental conditions, makes them an ideal taxon for monitoring the status and health of ecosystems.

At Point Reyes National Seashore and Golden Gate National Recreation Area, amphibians as a group are ideal candidates for monitoring and targeted study of the consequences of environmental change. The amphibian fauna in these coastal California locations includes a diverse group of species exhibiting different life cycles, from pond-breeding frogs and salamanders, to stream-breeding salamanders, to terrestrial salamanders with direct development. These species occur in a variety of habitats, thus making different groups more or less sensitive to different types of environmental changes. Furthermore, the amphibian fauna of Point Reyes National Seashore and Golden Gate National Recreation Area is relatively well-studied. This existing knowledge, combined with their diversity, means that amphibians could serve important roles for monitoring environmental changes and for more detailed assessments of the consequences of specific management actions at these National Parks.

This assessment revealed that much survey effort for amphibians in aquatic breeding habitats has occurred throughout most of Point Reyes National Seashore and Golden Gate National Recreation Area. Although spatially widespread, most sites were visited few times. Native pond-breeding amphibians appear widespread, with no apparent trends in the proportion of sites at which detections occurred. Thus, pond-breeding amphibian distribution appears stable. Little information about stream-breeding salamanders or terrestrial salamanders with direct development existed, and these species warrant further investigation into their distribution and habitat relationships. Confidence in the assessment of pond-breeding amphibians is high. Native pond-breeding species are common and widespread. Confidence in the assessment of stream-breeding amphibians, particularly California giant salamanders, is much lower (Table 5.2). Survey efforts must be targeted toward this species, so general amphibian visual encounter surveys, which comprise the majority of surveys, likely miss this

species. Terrestrial salamanders also require targeted surveys specifically for these taxa, and were therefore not included in this assessment. The status and trends of salamanders at Point Reyes National Seashore and Golden Gate National Recreation Area remain uncertain.

Table 5.2. Overall Condition Summary for Amphibians.

Indicators of Condition	Specific Measures	Condition Status	Rationale
Understanding of Status	Spatial distribution of survey effort		Survey effort has been distributed over a large area
	Temporal distribution of survey effort		Most sites surveyed five or fewer times in past 20 years
Amphibian Diversity	Species richness of native amphibians		# of native amphibian species detected indicates diversity of habitats sampled, rather than changes in species richness
Occurrence of Focal Species	Detections/non-detections of California red-legged frogs		California red-legged frogs widespread in multiple habitats
	Detections/non-detections of California giant salamanders		Too few surveys targeted for California giant salamanders have occurred to assess status or trend
	Detections/non-detections of American bullfrogs		American bullfrogs are present and negatively affect native species, but they are limited to a relatively small proportion of sites
Overall Condition Status and Trend for Amphibians			–

5.1.2. Resource Brief: Breeding Bird Diversity

Landbirds can be important indicators of ecosystem health (Carignan and Villard 2002, Chase and Geupel 2005) and changing ecological conditions like climate and development intensity (Gardali et al. 2012, Jongsomjit et al. 2013). Long-term monitoring can allow both baseline inventory as well as population trends over time and give managers the necessary information for adaptive management. National parks are important comparison sites for landbird population trends because they are more insulated from local changes in land use yet are still responsive to global issues like climate change (Siegel et al. 2010).

Riparian habitat was chosen as the focus for long-term landbird monitoring because of its high level of species diversity and richness, broad ecosystem function, and ubiquitous distribution within GOGA (Flannery et al. 2001, Gardali et al. 2010). Riparian landbird population trends appear to have a general pattern of stability. When riparian species population trends are compared between GOGA and the larger regional dataset of California Breeding Bird Survey, the trends from GOGA reflect a greater overall stability of species. Therefore, the condition of the landbird focal resource including all habitats for GOGA warrants low concern (Table 5.3).

Table 5.3. Overall Condition Summary for Breeding Bird Diversity.

Indicators of Condition	Specific Measures	Condition Status	Rationale
Habitats analyzed	Number of habitats with trend analysis		Riparian habitat is the primary focus for species population models. No trends published for other habitats.
Population trends	Number of focal species with negative trends		Riparian species show a mix of declining, increasing and neutral trends
Overall Condition Status and Trend for Breeding Landbird Diversity			–

5.1.3. Resource Brief: Forests

Golden Gate National Recreation Area manages 421 hectares of intact coast redwood forests in the San Francisco Bay Area. Two units, Muir Woods National Monument and the Phleger Estate, contain 92% of these redwood forests (Schirokauer et al. 2003). Muir Woods represents one of the oldest (1908) examples of "saving the redwoods" by placing the trees in public ownership and the Phleger Estate one of the most recent (1995). Yet as Ruskin Hartley notes (2012), legal protection as a park is no longer sufficient to protect the redwoods in the era of global change.

Muir Woods National Monument is famous for its groves of ancient coast redwood trees (*Sequoia sempervirens*) that developed along the shores of Redwood Creek. In 2014, more than one million visitors toured this 225 hectares park. While coast redwoods are the most abundant tree species, covering 2/3 of the area, the Monument supports a mix of evergreen trees (Schirokauer et al. 2003) including the conifer, Douglas-fir (*Pseudotsuga menziesii*), and three evergreen hardwoods: California bay laurel (*Umbellularia californica*), tanoak (*Notholithocarpus densiflorus*), and coast live oak (*Quercus agrifolia*). The redwood stands in the Monument are embedded within a large, contiguous expanse of intact forest that is protected by various forms of public ownership.

The Phleger Estate, a 495 hectare forest in San Mateo County, was added to GOGA in 1995 (SMCHA 2010). The redwood-tanoak forest dominates in the stream valleys and lower west-facing slopes (52% by area). California bay-coast live oak forests cover the upper slopes and ridge top (37% by area). The Phleger Estate together with property owned by the San Francisco Public Utilities Commission forms a large tract of protected lands. Like much of the coastal forests in the region and in contrast to the old-growth forests at Muir Woods, the forests on the Phleger Estate were extensively logged in the late 1800's and early 1900's (SMCHA 2010).

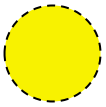
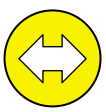
The forests at Muir Woods and the Phleger Estate supply essential structure and function to their ecosystems. The complex, multi-tiered canopy, characteristic of these forests (Ramage et al. 2010), provides critical wildlife habitat. For example, Muir Woods is a refuge not only for old-growth redwoods (Jacobs and McBride 1985) but also for threatened and endangered animals (NPCA 2011) like the northern spotted owl (*Strix occidentalis*) and coho salmon (*Oncorhynchus kisutch*). The coastal conifer forests are among the most productive forests in the world (Busing and Fujimori 2005). This flux of energy supports the base of the food chain and ensures close biotic regulation of water and nutrient cycles (Whittaker 1975). Degradation of these forests would clearly pose a risk to the resource condition of GOGA.

Primary risks to the forest include climate change, an altered fire regime, and the spread of exotic pathogens (NPCA 2011, Hartley 2012). By one account, shifts in vegetation resulting from projected changes in climate could result in the near elimination of the coast redwood forest by 2100 (ECN 2015). Fire is a critical component of the coast redwood disturbance regime (Ramage et al. 2010) but its role in these coastal forests is complex (Lorimer et al. 2009). However there is no doubt that the long-term policy of fire suppression has extended the current fire-free interval from the pattern of frequent, low-intensity burns that existed prior to European settlement (Jacobs and McBride 1985, Brown et al. 1999). In 1995, the presence of exotic pathogen, *Phytophthora ramorum* and causal

agent of Sudden Oak Death (SOD), was confirmed in Muir Woods. It has resulted in the widespread mortality of tanoak (Swiecki and Bernhardt. 2006).

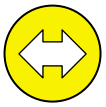
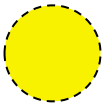
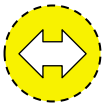
The ecological integrity of forests is an integrative measure that considers the structure, composition and function of the forest (Tierney et al. 2009). At Muir Woods, the progression of *P. ramorum* in the Douglas-fir/Coast Redwood Forest is having a widespread impact via the increased mortality of susceptible tree species. The decline in tanoak due to the presence of a "priority 1" pathogen (sensu Tierney et al. 2009) warrants significant concern. The expected changes in the climate, the altered fire regime, and their interaction with the disease pose potential yet unrealized threats to the condition of the forests. However the fact that the forest sustained its biomass capital despite the suite of stressors attests to the functional capacity for recovery. Clearly decreases in growth in *P. ramorum* infected stands were offset by gains elsewhere. In terms of the functioning of the forest as whole, the biomass trend suggests maintenance of the status quo. The primary conclusions of a forest resource holding its own despite substantial cause for concern are well-grounded in empiricism but Muir Woods lacks the comprehensive site-specific data needed to assign high confidence to this assessment (Table 5.4).

Table 5.4. Overall Condition Summary for Forests: Muir Woods.

Indicators of Condition	Specific Measures	Condition Status	Rationale
Biomass accumulation	Aboveground live biomass (AGL) accumulation (theoretical expectation)		Small increase in forest biomass from 2001 to 2010
	AGL accumulation (regional comparison)		Biomass trends improving relative to regional forests where AGL declined from 2001–2010
Future forest distributions under climate change	Predictive vegetation models		Climate niche suitable for conifer-dominated communities declines sharply by 2100
Risk of catastrophic fire	Fire hazard model		Most of the coastal forest classified as high or very high hazard but current impacts are effectively mitigated by fire management
Exotic disease progression	Tree mortality and growth as measured in field plots		Susceptible species continue to die but community wide collapse unlikely
Potential for compounding perturbations	Fuel load and future fire risk		Transient risk of more severe fire behavior associated with pathogen mortality
Overall Condition Status and Trend for Forest: Muir Woods			–

The absence of a *P. ramorum* at the Phleger Estate improves the assessment of the forest condition relative to Muir Woods. However the lack of biomass accumulation in this second growth forest raises the possibility of some yet undetected constraint on tree growth. Also considering the likely spread of sudden oak death, the potential for declines in the near-future is high (Table 5.5).

Table 5.5. Overall Condition Summary for Forests: Phleger Estate.

Indicators of Condition	Specific Measures	Condition Status	Rationale
Biomass accumulation	Aboveground live biomass (AGL) accumulation (theoretical expectation)		No increase in forest biomass from 2001 to 2010 despite theoretical expectations.
	AGL accumulation (regional comparison)		Biomass trends improving relative to regional forests where AGL declined from 2001–2010
Future forest distributions under climate change	Predictive vegetation models		Climate niche suitable for conifer-dominated communities declines sharply by 2100
Risk of catastrophic fire	Fire hazard model		Most of the coastal forest classified as high or very high hazard but current impacts are effectively mitigated by fire management
Exotic disease progression	Tree mortality and growth as measured in field plots		No documented presence of P. ramorum but presence likely
Potential for compounding perturbations	Fuel load and future fire risk		No increase in disease-associated fire hazard given limited impact of the pathogen
Overall Condition Status and Trend for Forest: Phleger Estate			–

5.1.4. Resource Brief: Invasive Plants

The current rate of invasive species introductions is unprecedented, and the dramatic impacts of invasive plant species on community and ecosystem function have been well documented (Vitousek and Walker 1989, D'Antonio and Vitousek 1992, Gordon 1998, Mack et al. 2000). Invasive species have been directly linked to the replacement of dominant native species (Tilman 1999), the loss of rare species (King 1985), changes in ecosystem structure, alteration of nutrient cycles and soil chemistry (Ehrenfeld 2003), shifts in community productivity (Vitousek 1990), reduced agricultural productivity, and changes in water availability (D'Antonio and Mahall 1991). Often the damage caused by these species to natural resources is irreparable and our understanding of the consequences incomplete.

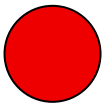
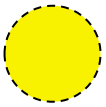
The National Park Service defines non-native plants as plant species that occur in a given location as a result of direct, indirect, deliberate, or accidental actions by humans. Invasive plants are non-native plants that have been introduced to new areas beyond their native ranges, adversely affect these habitats and bioregions, and have aggressive characteristics. For the National Park Service, the consequences of these invasions present a significant challenge to the management of the agency's natural resources "unimpaired for the enjoyment of future generations." National Parks, like other land management organizations, are inundated by new non-native species arriving through predictable (*e.g.*, road, trail, and riparian corridors), sudden (*e.g.*, long-distance dispersal through cargo containers and air freight), and unexpected anthropogenic pathways (*e.g.*, weed seeds in restoration planting mixes). Non-native plants claim an estimated 4,600 acres of public lands each year in the United States (Asher and Harmon 1995), significantly altering local flora. Invasive plants infest an estimated 2.6 million of the 83 million acres managed by the NPS (Welch et al. 2014).

Given the extraordinary biodiversity of the San Francisco Bay Area and urban development pressures, GOGA serves as crucial habitat for many native species. Invasive plants threaten many of these rare species. For example, in GOGA, 25 species of exotic plants have been noted as directly threatening rare plant populations (NPS 2004). GOGA is an unusual unit in the NPS in that it has many disjunct properties and a high ratio of urban interface along a lengthy and fragmented boundary. Many GOGA lands also have a long history of military and ranching use prior to their inclusion in the NPS. Because of these and other potential human activity vectors for the spread of invasive plants, GOGA has a great interest in understanding how invasive plants occur on the landscape. Further introductions and rates of invasion may be reduced by identifying natural and human invasion pathways and prioritizing the species and areas most in need of management.

The number of invasive plant species and the extent of area invaded in GOGA are high and continue to increase. Data indicate that nearly 5,650 acres have been invaded by high priority species since baseline data was collected in 1987. This assessment suggests that invasive plants in GOGA warrant significant concern. The condition of each individual indicator was ranked as either moderate or significant concern for the majority of management zones. Invasive plants were rated as low concern in only two zones, the Sensitive Resources Zone and Historic Immersion Zone. The reported values are likely underestimates of plant invasion indicators because of the limited area surveyed. In addition, the accuracy of comparisons among management zones is reduced because the percentage

of land area surveyed in each zone varied significantly. Confidence in existing data is limited by the non-systematic temporal and spatial coverage of past sampling efforts (Table 5.6).

Table 5.6. Overall Condition Summary for Invasive Plants.

Indicators of Condition	Specific Measures	Condition Status	Rationale
Potential for spread	Spread of high priority invasive species		Increase of more than 5,500 acres invaded since 1987
Propagule pressure/invasibility	Number of invasive species		174 invasive plant species identified for monitoring by the Early Detection program
	Number of new introductions		41 additional invasive species documented since 2011
Potential impacts on native species/ ecosystems	Extent of area invaded		Surveys have documented the presence of at least one invasive species in approximately 25% of park area
Overall Condition Status for Invasive Plants			–

5.1.5. Resource Brief: Landscape Context

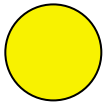
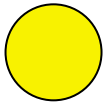
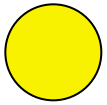
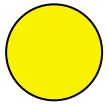
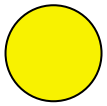
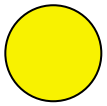
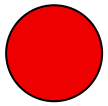
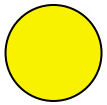
Golden Gate National Recreation Area consists of many individual land holdings dispersed through three Bay Area counties: Marin, San Francisco, and San Mateo. These lands range in size from large contiguous wildlands (e.g., Marin Headlands, 3,933 acres) to small inholdings in the urban core (e.g., China Beach, 6.5 acres). They include majestic forests (e.g., Muir Woods, 556 acres), historical icons (e.g., Alcatraz Island, 23.5 acres), former military bases (e.g., Crissy Field, 88.8 acres), and popular beaches (e.g., Stinson Beach, 614.5 acres). Clearly, GOGA encompasses a diversity of ecosystems embedded within vastly different landscapes.

This diversity is an essential feature of the Park but poses major challenges to management and assessment. For example the size of a natural area and the extent of developed features influence organisms from bobcats (Riley 2006) to bees (McFrederick and Le Buhn 2006). Moreover the public interacts very differently with the portfolio of GOGA's holdings through the three Bay Area counties. The perceptions and expectations of constituents can directly impinge on natural resources (e.g., Banks and Bryant 2007). Thus, quantifying the spatial arrangement of each parcel and its interface with the surrounding community is key aspect of a natural resource condition assessment. The landscape context provides a "logical and appropriate reference condition" for land holdings that span an urban-rural gradient (NPS 2014).

A host of indicators were calculated to quantify the landscape context of GOGA at multiple scales. As noted by Liu et al. (2016), some metrics are strongly correlated (e.g., patch size and core area; road density and core area ratio) and thus should not be considered independent indicators of condition. In addition, some of the standard landscape measures are not particularly relevant for some ecosystems. For example, the river/stream density (i.e., acres per river mile) did not provide much insight into the landscape context of GOGA. In absolute the terms, the parcels are small and typically do not encompass whole watersheds. Thus the analysis primarily relied on four indicators: the extent of wildlands, the percentage of impervious surface, the relative abundance of invasive vegetation types, and the core area ratio. Impervious surface is an excellent synoptic measure of the built environment (Nowak and Greenfield 2010). In combination with the percentage wildland area, impervious surface estimates the degree of human modification. Liu et al.'s (2016) showed that core area was one of the best predictors of habitat fragmentation, hence its inclusion in the summary assessment. The other metrics were considered but as secondary indicators.

Overall the GOGA parcels provided relatively more contiguous wildlands dominated by native vegetation with larger core areas than the region and their neighbors. However condition varied by region. At every scale, GOGA holdings in San Mateo County were in better condition. At the regional level in Marin County, the modest size of the core areas was cause for concern. In San Francisco, the small core area ratio was the most prominent threat (Table 5.7).

Table 5.7. Overall Condition Summary for Landscape Context.

Scale of Analysis	Indicators	GOGA Condition Status	Regional Condition Status			Rationale
			Marin	San Francisco	San Mateo	
Regional Unit	See Table 4.5.2					Collectively, GOGA parcels should provide relatively more intact wildlands composed of native vegetation than the region
Parcel-patch	See Table 4.5.2					Individual GOGA parcels should provide relatively more intact wildlands composed of native vegetation than the neighboring lands
Core Area	Core area ratio					Individual GOGA parcels should have a core area greater than 50% of their total size
Overall Condition Status for Landscape Context			–	–	–	**Collectively, GOGA land holdings provide relatively more intact wildlands than the region with a greater proportion of core area. However, the limited core area in San Francisco County is cause for concern**

5.1.6. Resource Brief: Rare Plants

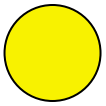
The California Floristic Province, considered a global biodiversity hotspot, hosts more endemic plant taxa (2,125 taxa) and more identifiable subspecies than any comparable area in the continental United States (Mittermeier 1998, Calsbeek et al. 2003). The unique geological history and globally-rare Mediterranean climate have allowed for the diversification of a unique assemblage of plant species (Médail and Pierre Quézel 1999, Calsbeek et al. 2003). California, and the San Francisco Bay Area in particular, are also under major development pressure to support a growing population (Lewis and Neiman 2002). Habitat fragmentation, alteration, and loss are major contributors to the extinction of rare plant species (Matthies et al 2004). Collaboration between the California Native Plant Society, California Department of Fish and Wildlife, US Fish and Wildlife, and land managers, such as the National Park Service, has been essential to the protection and enhancement of existing rare plant species in California (Falk and Holsinger 1991).

Eight rare plant taxa found within GOGA-managed lands were selected for a review of status and distribution: Franciscan manzanita (*Arctostaphylos franciscana*), Presidio manzanita (*Arctostaphylos montana* ssp. *ravenii*), marsh sandwort (*Arenaria paludicola*), Tiburon paintbrush (*Castilleja affinis* ssp. *neglecta*), Presidio clarkia (*Clarkia franciscana*), Marin dwarf flax (*Hesperolinon congestum*), San Francisco lessingia (*Lessingia germanorum*), and Hickman's cinquefoil (*Potentilla hickmanii*). Additional rare plant taxa were selected for a more general geospatial analysis of habitat and distribution.

The success of introduction efforts varied depending on species and site. Two species, Tiburon paintbrush and Hickman’s cinquefoil, had not had any documented introduction efforts by GOGA. Marin dwarf flax, San Francisco lessingia and Presido clarkia introduction efforts had both successes and failures, warranting moderate concern. Many of the recovery criteria outlined in Recovery Plans for the species of interest were in progress, partially met, or fully met for GOGA-managed populations. Most criteria involved preservation of habitat, management of threats, and introduction of new populations. However, long-term criteria were often not met.

In general, the natural populations observed within GOGA lands (excluding historical observations) continued to persist under GOGA management and monitoring. This assessment suggests that the overall condition of rare plant populations managed by GOGA warrants low concern. Overall, confidence ratings were high for the condition status rates given the consistent annual monitoring conducted by GOGA. However, the assessment does not include a trend analysis because the population data for the rare plants of interest was not robust enough (Table 5.8). Continued monitoring and management of the rare plants within GOGA is vital to sustain populations in a changing climate and with increasing urban population.

Table 5.8. Overall Condition Summary for Rare Plants.

Indicators of Condition	Specific Measures	Condition Status	Rationale
How many of the natural populations observed since GOGA management began are still extant?	Proportion of extant natural populations with > 0 individuals in 2012 and 2013. Populations not monitored will not be counted toward score.		Of the eight species of interest, seven were in good condition. Five conditions had high confidence in the rating and two had moderate confidence. Marsh sandwort only exists as introduced populations in GOGA lands, and was thus omitted from this summary category.
Have introduction efforts been successful?	Proportion of successful introductions into new sites. This does not include natural populations.		Of the eight species of interest, three were in good condition and the condition of three warranted moderate concern. Two condition had high confidence in the rating. Three conditions had moderate confidence, and one had low confidence. Tiburon paintbrush and Hickman's potentilla do not have introduced populations on GOGA lands, and were omitted from this summary category.
Have the USFWS Recovery Plan goals been fulfilled for populations within GOGA lands?	Proportion of interim and long-term goals realized or in progress. Goals carried out by other entities will not be counted toward score.		Of the eight species of interest, four were in good condition, and three warranted moderate concern. Five conditions had moderate confidence in the rating and two had low confidence. Franciscan manzanita did not have a Recovery Plan and was omitted from this summary category.
Overall Condition Status for Rare Plants			**Managed rare plant populations extant; introduction efforts somewhat successful; USFWS Recovery Criteria generally in progress or completed. Data gaps warrant moderate confidence in findings and fail to support trend analysis**

5.1.7. Resource Brief: Steelhead

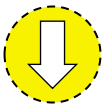
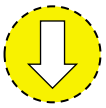
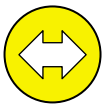
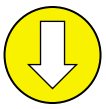
The native range of steelhead trout spans from Baja California to southwestern Alaska along the North American continent and continues along the Aleutian Islands to the Kamchatka Peninsula in eastern Russia (Quinn and Myers 2004). Steelhead populations at the southern end of their range in California are in decline. In 1998, steelhead populations within the central coast region of California were listed under the United States Endangered Species Act as a federally threatened species (NMFS 2011), thus effective management efforts are needed to prevent further declines. The National Park Service has identified multiple potential factors leading to the decline of steelhead in the PORE and GOGA regions (NPS 2012). Specifically, dam and culvert construction in the focal regions have acted as migration barriers to steelhead, influencing spawning migrations and in some cases restricting steelhead to lower sections of watersheds. Furthermore, historic logging has resulted in increased fine sediment delivery, fewer inputs of large woody debris, and decreases in vegetation along riparian areas, all of which can result in poor rearing conditions for steelhead (NPS 2012). Declines or local extirpations of steelhead would likely have ecological consequences. For example, juvenile steelhead are often the top predators in small streams, and can have strong top-down effects on river food webs (Power 1990).

The goal of this assessment was to determine the presence and abundance of steelhead within streams in the PORE and GOGA regions. Such information could be useful to natural resource managers for informing future steelhead surveys, land management decisions, and restoration efforts. A combination of steelhead presence/absence and abundance data from contemporary (defined here as 1993-present) and historical literature (pre-1993) were available. These data were used to evaluate the current trends in steelhead occurrence and abundance. Additionally data obtained from a literature search and an online database were used to document the presence of potential barriers to steelhead migration.

Of the 60 creeks in Marin County with steelhead population information, 50 were reported as having steelhead present at the time they were surveyed, whereas steelhead were absent during surveys for the remaining ten. Of the 18 creeks with data on steelhead occurrence in San Mateo County, 16 were reported as having steelhead present and two were documented as having no steelhead present. The lone creek in San Francisco that flows through GOGA land, Lobos Creek, did not have steelhead present.

Annual reports by NPS (beginning in 1993) have not shown clear trends in population size of steelhead through time. This is likely due to the strong inter-annual variability in climate conditions characteristic of California's Mediterranean-type climate, resulting in better survival conditions for steelhead in some years compared to others (NPS 2012). This assessment suggests that steelhead populations are widespread throughout the focal region, but at reduced abundances compared to the past, making these populations vulnerable to large-scale disturbance events, such as drought (Table 5.9).

Table 5.9. Overall Condition Summary for Steelhead.

Indicators of Condition	Specific Measures	Condition Status	Rationale
Population size and distribution	Abundance data		Steelhead populations are widespread throughout the focal region, but at reduced abundances; making these populations vulnerable to large-scale disturbance events
	Presence/Absence data		Steelhead populations are widespread throughout the focal region, but at reduced abundances; making these populations vulnerable to large-scale disturbance events
Migration barriers	Number of invasive species		Improved fish passage in some streams; many barriers remain
Overall Condition Status and Trend for Steelhead			**Steelhead in the focal region currently warrant moderate concern and have experienced declines in many streams in the region. Fish passage has been improved for some streams; however, numerous barriers remain. Additionally, other stressors that were not assessed pose a significant threat to populations within (and beyond) the focal region**

5.1.8. Resource Brief: Shorebirds

The San Francisco Bay and surrounding shoreline area provides important habitat for large populations of migrating and wintering shorebirds along the Pacific Flyway (Page et al. 1999). The Golden Gate National Recreation Area manages an important piece of protected shoreline within the Bay and outer Pacific Coast beaches that includes excellent foraging habitat for wintering shorebirds. Shorebird monitoring for GOGA is conducted through a non-profit research and education program, Beach Watch, which utilizes volunteers to conduct research in the Greater Farallons National Marine Sanctuary. The shorebird assessment was based on evaluation of shorebird abundance and population trends for segments of eight GOGA beaches: Muir Beach, Rodeo Beach, Baker Beach, China Beach, Ocean Beach North, Ocean Beach Central, Ocean Beach South, and Thornton Beach North (Beach Watch 2006). This chapter includes a trend analysis using twenty years of Beach Watch observations for four common, wintering shorebird species: Marbled Godwit (*Limosa fedoa)*, Sanderling (*Calidris alba)*, Whimbrel (*Numenius phaeopus)*, and Willet (*Tringa semipalmata)*.

Shorebirds found along the beaches of GOGA jurisdiction show a declining trend overall (Table 5.10). This decline in the numbers of shorebirds is not particular to GOGA and mirrors a similar decline among shorebirds along the coast of California and North America (NABCI 2014). Certain beaches and management zones are more of a concern than other beaches within GOGA. Confidence in this condition assessment is medium due to use of only one measure (trend analysis). However, the restrictions used on the Beach Watch dataset and the number of years used in the trend analysis allow a robust trend assessment for these four shorebird species.

Table 5.10. Overall Condition Summary for Shorebirds.

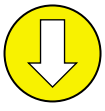
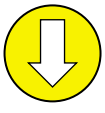
Indicators of Condition	Specific Measures	Condition Status	Rationale
Shorebird population trends	Marbled Godwit		Neutral trend
	Sanderling		Negative trend
	Whimbrel		Neutral trend
Shorebird population trends (cont'd)	Willet		Negative trend
Beach segment shorebird trends	Number of focal species with trend < -0.01		Majority of beach segments had 1–2 focal species with negative trend
Management zone shorebird trends	Cumulative beach segment condition by zone		Majority of beaches within each zone shorebird community is deteriorating

Table 5.10 (continued). Overall Condition Summary for Shorebirds.

Indicators of Condition	Specific Measures	Condition Status	Rationale
Overeall Condition Status and Trend for Shorebirds			**Shorebird condition warrants moderate concern and shows a declining trend overall the beaches. This assessment should be treated with caution because it is based on one metric from only four shorebird species**

5.2. Key Issues and Challenges for Management

Chapter 5 provides an opportunity to summarize the overarching themes that have emerged from the assessment of the focal natural resources selected for Golden Gate National Recreation Area. In this section, we summarize the stressors and data gaps or research needs for each focal resource and consider the role of these factors in the determination of the current condition assessment. Examination of these central themes can provide guidance regarding logical next-step activities that could be considered for improving conditions of the important natural resources within Golden Gate National Recreation Area.

Several stressors were identified that influence the condition of multiple priority resources within GOGA. Table 5.11 lists all the stressors that were included in this NRCA and summarizes the stressors which were designated as a primary threat for each focal resource. The most commonly cited stressors include climate change, pests and pathogens, and habitat loss due to human activity. Improved understanding of these threats, and how they relate to the condition of the assessed focal resources, can help GOGA to prioritize management objectives and better focus conservation strategies to maintain the integrity of park ecosystems.

Perhaps the greatest threat to the resources within GOGA is climate change. Climate change was listed as a primary stressor for five of the eight resources assessed in this report (breeding landbird diversity, forests, invasive plants, rare plants, and shorebirds) and would likely have wide-ranging impacts on many other resources in GOGA. As discussed in this assessment, it is predicted that the impacts of climate change in the San Francisco Bay Area will include increased rainfall and more intense and more frequent El Niño-Southern Oscillation events (Largier et al. 2010). Further, it remains unclear how climate change will impact coastal fog. A study of long-term airport records indicates that summer fog has declined significantly over the last century (Johnstone and Dawson 2010). Changes in the abundance and seasonality of fog could have important implications for GOGA's coastal habitats and species.

Table 5.11. Summary of the stressors considered most significant for each of the assessed focal resource at Golden Gate National Recreation Area.

Stressor	Focal Resource
Climate change	• Breeding Landbird Diversity • Forests • Invasive Plants • Rare Plants • Shorebirds
Pests, pathogens, disease	• Amphibians • Forests • Invasive plants • Rare Plants

Table 5.11 (continued). Summary of the stressors considered most significant for each of the assessed focal resource at Golden Gate National Recreation Area.

Stressor	Focal Resource
Habitat loss	• Amphibians • Rare Plants • Salmonids
Altered fire regime	• Forests • Invasive plants
Contaminants	• Amphibians • Shorebirds
Introduced species	• Amphibians • Rare Plants
Human activity	• Shorebirds • Rare plants
Fragmentation	• Invasive plants • Land Use
Overharvest	Amphibians
Genetic bottleneck	Rare plants
Migration barriers	Salmonids
Road density	Land Use
Low core area	Land Use

Sea-level rise is a significant concern for GOGA. Global average sea level rose at an average rate of 0.07 inches per year from 1961 to 2003 and at an accelerated average rate of about 0.12 inches per year during the last decade of this period (1993 to 2003; Parry et al. 2007). Climate change models predict that sea levels may rise up to 55 inches (1.4 m) over the next 100 years. Impacts to shorelines can include erosion, saltwater inundation of wetlands and groundwater aquifers, changes in wetland water regimes, threats to cultural, historic and natural resources, and threats to infrastructure (Pacific Institute 2009). In the San Francisco Bay Area, 140 years of tide-gauge data show a rise of about 2 millimeters per year and suggest an increase in severe winter storms since 1950 (Bromirski et al. 2003). Increased and more intense precipitation could also increase erosion and flood events within the parks. California estuaries and coastal areas will be subject to rising average sea level and increased impacts from high tides and storm surge waves (Cayan et al. 2012). These changes are particularly important for coastal species and communities that occur within future impact zones.

Point Blue Conservation Science has predicted major habitat loss at sites in some areas of San Francisco Bay as sea levels rise, even assuming a conservative global warming scenario such as 2°C increase within the next century (Galbraith et al. 2002). Along the GOGA coastlines, some urban areas, coastal beaches, tidal flats and small rocky islands and outcrops have the potential to be affected. In natural habitats these structural changes, have the potential to impact habitat use and result in ecological impacts. For instance, potential impacts may include the loss of offshore rocks

supporting bird nesting colonies and seal breeding sites, the loss of beaches that provide habitat for wintering and migrating shorebirds, and negative effects on bank swallow colonies due to increased bluff erosion.

The identification of key data and information gaps is an important objective of NRCAs. Data gaps or needs are those pieces of information that are currently unavailable, but are needed to help inform the status or overall condition of a key resource component in the park. Data gaps exist for all of the focal resources and stressors assessed in this NRCA. Table 5.3 provides a detailed list of the key data gaps by focal resource. Each data gap or need is discussed in further detail in the individual component assessments (Chapter 4).

Many of the resources analyzed in this report lacked enough data to allow long-term trend analyses. Further, none of the resource assessments were ranked as warranting high confidence. Many of the park's data needs involve establishing or continuing long-term monitoring programs, as a number of the park's resources have either insufficient data or outdated data. Consistent monitoring programs would establish a history of data records or repeat previous survey efforts in which current information could be compared to historic data and observations. Some long-term monitoring projects have already been established. For instance, the San Francisco Bay Area Network Early Detection of Invasive Species program appears to provide a consistent and efficient means of tracking the invasive plant species present in GOGA, the number of invasive plant occurrences, and most new invasive species introductions. However, only one comprehensive survey had been completed at the time of this assessment. With additional years of monitoring, this data should provide sufficient data for a high confidence assessment and a better indication of trends in the assessed indicators.

Due to the significance of the wide-ranging threats posed by climate change, there is currently much more information needed on the potential impacts of this stressor on GOGA's natural resources (Table 5.12). The possible effects of sea level rise in GOGA are currently being assessed through predictive models by various research institutions, including the USGS in cooperation with the NPS Geologic Resources Division and Point Blue Conservation Science. Remaining research needs and data gaps include downscaled climate predictions, scenario planning, and adaptation planning. Clearly, understanding the future climate and the implications for natural resources in sufficient detail is both a critical gap in knowledge and a research priority.

The ecological communities discussed in this assessment included coastal dunes, forests, and grasslands. Assessment of these communities, as well as focal resources such as rare plants, would benefit from an updated vegetation map for the park. The detailed vegetation map for GOGA is an indispensable tool for management and research. However, it is more than two decades old. Given that we are experiencing an era of accelerated ecological dynamics, the vegetation map needs to be updated as often as possible to understand ongoing shifts in the vegetation.

Table 5.12. Summary of data and research needs identified for the assessed focal resources in GOGA.

Focal Resource	Data Needs
Amphibians	• Status and distribution of California giant salamanders • Status and distribution of terrestrial salamanders • Variables that affect the probability of occurrence and diversity of pond-breeding amphibians • Assessment of abundance and demography • Variables that affect the abundance and vital rates of focal species
Breeding Landbird Diversity	• Monitoring and analysis in habitats other than riparian areas • Monitoring and analysis in unsurveyed areas
Forests	• Establishment of a forest monitoring network that is measured repeatedly over time • Re-assessment of wildfire hazard • Track spread of invasive plants in forested areas with particular attention focused on locations that have been recently disturbed • Updated vegetation map • Studies of climate change impacts on GOGA forests
Invasive Plants	• Additional years of monitoring to establish trends • Further assessment of the rate of spatial spread of invasive species • Improved understanding of the total area or patch size occupied • More in-depth data on treatments, including the species treated, population size treated, and person hours involved
Landscape Context	• Improved temporal data would allow a trend assessment • The absence of information on trends in patch geometry and habitat quality is a major gap in understanding
Rare Plants	• Continued monitoring with consistent methods to evaluate trends and provide feedback on the results of conservation efforts • Further research on fluctuations in population size and the biological and environmental mechanisms effecting population dynamics • Further studies of the mechanisms that govern small plant populations • Additional studies of the impacts of climatic variables, grazing, fire, and management actions, including dune restoration
Steelhead	• Survey streams that lack steelhead occurrence information • Improved precision of survey location information • Expand sampling efforts to include small watersheds • More in-depth analysis of barriers limiting steelhead movement
Shorebirds	• Improved understanding of human impacts on shorebird populations • A measure of shorebird species diversity over time

5.3. Conclusion

Since its establishment in 1972, Golden Gate National Recreation Area has earned recognition for providing "national park experiences to a large and diverse urban population while preserving and interpreting the outstanding natural, historic, scenic, and recreational values of the park lands" (NPS 2014). GOGA is a unique and diverse park; rich in natural resources including 19 types of ecosystems and habitat for many sensitive, rare, threatened, and endangered species. Golden Gate Recreation Area is also one of the most highly-visited NPS units. The park plays a central role in the life of many San Francisco Bay Area residents, and is a destination for millions of people from around the world.

This condition assessment provides a review and summary of the available data and literature for featured natural resources in the park. The information presented here can serve as a baseline against which future changes in condition of these natural resources can be compared. Understanding the condition of these resources can help managers prioritize management objectives and better focus conservation strategies. However, it is important to consider that these condition assessments were made with varying amounts of available data and with varying degrees of confidence.

The majority of the assessed focal natural resources at GOGA were rated as requiring moderate to low concern. However, Golden Gate National Recreation Area faces some significant challenges in the coming decades including climate change, exotic pests and pathogens, habitat loss, and the encroachment of invasive plant species. In addition, although park staff have gathered a considerable amount of information regarding natural resources, there are still many significant gaps in the existing data for natural resources and stressors. NPS resource managers need to establish and continue comprehensive monitoring projects in order to ensure that management strategies can be implemented in a timely and effective manner, so that these challenges do not result in the degradation of these valuable natural resources.

5.4. Literature Cited

Adams, M. J., C. A. Pearl, and R. Bruce Bury. 2003. Indirect facilitation of an anuran invasion by non-native fishes. Ecology Letters 6:343–351.

Asher, J. A., and D. W. Harmon. 1995. Invasive exotic plants are destroying the naturalness of U.S. Wilderness areas. International Journal of Wilderness 1:35–37.

Banks, P.B. and J.V. Bryant. 2007. Four-legged friend or foe? Dog walking displaces native birds from natural areas. Biology letters 3: 611–613.

Blaustein, A. R., and D. B. Wake. 1990. Declining amphibian populations: A global phenomenon? Trends in Ecology & Evolution 5:203–204.

Briggs, C. J., V. T. Vredenburg, R. A. Knapp, and L. J. Rachowicz. 2005. Investigating the population-level effects of chytridiomycosis: An emerging infectuous disease of amphibians. Ecology 86:3149–3159.

Bromirski, P. D., R. E. Flick and D. R. Cayan. 2003. Storminess variability along the California coast: 1958–2000. Journal of Climate 16:982–993.

Brown, P. M., M. W. Kaye, and D. Buckley. 1999. Fire history in Douglas-fir and coast redwood forests at Point Reyes National Seashore, California. Northwest Science 73:205–216.

Busing, R. T., and T. Fujimori. 2005. Biomass, production and woody detritus in an old coast redwood (*Sequoia sempervirens*) forest. Plant Ecology 177:177–188.

Calsbeek, R, J.N. Thompson, and J.E. Richardson. 2003. Patterns of Molecular Evolution and Diversification in a Biodiversity Hotspot: The California Floristic Province. *Molecular Ecology*, no. 12: 1021–29.

Carignan, V., and M. Villard. 2002. Selecting indicator species to monitor ecological integrity: a review. *Environmental monitoring and assessment* 78:45–61.

Cayan, D., M. Tyree, D. Pierce and T. Das. 2012. Climate change and sea level rise scenarios for California vulnerability and adaptation assessment. California Energy Commission. Publication number: CEC- 500-2012-008.

Chase, M. K., and G. R. Geupel. 2005. The use of avian focal species for conservation planning in California. In Proceedings of the Third International Partners in Flight conference, CJ Ralph and TD Rich (eds.). USDA Forest Service Gen. Tech. Report PSW-GTR-191.

Cushman, S. A. 2006. Effects of habitat loss and fragmentation on amphibians: A review and prospectus. Biological Conservation 128:231–240.

D'Antonio, C. M. and B. E. Mahall. 1991. Root profiles and competition between the invasive, exotic perennial, *Carpobrotus edulis,* and two native shrub species in California coastal scrub. American Journal of Botany 78:885–894.

D'Antonio, C. M., and P. M. Vitousek. 1992. Biological invasions by exotic grasses, the grass fire cycle, and global change. Annu. Rev. Ecol. Syst. 23:63–87.

Davidson, C. 2004. Declining downwind: Amphibian population declines in California and historical pesticide use. Ecological Applications 14:1892–1902.

Environmental Change Network (ECN). 2015. California Landscape Conservation Cooperative. Interactive map modeling bird distribution response to climate change. http://data.prbo.org/apps/ecn/ (accessed Dec 29, 2015).

Ehrenfeld, J.G. 2003. The effects of exotic plant invasions on soil nutrient cycling processes. Ecosystems 6:503–523.

Falk, D.A. and K.E. Holsinger. 1991. Genetics and Conservation of Rare Plants. New York, Oxford: Oxford University Press.

Flannery, M.E., D.L. Humple, G. Ballard, and G.R. Geupel. 2001. Landbird Inventory of the National Parks of the San Francisco Bay Area: Final Report, December 2001. PRBO Report to the National Park Service #1004.

Galbraith, H., R. Jones, R. Park, J. Clough, S. Herrod-Julius, B. Harrington, and G. Page. 2002. Global climate change and sea level rise: potential losses of intertidal habitat for shorebirds. Waterbirds 25:173–183.

Gardali, T., D. Humple, M. Herzog, M. Koenen, D. Press, W. Merkle, and S. Allen. 2010. Riparian landbird monitoring protocol for Golden Gate National Recreation Area and Point Reyes National Seashore: version 4.4. Natural Resource Report NPS/SFAN/NRR—2010/207. National Park Service, Fort Collins, Colorado.

Gardali, T., Seavy, N. E., DiGaudio, R. T., and Comrack, L. A. 2012. A Climate Change Vulnerability Assessment of California's At-Risk Birds. *PLoS ONE*, *7*(3).

Gordon, D. R. 1998. Effects of invasive, non-indigenous plant species on ecosystem processes: Lessons from Florida. Ecol. Appl. 8:975–989.

Harper, E. B., T. A. G. Rittenhouse, and R. D. Semlitsch. 2008. Demographic consequences of terrestrial habitat loss for pool-breeding amphibians: predicting extinction risks associated with inadequate size of buffer zones. Conservation Biology 22:1205–1215.

Hartley, R.K. 2012. Redwood forest conservation: Where do we go from here? Pages 3–10 *in* Standiford, R.B., T.J. Weller, D.D. Piirto, and J.D. Stuart (Editors). Proceedings of the Coast Redwood Forests in a Changing California: A Symposium for Scientists and Managers. US Forest Service PSW-GTR-238.

Jacobs, D. F., D. W. Cole, and J. R. McBride. 1985. Fire history and perpetuation of natural coast redwood ecosystems. Journal of Forestry 83:494–497.

Johnstone, J. A., and T. E. Dawson. 2010. Climatic context and ecological implications of summer fog decline in the coast redwood region. Proceedings of the National Academy of Sciences of the United States of America 107:4533–4538

Jongsomjit, D., Stralberg, D., Gardali, T., Salas, L., and Wiens, J. 2013. Between a rock and a hard place: the impacts of climate change and housing development on breeding birds in California. *Landscape Ecology*, *28*(2), 187–200.

King, W. B. 1985. Island birds: will the future repeat the past? Pages 3–15 *in* P. J. Moors, editor. Conservation of Island Birds. International Council for Bird Preservation. Cambridge University Press, Cambridge, UK.

Knapp, R. A. 2005. Effects of nonnative fish and habitat characteristics on lentic herpetofauna in Yosemite National Park, USA. Biological Conservation 121:265–279.

Knapp, R. A., D. M. Boiano, and V. T. Vredenburg. 2007. Removal of nonnative fish results in population expansion of a declining amphibian (mountain yellow-legged frog, *Rana muscosa*). Biological Conservation 135:11–20.

Largier, J. L., B.S. Cheng, and K. D. Higgason, editors. 2010. Climate change impacts: Gulf of the Farallones and Cordell Bank National Marine Sanctuaries. Report of a Joint Working Group of the Gulf of the Farallones and Cordell Bank National Marine Sanctuaries Advisory Councils. 121pp.

Lehtinen, R. M., S. M. Galatowitsch, and J. R. Tester. 1999. Consequences of habitat loss and fragmentation for wetland amphibian assemblages. Wetlands 19:1–12.

Lewis, P.G., M. Neiman. 2002. Cities Under Pressure: Local Growth Controls and Residential Development Policy. San Francisco, CA: Public Policy Institute of California. http://www.ppic.org/content/pubs/report/R_102PLR.pdf.

Lorimer, C. G., D. J. Porter, M. A. Madej, J. D. Stuart, S. D. Veirs, S. P. Norman, K. L. O'Hara, and W. J. Libby. 2009. Presettlement and modern disturbance regimes in coast redwood forests: implications for the conservation of old-growth stands. Forest Ecology and Management 258:1038–1054.

Liu, Z., C. He, and J. Wu. 2016. The relationship between habitat loss and fragmentation during urbanization: An empirical evaluation from 16 world cities. PlosOne 11:e0154613.

Mack, R. N., D. Simberloff, W. M. Lonsdale, H. Evans, M. Clout, and F. A. Bazzaz. 2000. Biotic invasions: Causes, epidemiology, global consequences, and control. Ecological Applications **10**:689–710.

Matthies, D, I Brauer, and T Tscharntke W Maibom. 2004. Population Size and the Risk of Local Extinction: Empirical Evidence from Rare Plants. *Oikos* 105: 481–88.

McFrederick, Q. S., and G. Le Buhn. 2006. Are urban parks refuges for bumble bees *Bombus* spp. (Hymenoptera: Apidae)? Biological Conservation 129: 372–382.

Medail, F. and P. Quezel. 1999. Biodiversity Hotspots in the Mediterranean Basin: Setting Global Conservation Priorities. Conservation Biology, no. 13: 1510–13.

Mittermeier, R.A., N. Myers, G.A.B. Da Fonseca, J.B. Thomsen, and S. Olivieri. 1998. Biodiversity Hotspots and Major Tropical Wilderness Areas: Approaches to Setting Conservation Priorities. Conservation Biology, no. 12: 516–20.

North American Bird Conservation Initiative, U.S. Committee (NABCI). 2014. The State of the Birds 2014 Report. U.S. Department of Interior, Washington, D.C. 16 pages.

National Marine Fisheries Service (NMFS). 2011. 5-year review: Summary and evaluation of Central California Coast steelhead DPS Northern California steelhead DPS

National Park Service (NPS). 2004. Rare plant monitoring report. Golden Gate National Recreation Area Unpublished Report, Fort Cronkhite, California.

National Park Service (NPS). 2012. Long-term monitoring of coho salmon and steelhead trout during freshwater life stages in coastal Marin County. Report by Sarah Carlisle, Michael Reichmuth, Katelyn Jordan, and Kelly Church.

National Park Service (NPS). 2014. National Park Service. Guidelines for Natural Resource Condition Assessment. http://www.nature.nps.gov/water/nrca/guidance.cfm (accessed Sept. 11, 2014).

Nowak, D.J. and E.J. Greenfield. 2010. Evaluating the National Land Cover Database tree canopy and impervious cover estimates across the conterminous United States: a comparison with photo-interpreted estimates. Environmental Management 46:378–390.

NPCA. 2011. Muir Woods National Monument: A resource assessment. National Parks Conservation Association, State of the Parks. Available at www.npca.org/stateoftheparks.

Pacific Institute. 2009. The impacts of sea-level rise on the California Coast. California Climate Change Center, Sacramento, CA. Available at http://www.pacinst.org/reports/sea_level_rise/index.htm (accessed 2010).

Page, G. W., L. E. Stenzel, and J. E. Kjelmyr. 1999. Overview of shorebird abundance and distribution in wetlands of the Pacific coast of the contiguous United States. Condor 101:461–471.

Parry, M. L., O. F. Canziani, J. P. Palutikof, P. J. van der Linden and C. E. Hanson, editors. 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom. 982pp.

Power, M.E. 1990. Effects of fish in river food webs. Science. 250: 811–814.

Quinn, T.P. and K.W, Myers. 2004. Anadromy and the migrations of Pacific salmon and trout: Rounsefell revisited. Reviews in Fish Biology and Fisheries. 14: 421–442.

Ramage, B. S., K. L. O'Hara, and B. T. Caldwell. 2010. The role of fire in the competitive dynamics of coast redwood forests. Ecosphere 1.

Riley, S. 2006. Spatial ecology of bobcats and gray foxes in urban and rural zones of a national park. Journal of Wildlife Management 70: 1425–1435.

Schirokauer, D., T. Keeler-Wolf, J. Menke, and P. van der Leeden. 2003. Point Reyes National Seashore, Golden Gate National Recreation Area, and surrounding wildlands plant community classification and mapping project final report. National Park Service, Point Reyes Station, California, USA.

Siegel, R. B., R. L. Wilkerson, and M. Goldin Rose. 2010. Bird monitoring protocol for national parks in the Sierra Nevada Network. Natural Resource Report NPS/SIEN/NRR—2010/231. National Park Service, Fort Collins, Colorado.

SMCHA. 2010. San Mateo County Historical Association. Historic Resource Study for Golden Gate National Recreation Area in San Mateo County. Part V. http://www.nps.gov/goga/learn/historyculture/upload/San-Mateo-HRS-Part-V-Phleger-Estate.pdf.

Sparling, D. W., J. Bickham, D. Cowman, G. M. Fellers, T. Lacher, C. W. Matson, and L. McConnell. 2015. In situ effects of pesticides on amphibians in the Sierra Nevada. Ecotoxicology 24:262–278.

Sparling, D. W., and G. Fellers. 2007. Comparative toxicity of chlorpyrifos, diazinon, malathion and their oxon derivatives to larval *Rana boylii*. Environmental Pollution 147:535–539.

Sparling, D. W., G. M. Fellers, and L. L. McConnell. 2001. Pesticides and amphibian population declines in California, USA. Environmental Toxicology and Chemistry 20:1591–1595.

Stuart, S. N., J. S. Chanson, N. A. Cox, B. E. Young, A. S. L. Rodrigues, D. L. Fischman, and R. W. Waller. 2004. Status and trends of amphibian declines and extinctions worldwide. Science 306:1783–1786.

Swiecki, T. J. and E. Bernhardt. 2006. Disease risk factors and disease progress in coast live oak and tanoak affected by *Phytophthora ramorum* canker (sudden oak death). In: Frankel, Susan J.; Shea, Patrick J.; and Haverty, Michael I., tech. coords. Proceedings of the sudden oak death second science symposium: the state of our knowledge. USDA Gen. Tech. Rep. PSW-GTR-196.

Tierney, G. L., D. Faber-Langendoen, B. R. Mitchell, W. G. Shriver, and J. P. Gibbs. 2009. Monitoring and evaluating the ecological integrity of forest ecosystems. Frontiers in Ecology and the Environment 7:308–316.

Tilman, D. 1999. The ecological consequences of changes in biodiversity: a search for general principles. Ecology 80:1455–1474.

Vitousek, P. M. 1990. Biological invasions and ecosystem processes: towards an integration of population biology and ecosystem studies. Oikos 57:7–13.

Vitousek, P. M., and L. R. Walker. 1989. Biological Invasion by *Myrica faya* in Hawaii – Plant Demography, Nitrogen-Fixation, Ecosystem Effects. Ecol. Monogr. 59:247–265.

Vredenburg, V. T. 2004. Reversing introduced species effects: Experimental removal of introduced fish leads to rapid recovery of a declining frog. Proceedings of the National Academy of Sciences of the United States of America 101:7646–7650.

Vredenburg, V. T., R. A. Knapp, T. S. Tunstall, and C. J. Briggs. 2010. Dynamics of an emerging disease drive large-scale amphibian population extinctions. Proceedings of the National Academy of Sciences of the United States of America 107:9689–9694.

Wake, D. B. 1991. Declining amphibian populations. Science 253:860.

Wake, D. B. 2012. Facing extinction in real time. Science 335:1052–1053.

Wake, D. B., and V. T. Vredenburg. 2008. Are we in the midst of the sixth mass extinction? A view from the world of amphibians. Proceedings of the National Academy of Sciences of the United States of America 105 Suppl: 11466–11473.

Welch, B.A., P.H. Geissler, and P. Latham. 2014, Early detection of invasive plants – Principles and practices: U.S. Geological Survey Scientific Investigations Report 2012–5162, 193 p.

Welsh, H. H., and L. M. Ollivier. 1998. Stream amphibians as indicators of environmental stress: A case study from California's redwoods. Ecological Applications 8:1118–1132.

Whittaker, R. H. 1975. Communities and ecosystems. 2nd edition. Macmillan Publishing, New York.

Appendix 4.4.1. List of priority invasive species at GOGA in 2014

Priority	Scientific Name	Common Name	Family	Code
1	*Ailanthus altissima*	tree-of-heaven	Simaroubaceae	AIAL
1	*Albizia lophantha*	silk tree	Fabaceae	ALLO
1	*Ammophila arenaria*	European beachgrass	Poaceae	AMAR4
1	*Ammophila breviligulata*	American beachgrass	Poaceae	AMBR
1	*Anthoxanthum odorata*	sweet vernal grass	Poaceae	ANOD
1	*Aptenia cordifolia*	heartleaf iceplant	Aizoaceae	APCO
1	*Arctotheca calendula*	fertile capeweed	Asteraceae	ARCA45
1	*Arctotheca prostrate*	creeping capeweed	Asteraceae	ARPR
1	*Arundo donax*	giant reed	Poaceae	ARDO4
1	*Berberis darwinii*	Darwin's berberis	Berberidaceae	BEDA
1	*Carduus acanthoides*	plumeless thistle	Asteraceae	CAAC
1	*Carex pendula*	hanging sedge	Cyperaceae	CAPE45
1	*Carpobrotus chilensis*	sea fig	Aizoaceae	CACH38
1	*Carthamus lanatus*	woolly distaff thistle	Asteraceae	CALA20
1	*Centaurea calcitrapa*	purple starthistle	Asteraceae	CECA2
1	*Centaurea solstitialis*	yellow starthistle	Asteraceae	CESO3
1	*Cirsium arvense*	Canada thistle	Asteraceae	CIAR4
1	*Conicosia pugioniformis*	narrow-leaved iceplant	Aizoaceae	COPU18
1	*Cortaderia selloana*	pampas grass	Poaceae	COSE4
1	*Crataegus monogyna*	singleseed hawthorn	Rosaceae	CRMO
1	*Cynara cardunculus*	Cardoon	Asteraceae	CYCA
1	*Cytisus scoparius*	Scotch broom	Fabaceae	CYSC4
1	*Cytisus striatus*	Portuguese broom	Fabaceae	CYST7
1	*Digitalis purpurea*	purple foxglove	Scrophulariaceae	DIPU
1	*Dittrichia graveolens*	Stinkweed	Asteraceae	DIGR3
1	*Drosanthemum floribundum*	showy dewflower	Aizoaceae	DRFL2
1	*Echium plantagineum*	salvation jane	Boraginaceae	ECPL
1	*Ehrharta calycina*	perennial veldt grass	Poaceae	EHCA
1	*Eichhornia crassipes*	water hyacinth	Pontederiaceae	EICR
1	*Euphorbia oblongata*	oblong spurge	Euphorbiaceae	EUOB4
1	*Hedera canariensis*	Algerian ivy	Araliaceae	HECA
1	*Helichrysum petiolare*	licorice plant	Asteraceae	HEPE8
1	*Hypericum grandifolium*	largeleaf St. Johnswort	Clusiaceae	HYGR6
1	*Hypericum perforatum*	Klamathweed	Clusiaceae	HYPE
1	*Ilex aquifolium*	English holly	Aquifoliaceae	ILAQ80
1	*Lepidium latifolium*	perennial pepperweed	Brassicaceae	LELA2

Priority	Scientific Name	Common Name	Family	Code
1	*Limonium ramosissimum*	Algerian sea lavender	Plumbaginaceae	LIRA2
1	*Ludwigia hexapetala*	six-petal water primrose	Onagraceae	LUGRH
1	*Ludwigia peploides* ssp. *Montevidensis*	floating water primrose	Onagraceae	LUPEM
1	*Maytenus boaria*	Chilean mayten	Celastraceae	MABO8
1	*Mesembryanthemum crystallinum*	ice plant	Aizoaceae	MECR3
1	*Myriophyllum aquaticum*	parrot's-feather	Haloragaceae	MYAQ2
1	*Myriophyllum spicatum*	Eurasian watermilfoil	Haloragaceae	MYSP2
1	*Nicotiana glauca*	tree tobacco	Solanaceae	NIGL
1	*Phalaris arundinacea*	reed canary grass	Poaceae	PHAR3
1	*Phalaris elongate*	?	?	?
1	*Pittosporum crassifolium*	stiffleaf cheesewood	Pittosporaceae	PICR
1	*Pyracantha angustifolia*	narrowleaf firethorn	Rosaceae	PYAN
1	*Rhamnus alaternus*	Italian buckthorn	Rhamnaceae	RHAL12
1	*Robinia pseudoacacia*	black locust	Fabacae	ROPS
1	*Romulea rosea var. australis*	rosy sandcrocus	Iridaceae	ROROA
1	*Rytidosperma caespitosum*	common wallaby grass	Poaceae	RYCA
1	*Rytidosperma penicillatum*	hairy wallaby grass	Poaceae	RYPE
1	*Scabiosa atropurpurea*	mourningbride	Dipsacaceae	SCAT
1	*Spartina alterniflora*	smooth cordgrass	Poaceae	SPAL
1	*Spartium junceum*	Spanish broom	Fabaceae	SPJU2
1	*Stipa manicata*	Andean tussockgrass	Poaceae	NAMA7
1	*Stipa chaetophora*	Stipoid ricegrass	Poaceae	?
1	*Stipa purpurata*	Bristly needle grass	Poaceae	?
1	*Trifolium angustifolium*	narrowleaf clover	Fabaceae	TRAN6
1	*Ulex europaeus*	gorse	Fabaceae	ULEU
1	*Vinca major*	periwinkle	Apocynaceae	VIMA
2	*Acacia melanoxylon*	blackwood acacia	Fabaceae	ACME
2	*Ageratina adenophora*	thoroughwort	Asteraceae	AGAD2
2	*Agrostis avenacea*	Pacific bentgrass	Poaceae	AGAV
2	*Ajuga reptens*	?	?	?
2	*Bromus madritensis* ssp. *rubens*	red brome	Poaceae	BRMAR
2	*Bromus tectorum*	cheat grass	Poaceae	BRTE
2	*Buddleja davidii*	butterfly bush	Scrophulariaceae	BUDA2
2	*Calendula arvensis*	field marigold	Asteraceae	CAAR
2	*Centaurea melitensis*	tocalote	Asteraceae	CEME2
2	*Cestrum parqui*	orange jessamine	Solanaceae	CEPA9
2	*Cynodon dactylon*	Bermudagrass	Poaceae	CYDA

Priority	Scientific Name	Common Name	Family	Code
2	*Dactylis glomerata*	orchard grass	Poaceae	DAGL
2	*Delairea odorata*	cape ivy	Asteraceae	DEOD
2	*Dipsacus fullonum*	Fuller's teasel	Dipsacaceae	DIFU2
2	*Eucalyptus globulus*	bluegum eucalyptus	Myrtaceae	EUGL
2	*Festuca arundinacea*	tall fescue	Poaceae	FEAR3
2	*Geranium purpureum*	herb robert	Geraniaceae	GEROP
2	*Geranium robertianum*	Robert geranium	Geraniaceae	GERO
2	*Glyceria declinata*	waxy mannagrass	Poaceae	GLDE
2	*Hedera helix*	English ivy	Araliaceae	HEHE
2	*Iris pseudacorus*	yellow flag iris	Iridaceae	IRPS
2	*Lamiastrum galeobdolon*	Yellow archangel	Lamiaceae	?
2	*Leptospermum laevigatum*	Australian teatree	Myrtaceae	LELA29
2	*Leucanthemum vulgare*	oxeye daisy	Asteraceae	LEVU
2	*Ligustrum lucidum*	glossy privet	Oleaceae	LILU2
2	*Mentha pulegium*	pennyroyal	Lamiaceae	MEPU
2	*Mercurialis annua*	annual mercury	Rubiaceae	MEAN
2	*Oxalis pes-caprae*	Bermuda buttercup	Oxalidaceae	OXPE
2	*Pennisetum clandestinum*	Kikuyu grass	Poaceae	PECL2
2	*Phoenix canariensis*	Canary isl. date palm	Arecaceae	?
2	*Roldana Petasitis*	velvet groundsel	Asteraceae	ROPE6
2	*Rosa rubiginosa*	sweetbriar rose	Rosaceae	ROEG
2	*Rubus armeniacus*	Himalayan blackberry	Rosaceae	RUDI2
2	*Salsola soda*	oppositeleaf Russian thistle	Chenopoiaceae	SASO3
2	*Solanum laciniatum*	New Zealand nightshade	Solanaceae	SOAV
2	*Sparixis tricolor hybrid*	Harlequin flower	Iridaceae	SPTR
2	*Tradescantia fluminensis*	Wandering jew	Commelinaceae	?
3	*Arrhenatherum elatius*	tall oatgrass	Poaceae	AREL3
3	*Brassica rapa*	field mustard	Brassicaceae	BRRA
3	*Carpobrotus edulis*	iceplant	Aizoaceae	CAED3
3	*Coprosma repens*	creeping mirrorplant	Rubiaceae	CORE4
3	*Cortaderia jubata*	jubata grass	Poaceae	COJU2
3	*Cotoneaster franchetii*	orange cotoneaster	Rosaceae	COFR3
3	*Cotoneaster lacteus*	milkflower cotoneaster	Rosaceae	COLA18
3	*Cotoneaster pannosus*	silverleaf cotoneaster	Rosaceae	COPA14
3	*Ehrharta erecta*	panic veldt grass	Poaceae	EHER
3	*Erigeron karvinskianus*	Latin American fleabane	Asteraceae	ERKA2
3	*Foeniculum vulgare*	sweet fennel	Apiaceae	FOVU
3	*Genista monspessulana*	French broom	Fabaceae	GEMO2

Priority	Scientific Name	Common Name	Family	Code
3	*Gunnera tinctoria*	Chilean gunnera	Gunneraceae	GUTI
3	*Lathyrus latifolius*	everlasting pea	Fabaceae	LALA4
3	*Ligustrum ovalifolium*	California privet	Oleaceae	LIOV
3	*Linaria vulgaris*	butter and eggs	Scrophulariaceae	LIVU2
3	*Lonicera japonica*	Japanese honeysuckle	Caprifoliaceae	LOJA
3	*Parietaria Judaica*	spreading pellitory	Urticaceae	PAJU
3	*Phalaris aquatica*	Harding grass	Poaceae	PHAQ
3	*Pinus radiate*	Monterey pine	Pinaceae	PIRA2
3	*Schinus molle*	pepper tree	Anacardiaceae	SCMO
3	*Tamarix chinensis*	saltcedar	Tamaricaceae	TACH2
3	*Xanthium spinosum*	spiny cockleburr	Asteraceae	XASP2
3	*Xanthium strumarium*	rough cockleburr	Asteraceae	XAST

Appendix 4.4.2. List of species newly documented in GOGA and PORE from 2011 to 2014.

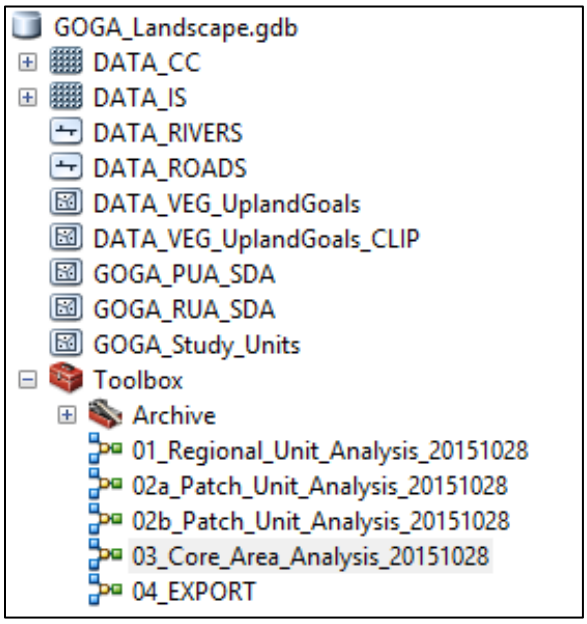
Park	Name	Family	Year
GOGA	*Agrostis avenacea*	Poaceae	2011
GOGA	*Allium vineale*	Alliaceae	2012
GOGA	*Buddleja davidii*	Scrophulariaceae	2011
GOGA	*Coreopsis tinctoria*	Asteraceae	2012
GOGA	*Cotoneaster integrifolius*	Rosaceae	2012
GOGA	*Crassula multicava*	Crassulaceae	2011
GOGA	*Dittrichia graveolens*	Asteraceae	2011
GOGA	*Elymus ponticus*	Poaceae	2011
GOGA	*Erigeron sumatrensis*	Asteraceae	2011
GOGA	*Fallopia baldschuanica*	Polygonaceae	2013
GOGA	*Fallopia japonica*	Polygonaceae	2013
GOGA	*Freesia laxa*	Iridaceae	2012
GOGA	*Geranium robertianum*	Geraniaceae	2012
GOGA	*Geranium rotundifolium*	Geraniaceae	2012
GOGA	*Heliotropium amplexicaule*	Boraginaceae	2011
GOGA	*Hyacinthoides hispanica*	Liliaceae	2014
GOGA	*Iris foetidissima*	Iridaceae	2012
GOGA	*Iris pseudacorus*	Iridaceae	2011
GOGA	*Kickxia elatine*	Plantaginaceae	2011
GOGA	*Lamiastrum galeobdolon*	Lamiaceae	2013
GOGA	*Ludwigia peploides subsp. Montevidensis*	Onagraceae	2011
GOGA	*Lychnis coronaria*	Caryophyllaceae	2014
GOGA	*Mercurialis annua*	Euphorbiaceae	2012
GOGA	*Montanoa hibiscifolia*	Asteraceae	2013
GOGA	*Nymphaea odorata*	Nymphaeaceae	2011
GOGA	*Parietaria Judaica*	Urtacaceae	2013
GOGA	*Passiflora tarminiana*	Passifloraceae	2013
GOGA	*Prunus caroliniana*	Rosaceae	2011
GOGA	*Rhamnus alaternus*	Rhamnaceae	2012
GOGA	*Roldana petasites*	Asteraceae	2012
GOGA	*Rytidosperma caespitosum*	Poaceae	2011
GOGA	*Salsola soda*	Chenopodiaceae	2012
GOGA	*Soleirolia soleirolii*	Urtacaceae	2011
GOGA	*Sporobolus airoides*	Poaceae	2013
GOGA	*Stipa manicata*	Poaceae	2012

Park	Name	Family	Year
GOGA	*Stipa miliacea*	Poaceae	2014
GOGA	*Teucrium fruiticans*	Lamiaceae	2011
GOGA	*Tradescantia fluminensis*	Commelinaceae	2013
GOGA	*Trifolium angustifolium*	Fabaceae	2011
GOGA	*Trifolium striatum*	Fabaceae	2011
GOGA	*Trifolium tomentosum*	Fabaceae	2011
GOGA	*Prunella vulgaris*	Lamiaceae	2014
PORE	*Glyceria declinata*	Poaceae	2011
PORE	*Ligustrum vulgare*	Oleaceae	2014
PORE	*Phalaris elongate*	Poaceae	2012
PORE	*Sorghum halepense*	Poaceae	2014
PORE	*Symphytum officinale*	Boraginaceae	2014

Appendix 4.5.1. ESRI Model Builder (with data layers)

The complete analysis and data are both stored in the file geodatabase (GDB) labeled GOGA_Landsacpe.gdb (see file tree below). The GDB contains the key input datasets listed in the report along with boundary layers for the regional unit analysis (GOGA_RUA_SDA) and the patch unit analysis (GOGA_PUA_SDA). The GDB also contains a detailed polygon feature set that contains all the GOGA landscape study units as defined by NPS (GOGA_Study_Area). In addition, the analytical models are stored in the Toolbox listed in the GDB. The 01_Regional_Unit_Analysis_20151028 model contains the script for the regional unit analysis, the 02a_Patch_Unit_Analysis_20151028 contains the script for building the target and neighborhood boundaries for the patch unit analysis. The 02b_Patch_Unit_Analysis_20151028 contains the script for summarizing the indicators for each patch unit boundary then summarizing them. The 03_Core_Area_Analysis_20151028 contains the script for implementing the core area analysis. The last model (04_EXPORT) is a script the exports all the results into a Microsoft excel format for reporting. Below is a link to the zipped file geodatabase.

https://www.dropbox.com/s/5dmbkuzmio2n7u9/GOGA_Landscape.gdb.zip?dl=0



Appendix 4.7.1.

The following is a list of all of the creeks in the focal regions that we were able to locate sources of information for. Stream physical habitat metrics (area and length of longest flow path) were obtained using the California StreamStat website developed by the USGS (http://water.usgs.gov/osw/streamstats/california.html).

Marin County Streams – Point Reyes National Seashore

1. Fish Hatchery Creek

Fish Hatchery Creek drains 4.1 km^2 and the longest flow path within the watershed is 5.0 km. The creek flows in an easterly direction and drains into the Pacific Ocean at the head of Tomales Bay on the western end of the Giacomini Wetlands.

In 2002, Avocet Research Associates observed steelhead in Fish Hatchery Creek during a field reconnaissance (ARA 2002). The report also notes that steelhead were abundant in the creek in the late 1800s and the population has experienced a marked decline.

In 2011, NPS staff captured 32 steelhead during a pre-construction fish clearing event (Reichmuth pers. comm. 2014).

2. First Valley Creek

First Valley Creek drains 2.1 km^2 and the longest flow path within the watershed is 3.1 km. The creek flows in an easterly direction and drains into the Pacific Ocean on the western shore of Tomales Bay.

A 1976 survey by California Department of Fish and Game (CDFW) staff and observed a single unidentified salmonid (CDFW 1976a). The report notes that streamflow was low, resulting in increased predation.

3. Haggarty Gulch

Haggarty Gulch is a tributary to Lagunitas Creek and drains approximately 1.8 km^2 and the longest flow path within the watershed is 3.0 km. The creek flows in a northeasterly direction and enters Lagunitas Creek near the White House Pool in the town of Inverness.

A list of Marin County streams compiled by CDFW in 2003 indicates that steelhead are known to occur in Haggarty Gulch (CDFW 2003). No primary sources of data were found that indicate steelhead occur in the stream.

4. Bear Valley Creek

Bear Valley Creek is a tributary to Lagunitas Creek and drains approximately 10.9 km^2 and the longest flow path within the watershed is 8.0 km. The creek flows in a northwesterly direction for most of its course prior to entering Lagunitas Creek just east of the town of Inverness.

A 1984 survey conducted by NPS staff estimated steelhead age-0 density at 41.5 individuals per 100 feet (NPS 1984).

NPS and CDFW staff surveyed Bear Valley Creek in 1995 above the road crossing near the Ranger Station. Large trout were captured and were believed to be resident rainbow trout (NPS 1995).

In annual surveys from 2005 to 2007, NPS staff captured multiple age-0+ and age-1+ steelhead in Bear Valley Creek (Reichmuth pers. comm. 2014).

5. Olema Creek

Olema Creek is a tributary to Lagunitas Creek and drains approximately 37.8 km^2 and the longest flow path within the watershed is 18.6 km. The creek flows in a northwesterly direction and enters Lagunitas Creek just in the town of Point Reyes Station. There are small dams on several of the tributaries that drain into Olema Creek, many of which likely restrict steelhead movement.

In 1869, the Marin County Journal reported the catch of a 3 pound salmon trout in Olema Creek (Van Kirk 2000).

In 1897, California Fish Commission staff captured 791 steelhead in Olema Creek and estimated that there were 37,000 steelhead in the creek (CFC 1897).

A 1927 article in the San Rafael Independent reported on the future planting of trout in Olema Creek near the Whitehouse Pool (Van Kirk 2000).

In 1942, CDFW staff reported a mass kill in Olema Creek in which all or nearly all trout were killed (CDFW 1942).

In 1970, Olema Creek was surveyed by CDFW staff and they observed multiple age classes within the creek (CDFW 1970).

A 1979 CDFW memo documented the presence of age-0+ and age-1+ steelhead in Olema Creek (CDFW 1979a).

CDFW staff surveyed Olema Creek in 1982 and estimated that Olema Creek had the most steelhead of all creeks in the Lagunitas Watershed (including mainstem Lagunitas) with an estimated population size of 55,382 individuals in Olema Creek (CDFW 1982).

In 1983, CDFW staff surveyed three stations at Redwood Creek and estimated that densities ranged from 28 fish per 100 feet to 41.8 fish per 100 feet at the three sites (CDFW 1983a).

Beginning in 1993, NPS staff and the Tomales Bay Association have been monitoring steelhead and coho populations in Olema Creek (NPS 2012).

6. Glenbrook Creek

Glenbrook Creek drains 5.6 km^2 and the longest flow path within the watershed is 6.0 km. The creek flows in a southwesterly direction and drains into the Pacific Ocean at the Estero de Limantour State Marine Reserve.

A 1984 survey by NPS staff found multiple age classes of steelhead in Glenbrook Creek upstream of the Turney Dam (NPS 1984).

In 2007, during a dam removal, NPS staff captured multiple steelhead including multiple age classes (Reichmuth pers. comm.).

7. Muddy Hollow Creek

Muddy Hollow Creek drains 8.8 km^2 and the longest flow path within the watershed is 7.2 km. The creek flows in a southwesterly direction and drains into the Pacific Ocean at the Estero de Limantour State Marine Reserve.

A 1984 survey by NPS staff found steelhead age-0 at several locations in the lower reach of Muddy Hollow Creek (NPS 1984).

In 2008, during a dam removal, NPS staff removed two age-1+ steelhead from Muddy Hollow Pond (Reichmuth pers. comm. 2014).

8. Arroyo Hondo

Arroyo Hondo drains 4.7 km^2 and the longest flow path within the watershed is 5.7 km. The creek flows in a southerly direction and drains into the Pacific Ocean just south of the Point Reyes Bird Observatory. There is a small dam in the lower part of the creek that is unlikely to be a total barrier to migration.

A 1984 survey by NPS staff found steelhead age-0 at upstream and downstream sites on Arroyo Hondo (NPS 1984).

9. Alamere Creek

Alamere Creek drains 6.5 km^2 and the longest flow path within the watershed is 5.5 km. The creek flows in a southwesterly direction and drains into the Pacific Ocean west of Crystal Lake. Alamere Creek has a natural waterfall located at the mouth of the stream.

A list of Marin County streams compiled by CDFW in 2003 indicates that steelhead are known to occur in Alamere Creek (CDFW 2003). No primary sources of data were found that indicate steelhead occur in the stream.

10. Coast Creek

Coast Creek drains 10.1 km^2 and the longest flow path within the watershed is 5.6 km. The creek flows in a southwesterly direction and drains into the Pacific Ocean north of Miller's Point.

NPS staff surveyed Coast Creek in 1984 and documented several age classes of steelhead at multiple points in Coast Creek (NPS 1984).

11. Santa Maria Creek

Santa Maria Creek drains 4.4 km^2 and the longest flow path within the watershed is 5.0 km. The creek flows in a southwesterly direction and drains into the Pacific Ocean at Santa Maria Beach.

A survey conducted by NPS staff in 1984 documented the presence of multiple age classes of steelhead at the downstream portion of Santa Maria Creek (NPS 1984).

12. Home Ranch Creek

Home Ranch Creek drains 4.1 km^2 and the longest flow path within the watershed is 4.2 km. The creek flows in a southwesterly direction and drains into the Pacific Ocean at the northeastern end of Home Bay.

A 1984 survey by NPS staff found one steelhead age-0 in the downstream reach of Home Ranch Creek (NPS 1984).

In 2002, NPS staff surveyed Home Ranch Creek and captured multiple age classes of steelhead (NPS 2004b).

During a culvert replacement in 2007, NPS staff captured and relocated multiple age-1+ steelhead from Home Ranch Creek (Reichmuth pers. comm. 2014).

13. Laguna Creek

Laguna Creek (alias Hostel Creek) drains 5.7 km^2 and the longest flow path within the watershed is 5.5 km. The creek flows in a southwesterly direction and drains into a lagoon near the Coast Trail.

A 2002 survey by NPS staff documented the presence of multiple age classes of steelhead in both upstream and downstream sections of Laguna Creek (NPS 2004b).

In 2008, prior to a fish passage restoration project, NPS staff captured multiple steelhead including multiple age classes in Laguna Creek (Reichmuth pers. comm. 2014).

14. Schooner Creek

Schooner Creek drains 2.0 km^2 and the longest flow path within the watershed is 5.2 km. The creek flows in a southwesterly direction and drains into the Pacific Ocean at the northern end of Schooner Bay.

A report published in 2001 by Jon Lee Consulting notes that there are anectodal reports of steelhead occurring in Schooner Creek (JLC 2001). No primary sources of data were found that indicate steelhead occur in the stream.

15. East Schooner Creek

East Schooner Creek (alias Drake's Creek) is a tributary to Schooner Creek and drains 6.7 km^2 and the longest flow path within the watershed is 5.7 km. The creek flows in a southwesterly direction and drains into Schooner Creek near the northern end of Home Bay.

NPS staff surveyed East Schooner Creek in 2002 and report the presence of multiple age classes in the creek (NPS 2002b)

A 2009 Resource Brief published by the NPS reported that steelhead were found in East Schooner Creek during a biological clearance survey and relocated to an unnamed location (NPS 2009).

16. Pine Gulch

Pine Gulch drains 20.5 km^2 and the longest flow path within the watershed is 13.1 km. The creek flows in a southerly direction and drains into the Pacific Ocean on the western end of Bolinas Lagoon just north of the town of Bolinas.

A newspaper article published in 1927 discussed the proposed planting of trout in Pine Gulch (Van Kirk 2000)

In 1977, CDFW electrofished a reach on Pine Gulch and captured age-0 fish (CDFW 1977a).

NPS staff surveyed Pine Gulch in 1984 and found multiple age classes of steelhead (NPS 1984)

In 2002, CDFW staff surveyed Pine Gulch and found age-0 and age-1 steelhead in the creek (CDFW 2002).

Beginning in 1997, NPS staff have been monitoring steelhead and coho populations in Pine Gulch annually (NPS 2012).

17. McClure's Creek

McClure's Creek drains 0.8 km^2 and the longest flow path within the watershed is 1.7 km. The creek flows in a westerly direction and drains into the Pacific Ocean at McClure's Beach.

A newspaper article published in 1927 commented on the proposed planting of trout fry in McClure's creek by CDFW (Van Kirk 2000).

18. Abbotts Creek

Abbotts Creek drains 2.3 km^2 and the longest flow path within the watershed is 3.5 km. The creek flows in a westerly direction and drains into the northeastern end of Abbotts Lagoon.

Based on personal communications with Michael Reichmuth of the NPS, steelhead are known to occur in Abbotts Creek (Reichmuth pers. comm. 2014).

19. Dream Farm Creek

Dream Farm Creek drains 1.8 km^2 and the longest flow path within the watershed is 3.1 km. The creek flows in an easterly direction and drains into the Pacific Ocean on the western shore of Tomales Bay.

Based on personal communications with Michael Reichmuth of the NPS, steelhead are known to occur in Dream Farm Creek (Fong pers. comm. 2014).

20. Kellam Creek

Kellam Creek drains 1.6 km^2 and the longest flow path within the watershed is 2.3 km. The creek flows in a southwesterly direction and drains into the Pacific Ocean south of Point Resistance.

A survey conducted by NPS staff in 1984 determined that there were no steelhead present in Kellam Creek at the time of the survey (NPS 1984).

21. Coast Camp Creek

Coast Camp Creek drains 0.3 km^2 and the longest flow path within the watershed is 0.9 km. The creek flows in a westerly direction and drains into the Pacific Ocean at the Coast Campground.

NPS staff conducted surveys of Coast Camp Creek in 1984 and found that multiple age classes of steelhead were present in the creek (NPS 1984).

22. Wildcat Creek

Wildcat Creek drains 2.3 km^2 and the longest flow path within the watershed is 2.6 km. The creek flows in a southwesterly direction and drains into the Pacific Ocean northwest of Wildcat Lake.

NPS staff surveyed Wildcat Creek in 1984 and did not encounter steelhead (NPS 1984).

23. Woodward Drainage

Woodward Drainage drains 1.8 km^2 and the longest flow path within the watershed is 2.8 km. The creek flows in a southwesterly direction and drains into the Pacific Ocean just south of Sculptured Beach.

NPS staff surveyed the Woodward Drainage in 1984 and did not encounter steelhead (NPS 1984).

Marin County Streams – Golden Gate National Recreation Area

24. Millerton Gulch

Millerton Gulch drains 9.6 km^2 and the longest flow path within the watershed is 6.1 km. The creek flows in a southwesterly direction and drains into the Pacific Ocean on the eastern shore of Tomales Bay.

In 1976, an extreme drought year, CDFW staff surveyed Millerton Gulch and its principal tributary (unnamed) and did not observe any steelhead (CDFW 1976b). However, the report indicates that there is a history of steelhead runs that occur during wet winters.

25. McIsaac Creek

McIsaac Creek is a tributary to Lagunitas Creek and drains approximately 1.3 km^2 and the longest flow path within the watershed is 2.1 km. The creek flows in a southwesterly direction and drains into Lagunitas just south of the juncture between Sir Francis Drake Blvd and Platform Road Bridge

Based on personal communications with Michael Reichmuth, a fisheries biologist with the NPS, steelhead are known to occur in McIsaac Creek (Reichmuth pers. comm. 2014).

26. Lagunitas Creek

Lagunitas Creek is the second largest creek in Marin County and drains 277.6 km^2 and the longest flow path within the watershed is 41.7 km. The creek flows in a northwesterly direction and drains into the Pacific Ocean at the head of Tomales Bay, bisecting the Giacomini Wetlands near the end of its course. The headwaters of Lagunitas Creek originate on the northern slopes of Mount Tamalpais. Peters Dam is located in the upper part of the watershed and is a complete barrier to migration.

An 1865 newspaper article in the Marin County Journal notes that Lagunitas Creek "abounds with trout". In 1870 and 1873, the Marin County Journal reported the capture of large trout by fishermen in Lagunitas Creek. A 1906 article in the San Francisco Chronicle reports on the capture of two large trout.

In 1876, the Marin County Journal reported a large fish kill in Lagunitas Creek, with fish (mainly trout) observed dead for over a mile stretch of the stream (Van Kirk 2000).

In 1897, California Fish Commission Staff surveyed Lagunitas Creek and observed "considerable numbers" of steelhead (CFC 1897). A follow-up survey in 1898 commented on the large numbers of steelhead observed and noted that the stream edges were "black with" steelhead.

Steelhead were planted in Lagunitas Creek sporadically from various source populations throughout the state between the years of 1960 and 1981 (CDFW 1983b).

In 1970, Lagunitas Creek was surveyed by CDFW staff and they observed multiple age classes within the creek (CDFW 1970).

In 1979, DW Kelley and Associates surveyed 25 reaches and found steelhead in all of the reaches (DWK 1980). They noted that most of the steelhead they encountered were planted from the Mad River Hatchery.

In 1982, CDFW staff surveyed Lagunitas Creek and estimated that there were 18,679 individuals in the creek at the time (CDFW 1982).

Between 1983 and 1985, DW Kelley and Associates conducted surveys of Lagunitas Creek and captured multiple age classes in each year (DWK 1988).

Beginning in 1995, spawner surveys have been conducted by Marin Municipal Water District staff annually. Smolt trapping surveys have been conducted annually since 2004 (MMWD 2013).

Based on 2006 smolt trapping data by Stillwater Science, an estimated 4,738 smolts emigrated from Lagunitas Creek (SW 2008).

27. Tomasini Creek

Tomasini Creek is a tributary to Lagunitas Creek and drains approximately 9.8 km^2 and the longest flow path within the watershed is 10.0 km. The creek flows in a southwesterly direction throughout most of its course and drains into Lagunitas on the eastern end of the Giacomini Wetlands at the head of Tomales Bay.

CDFW staff surveyed Tomasini Creek in 1976, an extreme drought year, and found that the stream channel was dry with the exception of two stagnant pools and no fish were reported being observed (CDFW 1976c). Based on information provided by a local resident to the CDFW staff, annual runs of steelhead and coho were observed in the creek prior to their 1976 visit.

As part of monitoring effort of the Giacomini Wetland Project, steelhead were captured in 2005, 2006, 2008, and 2009 by NPS staff (Reichmuth pers. comm. 2014).

28. Devil's Gulch

Devil's Gulch is a tributary to Lagunitas Creek and drains approximately 7.0 km^2 and the longest flow path within the watershed is 5.8 km. The creek flows in a southwesterly direction and enters Lagunitas Creek in Samuel P. Taylor State Park. There is a steep cascade in the upper part of the watershed that is impassable.

In 1955, CDFW staff surveyed Devil's Gulch and observed multiple age classes of steelhead (CDFW 1955). The report notes that the creek had good rearing and spawning habitat for salmonids.

In 1966, CDFW surveyed the entire creek and found juvenile steelhead present in a 2-mile stretch of stream (NMFS 2000).

A 1970 survey by CDFW staff indicated that there were multiple aged classes of steelhead found at stream mile 1.0 (CDFW 1970).

CDFW and consultants for MMWD surveyed Devil's Gulch sporadically between 1970 to 1995 and found multiple age classes of steelhead each year with the highest abundance observed in 1995 (CDFW 1979a, CDFW 1982, DWK 1988, TAI 1995).

A population estimate published in a 1985 report by CDFW estimated that there were a total of 7,635 steelhead within Devil's Gulch.

In 1995, NPS staff began annual monitoring of steelhead and coho populations in Devil's Gulch. Starting with the winter of 2000, MMWD staff have taken over this sampling program and continue to conduct annual surveys on Devil's Gulch (NPS 2012).

In 2005, Stillwater Science surveyed Devil's Gulch and captured multiple age classes during their survey (SW 2005).

29. Cheda Creek

Cheda Creek is a tributary to Lagunitas Creek and drains approximately 3.1 km^2 and the longest flow path within the watershed is 3.1 km. The creek flows in a southwesterly direction and enters Lagunitas Creek in Samuel P. Taylor State Park near the Jewell trailhead.

Beginning in 1995, NPS staff have been monitoring steelhead and coho populations in Cheda Creek annually (NPS 2012).

NPS and CDFW staff surveyed Cheda Creek in 1995 and observed steelhead in the creek above and below a restoration site (NPS 1995). The report notes that Cheda Creek had the highest density of age-0 steelhead of the creeks surveyed, which included Olema Creek and several of its tributaries.

In 2000 and 2001, NPS staff surveyed Cheda Creek and found multiple age classes of steelhead in 2000 and several age-1 steelhead in 2001 (NPS 2001).

30. John West Fork

John West Fork is a tributary to Olema Creek and drains approximately 3.1 km^2 and the longest flow path within the watershed is 3.9 km. The creek flows in a southwesterly direction draining the Bolinas Ridge and enters Olema Creek just south of the Five Brooks Ranch.

Beginning in 1995, NPS staff have been monitoring steelhead and coho populations in John West Fork annually (NPS 2012).

UC Berkeley researches surveyed the John West Fork from 2009 to 2012 and found multiple age classes of steelhead in all years (Hwan pers. comm. 2014). In 2015, UC Berkeley researchers observed age-1+ steelhead during a survey of the creek (Bogan pers. comm. 2015).

31. Giacomini Gulch

Giacomini Gulch is a tributary to Olema Creek and drains approximately 1.8 km^2 and the longest flow path within the watershed is 3.1 km. The creek flows in a southwesterly direction draining the Bolinas Ridge and enters Olema Creek near the road entrance to Five Brooks Ranch.

Based on personal communications with Michael Reichmuth of the NPS, steelhead are known to occur in Giacomini Gulch (Reichmuth pers. comm. 2014).

A surveys of Giacomini Gulch by UC Berkeley researchers in 2015 documented the presence of age-1+ steelhead in the creek (Bogan pers. comm. 2015).

32. Horse Camp Gulch

Horse Camp Gulch is a tributary to Olema Creek and drains approximately 1.0 km^2 and the longest flow path within the watershed is 2.8 km. The creek flows in a southwesterly direction draining the Bolinas Ridge and enters Olema Creek just west of Stewart Horse Camp.

Based on personal communications with Michael Reichmuth of the NPS, steelhead are known to occur in Horse Camp Gulch (Reichmuth pers. comm. 2014).

UC Berkeley researches surveyed Horse Camp Gulch in 2015 and observed multiple age classes of steelhead in the creek (Bogan pers. comm. 2015).

33. Boundary Gulch

Boundary Gulch is a tributary to Olema Creek and drains approximately 1.3 km^2 and the longest flow path within the watershed is 2.5 km. The creek flows in a southwesterly direction draining the Bolinas Ridge and enters Olema Creek north of Stewart Horse Camp.

Based on personal communications with Michael Reichmuth of the NPS, steelhead are known to occur in Boundary Gulch (Reichmuth pers. comm. 2014).

34. Copper Mine Gulch

Copper Mine Gulch is a tributary to Pine Gulch and drains 3.4 km^2 and the longest flow path within the watershed is 4.0 km. The creek flows in a southwesterly direction and drains into Pine Gulch just northwest of the town of Dogtown.

Based on personal communications with Michael Reichmuth of the NPS, steelhead are known to occur in Copper Mine Gulch (Reichmuth pers. comm. 2014).

35. McCurdy Gulch

McCurdy Gulch is a tributary to Pine Gulch and drains 3.1 km^2 and the longest flow path within the watershed is 3.5 km. The creek flows in a southwesterly direction and drains into Pine Gulch near the McCurdy Trail.

Based on personal communications with Michael Reichmuth of the NPS, steelhead are known to occur in McCurdy Gulch (Reichmuth pers. comm. 2014).

UC Berkeley researches surveyed McCurdy Gulch in 2014 and observed age-1+ steelhead in the creek (Bogan pers. comm. 2015).

36. Stinson Gulch

Stinson Gulch drains 2.6 km^2 and the longest flow path within the watershed is 2.8 km. The creek flows in a southwesterly direction and drains into the Pacific Ocean on the southern end of Bolinas Lagoon.

In 1960, CDFW staff surveyed Stinson Gulch and estimated that steelhead density ranged from 35 to 50 individuals per 100 feet (CDFW 1960).

In 1997, NPS staff surveyed the creek and observed steelhead up to river mile 0.75. They estimated the density for age-0 steelhead to be 1.2 fish per meter and 1+ steelhead to be 0.2 fish per meter. Interviews of local residents by NPS staff indicated that steelhead occurred in high abundances in the creek during the 1950s (NPS 2002b).

Spawner surveys conducted by NPS staff in 1999 and 2000 indicated the presence of two redds in each year (NPS 2002b).

37. Audubon Canyon Creek

Audubon Canyon Creek drains 1.29 km^2 and the longest flow path within the watershed is 2.8 km. The creek flows in a southwesterly direction and drains into the Pacific Ocean on the northeastern end of Bolinas Lagoon.

University of San Francisco researchers conducted surveys on Audubon Canyon Creek in 1997 and 1998 and found that steelhead were only present in 1998 (Szychowski 1999).

38. Volunteer Canyon Creek

Volunteer Canyon Creek drains 1.6 km^2 and the longest flow path within the watershed is 2.7 km. The creek flows in a southwesterly direction and drains into the Pacific Ocean on the eastern end of Bolinas Lagoon.

University of San Francisco researchers conducted surveys on Audubon Canyon Creek in 1997 and 1998 and found that steelhead were present in both years (Szychowski 1999). They note that the

abundance of steelhead was much higher than in two nearby creeks that were also surveyed (Audubon Canyon Creek and Garden Club Canyon Creek).

39. Garden Club Canyon Creek

Garden Club Canyon Creek (alias Egret Creek) drains 0.8 km^2 and the longest flow path within the watershed is 2.8 km. The creek flows in a southwesterly direction and drains into the Pacific Ocean on the northwestern end of Bolinas Lagoon.

University of San Francisco researchers conducted surveys on Garden Club Canyon Creek in 1997 and 1998 and found that steelhead were only present in 1998 (Szychowski 1999).

40. Morses Gulch

Morses Gulch drains 1.8 km^2 and the longest flow path within the watershed is 3.0 km. The creek flows in a southwesterly direction and drains into the Pacific Ocean on the eastern end of Bolinas Lagoon. There is a steep cascade in the upper part of the watershed that is impassable.

Spawner surveys conducted by NPS staff on Morses Gulch in 1999 and 2000 indicated the presence of five redds and three redds, respectively. An additional survey that occurred between 1999 and 2000 also documented the presence of juvenile steelhead (NPS 2002c).

Surveys of juveniles in the summer of 2001 by NPS staff indicated that steelhead densities were low (NMFS 2000)

41. McKinnan Gulch

McKinnan Gulch drains 1.8 km^2 and the longest flow path within the watershed is 2.9 km. The creek flows in a southwesterly direction and drains into the Pacific Ocean on the eastern end of Bolinas Lagoon. There is a steep cascade in the upper part of the watershed that is impassable.

Interviews of local residents by NPS staff noted that McKinnan Gulch supported a large number of steelhead in the 1950s (NPS 2002c).

Spawner surveys conducted by NPS staff on McKinnan Gulch in 1999 and 2000 indicated the presence of four redds and two redds, respectively. An additional survey that occurred between 1999 and 2000 also documented the presence of juvenile steelhead (NPS 2002c).

42. Easkoot Creek

Easkoot Creek drains 4.4 km^2 and the longest flow path within the watershed is 3.9 km. The creek flows in a westerly direction and drains into the Pacific Ocean on the southern end of Bolinas Lagoon near Stinson Beach.

Interviews of local residents by NPS staff noted that Easkoot Creek supported a large number of steelhead through the 1970s (NPS 2002c).

Spawner surveys conducted by NPS staff on Easkoot Creek in 1999 and 2000 indicated the presence of five redds and two redds, respectively (NPS 2002c).

Juvenile surveys conducted by NPS staff from 1998 to 2000 indicated that multiple age classes were present in the stream with the exception of 1999 when only age-0 steelhead were found (NPS 2002c).

During the winter of 2004–2005, NPS staff observed steelhead spawners in Easkoot Creek (Reichmuth pers. comm. 2014).

Steelhead were also observed by NPS staff in annual surveys that occurred between 2005 and 2007 (Reichmuth pers. comm. 2014).

43. Wilkins Gulch

Wilkins Gulch drains 1.8 km^2 and the longest flow path within the watershed is 3.1 km. The creek flows in a southwesterly direction and drains into the Pacific Ocean on the northern end of Bolinas Lagoon. These is a waterfall in the middle section of the watershed that is likely impassable.

A survey that occurred between 1999 and 2000 also documented the presence of juvenile steelhead in Wilkins Gulch (NPS 2002b)

44. Lewis Gulch

Lewis Gulch drains 1.8 km^2 and the longest flow path within the watershed is 3.9 km. The creek flows in a southwesterly direction and drains into the Pacific Ocean on the northern end of Bolinas Lagoon.

A survey by NPS staff in 1995 documented the presence of steelhead in Lewis Gulch (NPS 1995).

45. Webb Creek

Webb Creek (alias Steep Ravine Creek) drains 2.8 km^2 and the longest flow path within the watershed is 4.0 km. The creek flows in a southwesterly direction and drains into the Pacific Ocean just north of the Steep Ravine Environmental Campground.

A newspaper article published in 1927 commented on the proposed planting of trout fry in Steep Ravine Creek by CDFW (Van Kirk 2000).

In 1946, CDFW staff surveyed Webb Creek and found resident rainbow trout to be common in the creek (CDFW 1946). A barrier at near the stream mouth was believed to be impassable.

A 1953 field memo by CDFW staff noted that several hundred resident trout were present each year (CDFW 1953). The memo also notes that steelhead spawning has not been observed on the creek, despite the author having heard cases of steelhead and salmon runs entering the creek.

46. Redwood Creek

Redwood Creek drains 22.8 km^2 and the longest flow path within the watershed is 10.7 km. The creek flows in a southwesterly direction and drains into Big Lagoon near Muir Beach.

In 1914, the Marin County Journal reported that 15,000 steelhead were to be planted in Muir Woods (Redwood Creek) and its tributaries (Van Kirk 2000).

In 1956, CDFW staff surveyed Redwood Creek and observed few fingerling steelhead (CDFW 1956). They note that the scarcity of fish was likely due to the survey occurring in March when many steelhead had not yet emerged.

In 1969 and 1970, CDFW staff surveyed Redwood Creek and estimated the density of adult steelhead in the creek to be one fish per 100 feet in 1969 four fish per 100 feet in 1979 (CDFW 1978).

CDFW staff surveyed Redwood Creek 1977 (CDFW 1977) and 1979 (CDFW 1979b) and found age-0+ fish present in two different study reaches in Muir Woods in 1977 and 1979. Additionally, multiple age classes were found at another site in Muir woods in 1979.

In 1988, NPS staff surveyed Redwood Creek and observed steelhead in four reaches (NPS 1988).

Between 1992 and 2001, Dr. Jerry Smith at Jan Jose State University surveyed Redwood Creek annually and observed multiple age classes of steelhead in the creek each year. (SJS 1998, SJS 2000, SJS 2001).

Beginning in 1994, NPS staff have been monitoring steelhead and coho populations in Redwood Creek annually (NPS 2012b).

47. Kent Canyon Creek

Kent Canyon Creek is a tributary to Redwood Creek and drains 2.6 km^2 and the longest flow path within the watershed is 3.2 km. The creek flows in a southeasterly direction and drains into Redwood Creek in Kent Canyon. There is a dam in the middle section of the watershed that is a potential barrier to migration.

Based on personal communications with Michael Reichmuth of the NPS, steelhead are known to occur in Kent Canyon Creek. Spawner surveys conducted by NPS staff have also documented the presence of spawning steelhead in the creek (Reichmuth pers. comm.).

48. Fern Creek

Fern Creek is a tributary to Redwood Creek and drains 2.8 km^2 and the longest flow path within the watershed is 3.8 km. The creek flows in a southerly direction and drains into Redwood Creek near the junction of the Marin and Fern Creek Trails. There is a waterfall in the middle section of the watershed that is likely impasable.

NPS staff conducted surveys of Fern Creek in 1967 and 1968 and report the presence of steelhead juveniles (CDFW 1984).

Beginning in 2004, NPS staff have been monitoring steelhead and coho populations in Fern Creek annually (NPS 2012b).

49. Spikebuck Creek

Spikebuck Creek is a tributary to Redwood Creek and drains 0.8 km^2 and the longest flow path within the watershed is 2.5 km. The creek flows in a southeasterly direction and drains into Redwood Creek south of the Van Wyck Meadow.

A list of Marin County streams compiled by CDFW in 2003 indicates that steelhead are known to occur in Spikebuck Creek (CDFW 2003). No primary sources of data were found that indicate steelhead occur in the stream.

50. Rattlesnake Creek

Rattlesnake Creek is a tributary to Redwood Creek and drains 1.3 km^2 and the longest flow path within the watershed is 2.3 km. The creek flows in a southeasterly direction and drains into Redwood Creek south of the Van Wyck Meadow.

NPS staff conducted surveys of Rattlesnake Creek in 1967 and 1968 and report the presence of steelhead juveniles (CDFW 1984).

A survey conducted by NPS staff in 2013 documented the presence of steelhead in the lower section of the creek (NPS 2013).

51. Bootjack Creek

Bootjack Creek is a tributary to Rattlesnake Creek and drains 0.8 km^2 and the longest flow path within the watershed is 1.7 km. The creek flows in a southeasterly direction and drains into Redwood Creek southwest of the Van Wyck Meadow.

NPS staff conducted surveys of Bootjack Creek in 1967 and 1968 and report the presence of steelhead juveniles (CDFW 1984).

52. Rodeo Creek

Rodeo Creek drains 9.1 km^2 and the longest flow path within the watershed is 4.7 km. The creek flows in a southwesterly direction and drains into the western end of Rodeo Lagoon. There is a weir/dam structure installed by the Army at the east end of Rodeo Lagoon. The weir structure is a partial barrier to upstream movements of salmonids.

NPS staff surveyed Rodeo Creek in 2000 and estimated steelhead density at the survey site to be 0.16 individuals per meter (NPS 2005).

In 2013, NPS staff and park partners documented the presence of 27 adult steelhead in Rodeo Lagoon (Fong pers. comm. 2014).

53. Gerbode Creek

Gerbode Creek is a tributary of Rodeo Creek and drains 4.4 km^2 and the longest flow path within the watershed is 3.3 km. The creek flows in a southwesterly direction and drains into the western end of Rodeo Lagoon.

NPS staff surveyed Gerbode Creek in 2000 and estimated steelhead density at the survey site to be 0.08 individuals per meter (NPS 2005).

54. Cemetery Creek

Cemetery Creek (alias Quarry Gulch) is a tributary to Olema Creek and drains approximately 2.3 km^2 and the longest flow path within the watershed is 3.0 km. The creek flows in a westerly direction and enters Olema Creek near the Olema Cemetary.

NPS surveys of Cemetery Creek in 1995 report that there were several age classes of steelhead in the creek (NPS 1995).

Annual surveys by the NPS from 2005 to 2007 also documented the presence of juvenile steelhead in Cemetery Creek (Reichmuth pers. comm. 2014).

55. Unnamed Creek (South Fork Cemetery Creek)

This creek is a tributary to Olema Creek and drains approximately 0.8 km^2 and the longest flow path within the watershed is 2.1 km. The creek flows in a westerly direction and enters Olema Creek just south of Cemetery Creek.

UC Berkeley researches surveyed the creek in 2013 and observed age-1+ steelhead in the creek (Bogan pers. comm. 2015).

56. Tennessee Valley Creek

Tennessee Valley Creek drains approximately 6.2 km^2 and the longest flow path within the watershed is 4.4 km. The creek flows in a southwesterly direction and enters the Pacific Ocean at Tennessee Cove. There is a dam in the lower part of the watershed that blocks upstream movement.

Based on information provided by NPS staff, Tennessee Valley Creek is not known to have steelhead occurrence (Fong pers. comm. 2014).

57. Cottinham Gulch

Cottinham Gulch is a tributary to McCurdy Gulch and drains approximately 1.0 km^2 and the longest flowpath in within the watershed is 2.8km. The creek flows in a southwesterly direction and enters McCurdy Gulch near the McCurdy Trail.

UC Berkeley researches surveyed Cottinham Gulch in 2015 and did not encounter any steelhead (Bogan pers. comm. 2015).

58. Cronin Gulch

Cronin Gulch is a tributary to Copper Mine Gulch and drains approximately 1.5 km^2 and the longest flowpath in within the watershed is 3.1km. The creek flows in a southwesterly direction and enters Copper Mine Gulch near the town of Dogtown. There is a small dam in the lower part of the watershed that is likely impassable.

UC Berkeley researches surveyed Cronin Gulch in 2015 and did not encounter any steelhead (Bogan pers. comm. 2015).

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59. San Pedro Creek

San Pedro Creek drains 18.9 km^2 and the longest flow path within the watershed is 7.6 kilometers (includes mainstem and longest tributary). The creek flows in a northwesterly direction and drains into the Pacific Ocean at Pacifica State Beach. The headwaters of San Pedro Creek originate on the Sweeney Ridge and Montara Mountain and are relatively undisturbed; however, the lower reaches of the watershed occur in urbanized areas.

CDFW staff documented spawning on San Pedro Creek in 1941. In 1968, CDFW estimated that the steelhead run within the creek consisted of 100 individuals (Becker and Reining 2008).

CDFW staff observed two adult steelhead in the creek during a spot check in 1971. UC Berkeley researchers observed adult steelhead entering the creek in 1972 and 1973 as well (Titus et al. 2011).

In 1973, CDFW staff surveyed the creek and estimated that juvenile trout density to be 5.1 fish per meter. Juvenile steelhead were also captured during surveys in 1974, 1976, and 1979, with densities in 1979 estimated to be between 0.2 and 0.9 fish per meter (Titus et al. 2011).

Approximately 600 steelhead died 1978 following the discharge of an unknown poison into the water (Titus et al. 2011).

In 1985, steelhead from Dry Creek were stocked in San Pedro Creek. 40 pairs of adults spawners were estimated within a 30-meter stretch of stream during a spawning survey in 1985 (Titus et al. 2011).

In 1988, CDFW staff surveyed the lowermost 880 meters of the stream and found age-0+ and age-1+ fish throughout the survey reach (Titus et al. 2011).

USFW staff documented the presence of steelhead in the lower reaches of the creek following a 1989 survey (Becker and Reining 2008).

Hagar Environmental Science, a consulting firm, conducted surveys of San Pedro Creek between 2000 and 2002 and documented the presence of steelhead in the creek and its tributaries, noting that the mainstem and Middle Fork provide the most suitable habitat for steelhead (HES 2002).

In 2004, researchers at San Francisco State University surveyed the creek and observed over 500 fish including multiple age classes (Johnson 2005).

60. Middle Fork San Pedro

The Middle Fork San Pedro Creek is a tributary to San Pedro Creek and drains approximately 3.4 km^2. The length of the longest flow path within the watershed is 2.9 km. The creek flows in a westerly direction and drains into San Pedro Creek near Weiler Ranch Road.

CDFW staff surveyed the Middle Fork San Pedro in 1973 and collected steelhead juveniles (Becker and Reining 2008).

A 2002 report published by Hagar Environmental Science found that the Middle Fork San Pedro had the best spawning habitat in the watershed along with good quality rearing habitat (HES 2002).

In 2004, researchers at San Francisco State University surveyed the Middle Fork San Pedro and observed over 150 fish spanning multiple age classes (Johnson 2005).

61. South Fork San Pedro

The South Fork San Pedro Creek is a tributary to San Pedro Creek and drains approximately 2.9 km^2. The length of the longest flow path within the watershed is 3.5 km. The creek flows in a northerly direction and drains into San Pedro Creek near Weiler Ranch Road. There is a dam in the lower part of South Fork San Pedro that has an unknown pasability status.

CDFW staff surveyed the South Fork San Pedro in 1973 and collected steelhead juveniles (Becker and Reining 2008).

A 2002 report published by Hagar Environmental Science found that steelhead were present in the South Fork San Pedro, but abundances were relatively low compared to the mainstem and Middle Fork because of the lack of suitable spawning habitat (HES 2002).

In 2004, researchers at San Francisco State University surveyed the South Fork San Pedro and estimated the densities of three different age classes in the creek, with an estimated density of 0.144 fish per m^2 for age-0+ fish, 0.015 fish per m^2 for age-1+ fish, and 0.013 fish per m^2 for age-2+ fish (Johnson 2005).

62. Sanchez Fork

The Sanchez Fork is a tributary to Brooks Creek and drains approximately 2.3 km^2. The length of the longest flow path within the watershed is 2.4 km. The creek flows in a northerly direction and drains into San Pedro Creek near the Sanchez Art Center.

In 2004, researchers at San Francisco State University surveyed the Sanchez Fork and observed 16 fish that were age-0+ and age-1+ (Johnson 2005).

63. Martini Creek

Martini Creek drains 2.6 km^2 and the longest flow path within the watershed is 3.3 km. The creek flows in a southwesterly direction and drains into the Pacific Ocean at Montara State Beach. The headwaters of Martini Creek originate on Montara Mountain.

A CDFW memo in 1995 indicates that steelhead/rainbow trout inhabit the creek, despite the presence of a culvert acting as a possible barrier 100 yards upstream of highway 1 (Becker and Reining 2008).

64. San Vicente Creek

San Vicente Creek drains 4.6 km^2 and the longest flow path within the watershed is 6.8 km. The creek flows in a southwesterly direction and drains into the Pacific Ocean just south of the town of Moss Beach. The headwaters of San Vicente Creek drain the western slope Montara Mountain.

A 1994 CDFW creek inventory indicates that a culvert near the Fitzgerald Marine Reserve parking lot blocks steelhead passage into the stream. Ross Taylor and Associates report that anadromous fishes are not likely to be found in the stream (Becker and Reining 2008).

65. Denniston Creek

Denniston Creek drains 10.6 km^2 and the longest flow path within the watershed is 7.7 km. The creek flows in a southwesterly direction and drains into the Pacific Ocean at the city of Half Moon Bay. The headwaters of Denniston Creek drain the western slope Montara Mountain. There is a dam in the lower part of the watershed that is likely a barrier to migration.

Steelhead were documented to occur in the creek in 1941 according to a note by CDFW staff. A survey by CDFW staff in 1953 indicated that steelhead were present in the creek (Becker and Reining 2008).

CDFW staff surveyed Denniston Creek in 1974 and captured six juvenile *O. mykiss* above the dam located at stream kilometer 1.6. Juvenile trout were observed throughout the stream and it is believed that trout observed upstream of the dam are resident rainbow trout (Titus et al. 2011).

In 1992, CDFW staff observed *O. mykiss* throughout the creek (Titus et al. 2011).

In 2011, NPS staff surveyed Denniston Creek and observed 11 resident trout ranging from age-0 to age-1+ (NPS 2011).

66. Pilarcitos

Pilarcitos Creek drains 74.2 km^2 and the longest flow path within the watershed is 22.8 km. The creek flows in a southwesterly direction throughout most of its course and drains into the Pacific Ocean at the city of Half Moon Bay. The headwaters of Pilarcitos Creek drain the eastern slope of Montara Mountain. Pilarcitos Dam and Stone Dam are operated by the San Francisco Public Utilities Commission in the upper part of the watershed.

In 1953, CDFW staff surveyed Pilarcitos Creek and estimated that there were approximately 5,500 steelhead between Stone Dam and Contra Costa Water District property (Becker and Raining 2008).

In 1960, CDFW staff estimated that steelhead runs in Pilarcitos Creek consisted of 50 to100 fish (Becker and Raining 2008).

In 1995, Phil Williams and Associated sampled two reaches on Pilarcitos Creek and found age-0 and age-1 fish (PWA 1996).

67. Arroyo Leon

Arroyo Leon is a tributary to Pilarcitos Creek and drains approximately 22.3 km^2 and the longest flow path within the watershed is 11.4 km. It flows in a northwesterly direction entering Pilarcitos in the city of Half Moon Bay. There is a waterfall in the lower section of the creek that is unlikely to be a barrier to migration.

Steelhead were documented to occur in Arroyo Leon according to a note by CDFW staff in the mid-1930s (Titus et al. 2011) and in 1941 (Becker and Reining 2008).

A 1958 survey by CDFW staff indicates that multiple age classes of steelhead were present and that the spawning and rearing habitat of Arroyo Leon exceeded Pilarcitos Creek in terms of quality (Becker and Reining 2008).

A survey by Philip Williams and Associates in 1995 documented the presence of smolt-sized *O. mykiss* occurring in the creek (PWA 1996).

A 2002 report published by Hagar Environmental Science found multiple year classes of steelhead in Arroyo Leon (HES 2002).

68. Mills

Mills Creek is a tributary to Arroyo Leon and drains approximately 10.1 km^2 and the longest flow path within the watershed is 6.8 km. It flows in a westerly direction entering Arroyo Leon in Higgins Canyon.

CDFW staff noted the presence of *O. mykiss* juveniles in 1958 despite providing suboptimal rearing habitat (Becker and Reining 2008).

In 1995, surveys conducted for a restoration project on Mills Creek and documented the presence of *O. mykiss* juveniles and noted that there were high densities (PWA 1996).

69. Madonna Creek

Madonna Creek is a tributary to Pilarcitos Creek and drains approximately 4.4 km^2 and the longest flow path within the watershed is 5.1 km. It flows in a westerly direction entering Pilarcitos Creek in Digges Canyon.

In 1995, Philip Williams and Associates surveyed Madonna Creek to determine if salmonids were present and they did not observe any. They noted that the presence of a downstream barrier at stream mile 0.3 and low stream flow meant that the creek had a "low potential for salmonid fisheries" (PWA 1996).

70. Apanolio Creek

Apanolio Creek is a tributary to Pilarcitos Creek and drains approximately 5.4 km^2 and the longest flow path within the watershed is 6.7 km. It flows in a southerly direction entering Pilarcitos Creek at Digges Canyon. There is a dam in the middle section of the watershed that is impassable throughout most of the year.

Multiple age classes of *O. mykiss* were observed in Apanolio Creek by CDFW staff in 1987 (Becker and Reining 2008).

Philip Williams and Associates surveyed the creek in 1995 and found relatively high densities of *O. mykiss* (PWA 1996).

71. Corinda Los Trancos

Corinda Los Trancos Creek is a tributary to Pilarcitos Creek and drains approximately 2.3 km^2 and the longest flow path within the watershed is 5.0 km. It flows in a southerly direction entering Pilarcitos Creek just east of Digges Canyon.

In 1974, a letter by CDFW reported that juvenile steelhead were present in the lower sections of the stream and absent from upstream reaches (Becker and Reining 2008).

In 1995, Philip Williams and Associates surveyed a section of the creek and observed 4 *O. mykiss* juveniles (PWA 1996).

72. Nuff Creek

Nuff Creek is a tributary to Pilarcitos Creek and drains approximately 2.8 km^2 and the longest flow path within the watershed is 3.7 km. It flows in a southerly direction entering Pilarcitos Creek in Albert Canyon.

Phil Williams and Associates spot checked the creek in 1995 and did not observe any steelhead (PWA 1996). They report that steelhead have not been present in the creek for at least 30 years.

73. Albert Canyon Creek

Albert Canyon Creek is a tributary to Pilarcitos Creek and drains approximately 3.1 km^2 and the longest flow path within the watershed is 3.3 km. It flows in a northerly direction entering Pilarcitos Creek in Albert Canyon.

Multiple age classes of *O. mykiss* were observed in Albert Canyon Creek by CDFW staff in 1988. Surveys by Phil Williams and Associates in 1997 and 1998 reported the presence of *O. mykiss* in both years (Becker and Reining 2008).

74. West Union Creek

West Union Creek is a tributary to Bear Creek and drains 22.5 km^2 and the longest flow path within the watershed is 8.2 km. The creek flows in a southeasterly direction and drains into Bear Creek in the town of Woodside. There is a waterfall in the upper part of the watershed that is likely a migration barrier.

Surveys in 1996 and 1999 by NPS staff documented the presence of multiple age classes of steelhead in West Union Creek (NPS 2004a).

75. Locks Creek

Locks Creek is a tributary to Frenchmans Creek and drains 0.8 km^2 and the longest flow path within the watershed is 1.6 km. The creek flows in a southerly direction entering Frenchmans Creek in Rancho Corral de Tierra.

CDFW staff noted that steelhead spawning occurred in Locks Creek during the 1960s (Becker and Reining 2008).

76. Deer Creek

Deer Creek drains 1.8 km^2 and the longest flow path within the watershed is 3.7 km. The creek flows in a southwesterly direction and drains into the Pacific Ocean in the town of El Granada.

A report published in 1962 listed Deer Creek along with other several other streams as having resident trout populations and some of these including steelhead as well; however, the streams with known steelhead occurrence were not specified (CDFW 1962).

In 1994, CDFW staff reported that Deer Creek resembled an urban ditch; however, local residents recall a history of trout occurrence in the stream (Becker and Reining 2008).

San Francisco County Streams – Golden Gate National Recreation Area

77. Lobos Creek

Lobos Creek drains 9.8 km^2 and the longest flow path within the watershed is 6.2 km. The creek flows in a westerly direction and drains into the Pacific Ocean at China Beach in the city of San Francisco.

NPS staff surveyed Lobos Creek in 1998 and did not encounter steelhead (NPS 1998).

List of streams lacking steelhead occurrence data

These streams can be located using the "stream layer" in the GIS data available through NPS. Note that this list is limited to streams that we could locate stream names for. There are many others unnamed streams that are not included.

Marin County Streams – Point Reyes National Seashore

- McCormick Creek
- Mesa Creek
- Silver Hills Creek

Marin County Streams – Golden Gate National Recreation Area

- Blackrock CreekCold Stream
- Coyote Creek
- Deadmans Gulch
- Frank Valley Creek
- Green Gulch Irigation
- Irving Creek
- Lone Tree Creek
- Pike County Creek
- Ranchhouse Creek
- Stewart Point Creek

- Water Tank Gulch
- Zanardi Creek

San Mateo County Streams – Golden Gate National Recreation Area

Arroyo de en Medio

Literature Cited

Avocet Research Associates (ARA). 2002. Giacomini Wetlands Restroation Site: Special Status Animal Species—reconnaissance and compliance. Final Report to Point Reyes National Seashore, National Park Service. 22 November 2002.

Becker, G.S., and I.J. Reining. 2008. Steelhead/rainbow trout (*Oncorhynchus mykiss*) resources south of the Golden Gate, California. Cartography by D.A. Asbury. Center for Ecosystem Management and Restoration. Oakland, CA.

California Fish Commission (CFC). 1897. Notes on the movement of the young of the steelhead trout (Salmo gairdneri, Richardson) in Marin County streams. Report by N.B. Schofield.

Department of Fish and Game (CDFW). 1942. Report of fish kill on Olema. Report by Leo Shapovalov.

Department of Fish and Game (CDFW). 1946. Steep Ravine Creek Stream Survey. Report by Leo Shapovalov.

Department of Fish and Game (CDFW). 1953. Steep Ravine Creek Field Memo. Report by A. Giddings.

Department of Fish and Game (CDFW). 1955. Devil's Gulch Stream Survey. Report by W.A. Evans.

Department of Fish and Game (CDFW). 1956. Redwood Creek Stream Survey. Report by C.K. Fisher.

Department of Fish and Game (CDFW). 1960. Stinson Gulch Creek Stream Survey. Report by Jack T. Allen.

Department of Fish and Game (CDFW). 1962. The freshwater fish and fisheries of the San Francisco Bay Area. Report by John E. Skinner.

Department of Fish and Game (CDFW). 1970. Juvenile steelhead and silver salmon population estimates, San Geronimo, Lagunitas, and Olema Creeks, Marin County. Report by E. Vestal.

Department of Fish and Game (CDFW). 1976a. First Valley Creek Stream Survey. Report by Ron Curtis and Gary Scoppettone.

Department of Fish and Game (CDFW). 1976c. Field observations of Tomasini Creek, Marin County; 15 September, 1976. Report by Maureen Cogger and Ron Curtis.

Department of Fish and Game. 1977a. Fish population samplings; Marin County streams. Report by Ivan L. Paulsen.

Department of Fish and Game (CDFW). 1977b. Fish population; Redwood Creek, Marin County. Report by Ivan L. Paulsen.

Department of Fish and Game (CDFW). 1978. Silver salmon and steelhead survey of Redwood Creek, Marin County. Report by Ivan L. Paulsen.

Department of Fish and Game (CDFW). 1979a. Devil's Gulch Creek, Marin County; Steelhead observation. Report by Keith R. Anderson and Ivan L. Paulsen.

Department of Fish and Game (CDFW). 1979b. Redwood Creek, Marin County. Report by Bill Cox.

Department of Fish and Game (CDFW). 1982. Fish population survey, Lagunitas Creek Drainage, Marin County, 1982. Report by John W. Emig.

Department of Fish and Game (CDFW). 1983a. Lagunitas and Nicasio Creek planting of coho and steelhead (1958–1981). Letter to D.W. Kelley by E. Royce Gunter Jr.

Department of Fish and Game (CDFW). 1983b. Lagunitas and Nicasio Creek planting of coho and steelhead (1958–1981). Letter to D.W. Kelley by E. Royce Gunter Jr.

Department of Fish and Game (CDFW). 1984. An assessment of coho on and steelhead resource requirements in Redwood Creek, Marin County. Report by William M. Snider.

Department of Fish and Game (CDFW). 2002. Pine Gulch Creek, Marin County. Report by Bill Cox.

Department of Fish and Game (CDFW). 2003. Major streams in Marin County. Report by Bill Cox.

D.W. Kelley and Associates (DWK). 1980. Relationships between streamflow, rearing habitat, substrate conditions, and juvenile steelhead populations in Lagunitas Creek, Maring County, 1979. Report by Don W. Kelley and D.H. Dettman.

D.W. Kelley and Associates (DWK). 1988. Investigations of salmon and steelhead in Lagunitas Creek, Marin County, California. Volume I: Migration, spawning, embryo incubation and emergence, juvenile rearing, emigration. Report by Paul M. Bratovich and Don W. Kelley.

Hagar Environmental Science (HES). 2002. Steelhead habitat assessment for the San Pedro Creek Watershed.

John Lee Consulting (JLC). 2001. Benthic macroinvertebrate analysis of twelve sites in Point Reyes National Seashore using the California Stream Bioassessment Procedure. Report by Jon Lee Consulting and Brannon Ketcham.

Johnson, R.M. 2005. A basin-wide snorkel survey of the San Pedro Creek steelhead (*Oncorhynchus mykiss*) population. San Francisco State Master's Thesis.

Marin Municipal Water District (MMWD). 2013. Smolt monitoring in the Lagunitas Creek Watershed – 2013. Report by Eric Ettlinger, Ariana Chiapella, Mike Paccassi, and Gregory Andrews.

National Marine Fisheries Service (NMFS). 2000. California coastal salmon and steelhead current stream habitat distribution table. Prepared by Weldon Jones.

National Marine Fisheries Service (NMSF). 2011. 5-year review: Summary and evaluation of Central California Coast steelhead DPS Northern California steelhead DPS

National Park Service (NPS). 1984. Inland fish survey of Point Reyes National Seashore. Report by Gary M. Fellers, David W. Self, and John F. Ranlett

National Park Service (NPS). 1988. Survey of salmonid fish and their habitat Redwood Creek, Marin County, California. Report by Terrence D. Hofstra and David G. Anderson

National Park Service (NPS). 1995. Olema Creek watershed and Cheda Creek fish surveys.

National Park Service (NPS). 1998. Fish and flow measurements and general observations for Lobos Creek, San Francisco, California, Spring 1998.

National Park Service (NPS). 2002a Restoring salmon and trout habitat at East Schooner Creek, Point Reyes National Seashore. Report by Alison Williams.

National Park Service (NPS). 2005. California Freshwater Shrimp and Fish Surveys Along Tennessee, Rodeo, and Gerbode Creeks, Marin Co. for the Marin Headlands-Fort Baker Transportation Plan. Report by Darren Fong.

National Park Service (NPS). 2012a. Summary of fish sampling activities within Denniston Creek near Upper Cabrillo Farms Field (San Mateo County, CA) on November 8–9, 2011. Report by Darren Fong.

National Park Service (NPS). 2013. Bootjack Trail fish survey, Rattlesnake Creek, Mount Tamalpais State Park. Survey area map.

Philip Williams and Associates (PWA), Habitat Restoration Group, Prunuske Chatham, and Callander Associates. 1996. Pilarcitos Creek Restoration Plan.

Szychowski, L.S. 1999. Fish species identification and stream habitat evaluations of the three creeks that drain from Audubon Canyon Ranch, Bolinas, California. University of San Francisco Master's Thesis.

San Jose State University (SJS). 1998. Distribution and abundance of coho and steelhead in Redwood Creek in Fall 1998. Report by Jerry Smith.

San Jose State University (SJS). 2000. Distribution and abundance of juvenile coho and steelhead in Redwood Creek in Fall 2000. Report by Jerry Smith.

San Jose State University (SJS). 2001. Distribution and abundance of juvenile coho and steelhead in Redwood Creek in Fall 2001. Report by Jerry Smith.

Trihey and Associates, Inc (TAI). 1995. Abundance of steelhead and coho salmon in the Lagunitas Creek Drainage, Maring County, California.

Titus, R.G., Erman, D.C., and W.M. Snider. 2011. History and status of steelhead in California coastal drainages south of San Francisco Bay.

Appendix 4.7.2. Steelhead occurrence data

Microsoft Excel spreadsheets containing data on information that was extracted from information sources pertaining to steelhead occurrence. The “Known.point.location” worksheet includes information on surveys that included a single location description. The “Reach.location” worksheet includes information on surveys that provided upstream and downstream location information (i.e., a defined study reach). The “Unknown.point.location” includes information on sources of information that only included the stream name and no other location description. The “No.fish.location” worksheet includes information on surveys that reported that no fish were observed or captured during the survey. Lastly, the “Column.explanation” worksheet includes a detailed description of column headings in the other worksheets.

Appendix 4.7.3. Barriers data

Microsoft Excel spreadsheets containing data on (1) information that was extracted from information sources pertaining to potential barriers from literature sources and (2) CFPAD. The “Barriers.report” worksheet includes barrier information from reports that we found during our literature search. The “CFPAD” worksheet includes data obtained from California Fish Passage Assessment Database. The “Column.explanation” worksheet includes a detailed description of column headings in the other worksheets.

Appendix 4.8.1. Shorebird analysis details and model results

Dataset Clarification

Beach Watch data was restricted for beaches within GOGA jurisdiction and the four most common and easily identifiable shorebird species: Marbled Godwit, Sanderling, Whimbrel, and Willet. Before analysis, 700 rows were deleted from the datasheet. These were rows in which the number of kilometers surveyed was zero. In all these rows (except one) the number of birds observed was also zero, so it was assumed that these were not actual surveys that should be included in the analysis.

Focal Species Individual Trend 1993–2013 Results

Likelihood ratio tests showed that all three independent variables (Year, Beach, and Season) for all four species were significant. Interactions between Year and Beach were also significant for all four species meaning that the abundance trend observed over the 20-year sampling window varied depending on which beach was being sampled. While the main effect of Year was still significant in all cases, it's important to understand that the effect size (and sign) varied significantly among the beaches.

Marbled Godwit

Tables 1a and 1b provide additional information about Marbled Godwit.

Table 1a. Results of model selection using AIC for Marbled Godwit.

Model (Independent Variables)	AIC Value
Year	2752.7
Beach	2299.0
Season	2733.1
Year + Beach	2288.7
Year + Season	2734.9
Beach + Season	2258.4
Year + Beach + Season	2251.2
Year * Beach + Season (Year*Beach Interaction Present)	2223.1

Table 1b. Marbled Godwit best fitting model summary.

Parameter	Estimate (b)[1]	Standard Error[2]	p-value[3]
Intercept	160.70000	75.75000	NA
Year	-0.08044	0.03783	0.00200

[1] "Estimate" values are in the transformed units used by the model. To get estimated values the equation $\hat{p} = exp\,(b)^x \times exp\,(a)$ must be used; where a is the intercept and x is the year. Parameter estimates are not given for individual coefficients for categorical variables (beach and season).

[2] Standard errors are only reported for year and intercept.

[3] The function glm.nb does not calculate group-wide p-values. The p-values reported here were calculated using likelihood ratios by comparing models with and without each factor using the anova() function in R.

Table 1b (continued). Marbled Godwit best fitting model summary.

Parameter	Estimate (*b*)[1]	Standard Error[2]	p-value[3]
Beach	NA	NA	<0.00010
Season	NA	NA	<0.00010
Year:Beach (interaction)	NA	NA	<0.00010

[1] "Estimate" values are in the transformed units used by the model. To get estimated values the equation $\hat{p} = exp(b)^x \times exp(a)$ must be used; where a is the intercept and x is the year. Parameter estimates are not given for individual coefficients for categorical variables (beach and season).

[2] Standard errors are only reported for year and intercept.

[3] The function glm.nb does not calculate group-wide p-values. The p-values reported here were calculated using likelihood ratios by comparing models with and without each factor using the anova() function in R.

Sanderling

Tables 2a and 2b provide additional information about Sanderling.

Table 2a. Results of model selection using AIC for Sanderling.

Model (Independent Variables)	AIC Value
Year	5115.4
Beach	4661.1
Season	5098.0
Year + Beach	4587.0
Year + Season	5084.3
Beach + Season	4499.4
Year + Beach + Season	4430.4
Year * Beach + Season (Year*Beach Interaction Present)	4362.4

Table 2b. Sanderling best fitting model summary.

Parameter	Estimate (*b*)[1]	Standard Error[2]	p-value[3]
Intercept	442.50000	68.33000	NA
Year	-0.02200	-0.03412	<0.0001
Beach	NA	NA	<0.0001
Season	NA	NA	<0.0001
Year:Beach (interaction)	NA	NA	<0.0001

[1] "Estimate" values are in the transformed units used by the model. To get estimated values the equation $\hat{p} = exp(b)^x \times exp(a)$ must be used; where a is the intercept and x is the year. Parameter estimates are not given for individual coefficients for categorical variables (beach and season).

[2] Standard errors are only reported for year and intercept.

[3] The function glm.nb does not calculate group-wide p-values. The p-values reported here were calculated using likelihood ratios by comparing models with and without each factor using the anova() function in R.

Whimbrel

Tables 3a and 3b provide additional information about Whimbrel.

Table 3a. Results of model selection using AIC for Whimbrel**.**

Model (Independent Variables)	AIC Value
Year	1836.8
Beach	1636.3
Season	1725.3
Year + Beach	1621.1
Year + Season	1709.2
Beach + Season	1437.0
Year + Beach + Season	1415.9
Year * Beach + Season (Year*Beach Interaction Present)	**1362.2**

Table 3b. Whimbrel best fitting model summary.

Parameter	Estimate (*b*)[1]	Standard Error[2]	p-value[3]
Intercept	-68.51441	101.29014	NA
Year	0.03273	0.05052	<0.0001
Beach	NA	NA	<0.0001
Season	NA	NA	<0.0001
Year:Beach (interaction)	NA	NA	<0.0001

[1] "Estimate" values are in the transformed units used by the model. To get estimated values the equation $\hat{p} = exp(b)^x \times exp(a)$ must be used; where a is the intercept and x is the year. Parameter estimates are not given for individual coefficients for categorical variables (beach and season).

[2] Standard errors are only reported for year and intercept.

[3] The function glm.nb does not calculate group-wide p-values. The p-values reported here were calculated using likelihood ratios by comparing models with and without each factor using the anova() function in R.

Willet

Tables 4a and 4b provide additional information about Willet.

Table 4a. Results of model selection using AIC for Willet**.**

Model (Independent Variables)	AIC Value
Year	4193.4
Beach	3725.4
Season	4055.3
Year + Beach	3655.3
Year + Season	4024.3

Table 4a (continued). Results of model selection using AIC for Willet**.**

Model (Independent Variables)	AIC Value
Beach + Season	3553.5
Year + Beach + Season	3481.8
Year * Beach + Season (Year*Beach Interaction Present)	**3473.1**

Table 4b. Willet best fitting model summary.

Parameter	Estimate (*b*)[1]	Standard Error[2]	p-value[3]
Intercept	239.6	63.86	NA
Year	-0.1193	0.03189	<0.0001
Beach	NA	NA	<0.0001
Season	NA	NA	<0.0001
Year:Beach (interaction)	NA	NA	<0.0001

[1] "Estimate" values are in the transformed units used by the model. To get estimated values the equation $\hat{p} = exp(b)^x \times exp(a)$ must be used; where a is the intercept and x is the year. Parameter estimates are not given for individual coefficients for categorical variables (beach and season).

[2] Standard errors are only reported for year and intercept.

[3] The function glm.nb does not calculate group-wide p-values. The p-values reported here were calculated using likelihood ratios by comparing models with and without each factor using the anova() function in R.

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