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A Natural Resource Condition Assessment for Point Reyes National Seashore

Natural Resource Report NPS/PORE/NRR—2019/1895



ON THE COVER
Drakes Estero, Point Reyes National Seashore
Photograph by: Robert Campbell

A Natural Resource Condition Assessment for Point Reyes National Seashore

Natural Resource Report NPS/PORE/NRR—2019/1895

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Table A. List of authors and contributed chapters.

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Acronyms and Abbreviations

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
ESD:	Ecological Site Description
ESU:	Evolutionary Significant Unit

Acronyms and Abbreviations (continued)

GFNMS:	Gulf of The Farallones National Marine Sanctuary
GGNPC:	Golden Gate National Park Conservancy
GIS:	Geographic Information System
GMP:	General Management Plan
GOGA:	Golden Gate National Recreation Area
I&M:	Natural Resources Inventory & Monitoring Program
IMPROVE:	Interagency Monitoring of Protected Visual Environments
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

Acronyms and Abbreviations (continued)

RCDT:	Rancho Corral De Tierra
RDM:	Residual Dry Matter
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 Point Reyes National Seashore (PORE) managers and scientists in developing recommendations for improving or maintaining natural resource conditions in the park.

Point Reyes National Seashore was established by President John F. Kennedy on September 13, 1962, to preserve and protect wilderness, natural ecosystems, and cultural resources along the diminishing undeveloped coastline of the western United States. PORE forms a large continuous expanse of land along the central coast of California that includes more congressionally designated wilderness than any other national seashore (32,370 acres or 46% of the park's total 71,000 acres). Located just an hour drive from a densely populated metropolitan area, the Seashore is a sanctuary for many plant and animal species.

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 restricted 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 PORE. The final report includes eight focal resources:

- Amphibians/California Red-legged Frog
- Breeding Landbird Diversity
- Coastal Dunes
- Forests
- Grasslands
- Invasive plants
- Rare plants
- Salmonids

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. 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. These resource assessments review not only the most current published literature, but also unpublished park information and the perspectives of park experts.

Each focal resource assessed in this report was characterized by one or more indicators. When possible, existing data for the established measures of each indicator were analyzed and compared to designated reference conditions. The impact of key stressors was also considered in the evaluation of current condition. Following analysis of each focal resource, lead scientists worked with NPS collaborators to assign condition levels to the resource. Where data permitted, the future trend of each resource condition was also projected and the focal resource condition assessments were calculated for each management zone (i.e., natural lands, wilderness, and pastoral lands).

The final project framework included 8 focal resources and 25 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. Four indicators were determined to be of significant concern: the future forest distributions under climate change, forest exotic disease progression, the potential for spread of invasive plants, and the success of rare plant introduction efforts. Eleven of the indicators were rated as warranting moderate concern: forest biomass accumulation, the risk of a high intensity forest fire, the potential for compounding perturbations in forests, the number of landbird habitats, the invasion of exotic plant species in grasslands, the encroachment of shrub and tree species in grasslands, the decreased frequency and abundance of desired native plant species in coastal grasslands, levels of exotic plant propagule pressure, steelhead population size, steelhead population distribution, and barriers to steelhead migration. There was not enough available data to assign a condition to two indicators: coastal dune ecological site description and detections of California giant salamanders. Information sufficient to estimate trends was lacking for 9 of the 25 indicators and none of the indicator rankings 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 were determined to be in moderate or good condition. However, the analysis suggests a declining trend for both grasslands and steelhead populations. Amphibians, breeding birds, and rare plant species were categorized as being in good condition. Only the condition of invasive plants was considered to be of significant concern. Amphibians, breeding birds, and forests all exhibited a stable trend. Information was insufficient to determine the trend for invasive plant and rare plant populations and there was not enough data available to assign a condition to one focal resource - the coastal dunes.

Several stressors have been identified that influence the condition of multiple priority resources within PORE. Those of primary concern include climate change, the presence of non-native species, and habitat loss and fragmentation due to human activity. Improved understanding of these threats, and how they relate to the condition of the assessed focal resources, would help Point Reyes National Seashore 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 GIS (map) products;[4]
- Summarize key findings by park areas; and[5]
- 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.

[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.

These influences may include past activities or conditions that provide a helpful context for 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

Point Reyes National Seashore (PORE) and the Northern lands of Golden Gate National Recreation Area (GOGA) form a large continuous expanse of land along the central coast of California which, except for a significant agricultural presence, has few human inhabitants within or near the park's borders (Figure 2.1.1). Located just an hour drive from the densely populated San Francisco Bay area, the Seashore is a sanctuary for a myriad of plant and animal species, and for humans to experience, learn about and enjoy natural California ecosystems. PORE has a long and rich history of Native American (Coast Miwok) presence and culture that is preserved, curated, studied, celebrated, and interpreted by NPS and its Native American partners. Importantly, Point Reyes National Seashore includes more congressionally designated wilderness (32,730 acres or 46% of the park's total 71,000 acres) than any other national seashore (GOGA lands do not include any federally designated wilderness areas).



Figure 2.1.1. Overview of areas managed by Point Reyes National Seashore. Marine boundary extends ¼ mile from shore in both the Pacific Ocean and Tomales Bay. All of Drakes Estero is within park boundaries.

2.1.1. Enabling Legislation

Point Reyes National Seashore was established by President John F. Kennedy on September 13, 1962 (Public Law 87-657). The original enabling legislation emphasized the need to "save and preserve a portion of the diminishing seashore of the United States that remains undeveloped."

In 1976 the Congress passed the Point Reyes Wilderness Act, designating approximately 25,000 acres within the Seashore as Wilderness (Public Law 94-544). Under Public Law 99-68, this Wilderness was renamed the Phillip Burton Wilderness to honor the United States Congressman from California for his efforts to preserve natural lands in the San Francisco Bay Area. With the Point Reyes Wilderness Act, the US Congress directed the Park Service to protect the Seashore and its resources "in a manner which provides for such recreational, educational, historic preservation, interpretation, and scientific research opportunities as are consistent with, based upon, and supportive of the maximum protection, restoration, and preservation of the natural environment."

In both legislation and deliberation, Congress described the resources of the Point Reyes Peninsula that inspired the American people to place it under public stewardship. These "Fundamental Resources and Values" which warrant primary consideration during planning and management of the Seashore were reiterated in the park's Foundation Document (NPS 2017b) and include:

- Wilderness.
- Scenic Coastal Landscapes.
- Marine, Estuarine, and Freshwater Environments.
- Diversity of Habitats and Native Species.
- Maritime Cultural Landscapes.
- Continuum of Human Use.
- Opportunities for Inspiration and Recreation.
- Science and Learning.

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

Point Reyes National Seashore is located in west Marin County California, approximately 40 miles northwest of San Francisco (Figure 2.1.1). The jurisdictional boundary of PORE encompasses 71,046 acres of beaches, coastal cliffs and headlands, marine terraces, coastal uplands, and forests. 32,730 acres are congressionally designated wilderness and the only marine wilderness on the Pacific Coast south of Alaska. PORE manages 19,265 acres of the North District of GOGA lands adjacent to PORE and north of Bolinas-Fairfax Road (Figure 2.1.1). This area includes over 20,000 acres of estuarine and marine waters. The marine boundary of PORE generally extends ¼ mile offshore. It is primarily adjacent to the Greater Farallones National Marine Sanctuary and includes four California State Areas of Special Biological Significance (ASBS) at Duxbury Reef, Double Point, Point Reyes Headlands, and Bird Rock. Importantly, three State Marine Protected Areas that limit or completely

restrict fishing also occur partially or wholly within the PORE boundaries, the Drakes Estero State Marine Conservation Area, the Estero de Limantour State Marine Reserve, and the Point Reyes State Marine Reserve. Three additional special closure (no access) areas were established by the state within PORE boundaries at the Point Reyes Headlands (to 1000 ft from shore), Point Resistance Rock (300 ft radius), and Stormy Stack (300 ft radius), to protect breeding seabird and mammal colonies from disturbance. Finally, there are two wetland sites (Tomales Bay and Bolinas Lagoon) adjacent to NPS lands that are listed on the Ramsar List of Wetlands of International Importance.

PORE and the northern areas of GOGA managed by PORE have little urban disturbance and are dominated by coastal scrub and forests throughout the upland areas of the park (Figure 2.1.2). The area is bounded to the north, west and southwest by the Pacific Ocean and to the east by the residential communities of Inverness, Inverness Park, Point Reyes Station, Olema, and Dogtown. Figure 2.1.3 depicts the calculated land cover extent for various land cover types within PORE and the GOGA Northern lands, and Figure 2.1.4 and Figure 2.1.5 show coastal habitats and marine bathymetry.

The town of Bolinas is south of PORE at the southern tip of the peninsula. An estimated 3,800 permanent residents live in the towns and communities close to the PORE Management area from the tip of Tomales Bay in the north to Stinson Beach in the south (U.S. Census Bureau 2000). This census population figure does not count the many part-time residents of western Marin who maintain second homes in the area.

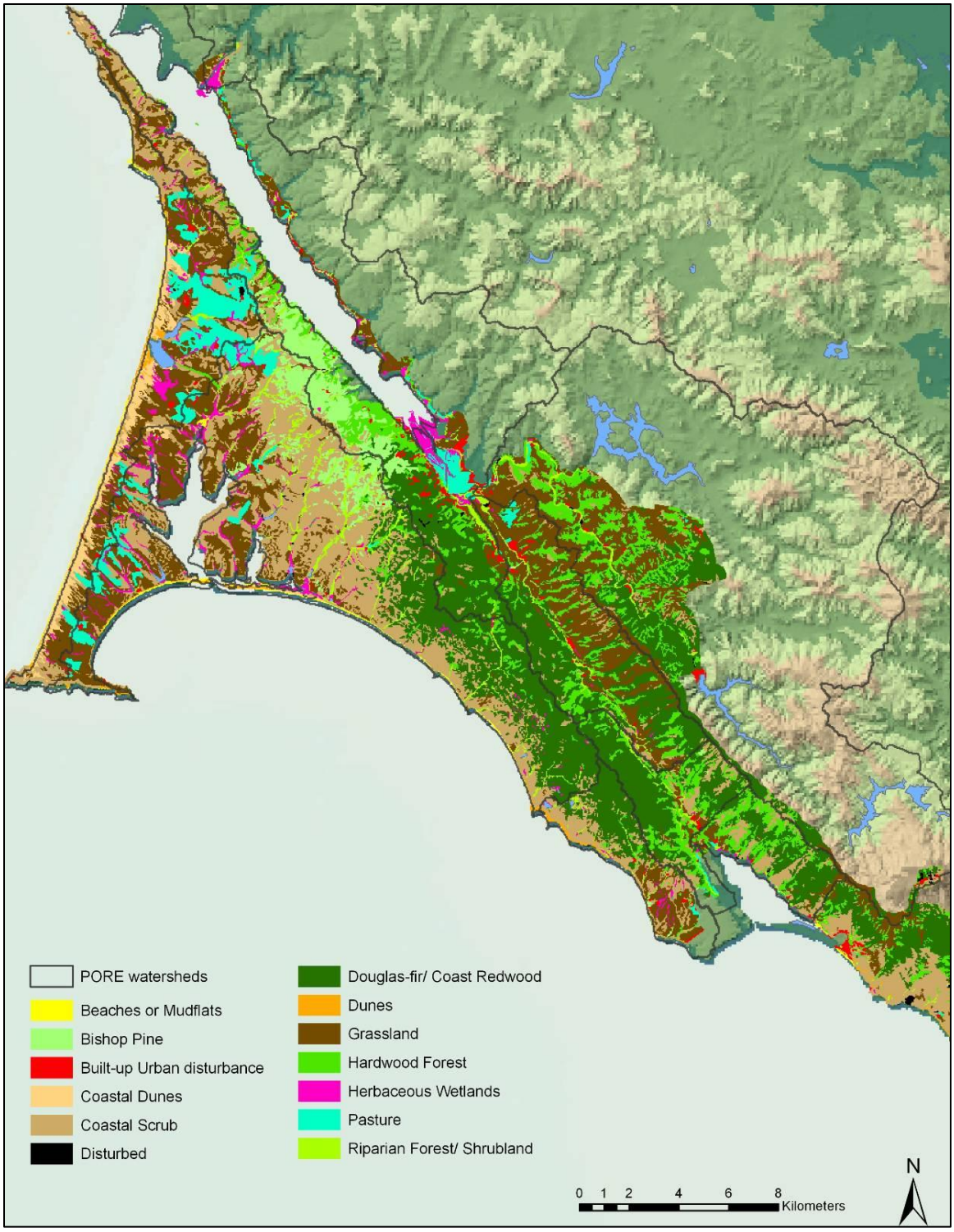


Figure 2.1.2. Land cover types for the PORE and PORE-managed GOGA lands. Note that this area has minimal urbanized boundaries.

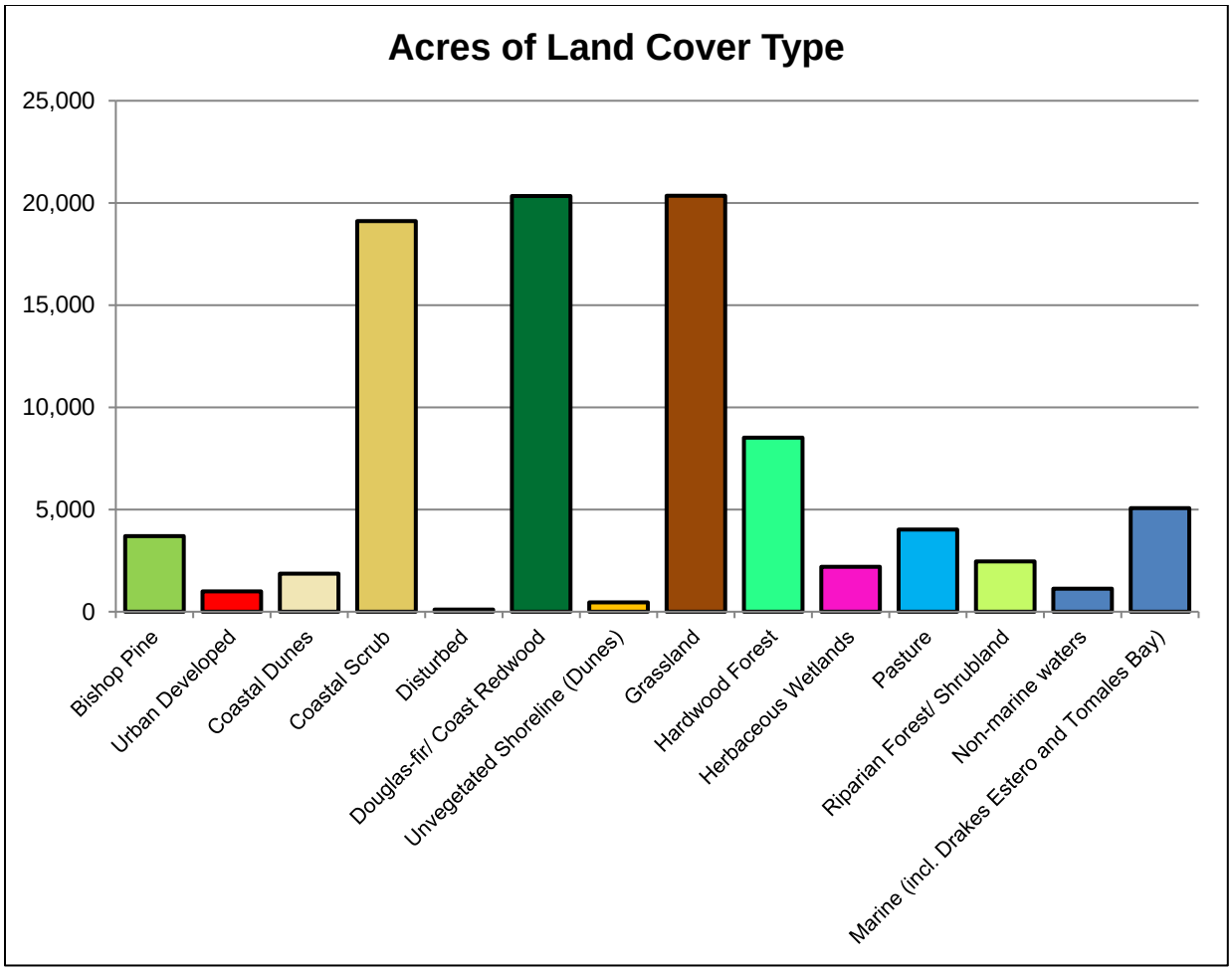


Figure 2.1.3. The land cover types for PORE and PORE-managed GOGA watersheds. Note that both pasture and some grasslands are grazed by cattle. More detail can be found in Chapter 4. Data source: Vegetation PORE/GOGA 1994 coverage.

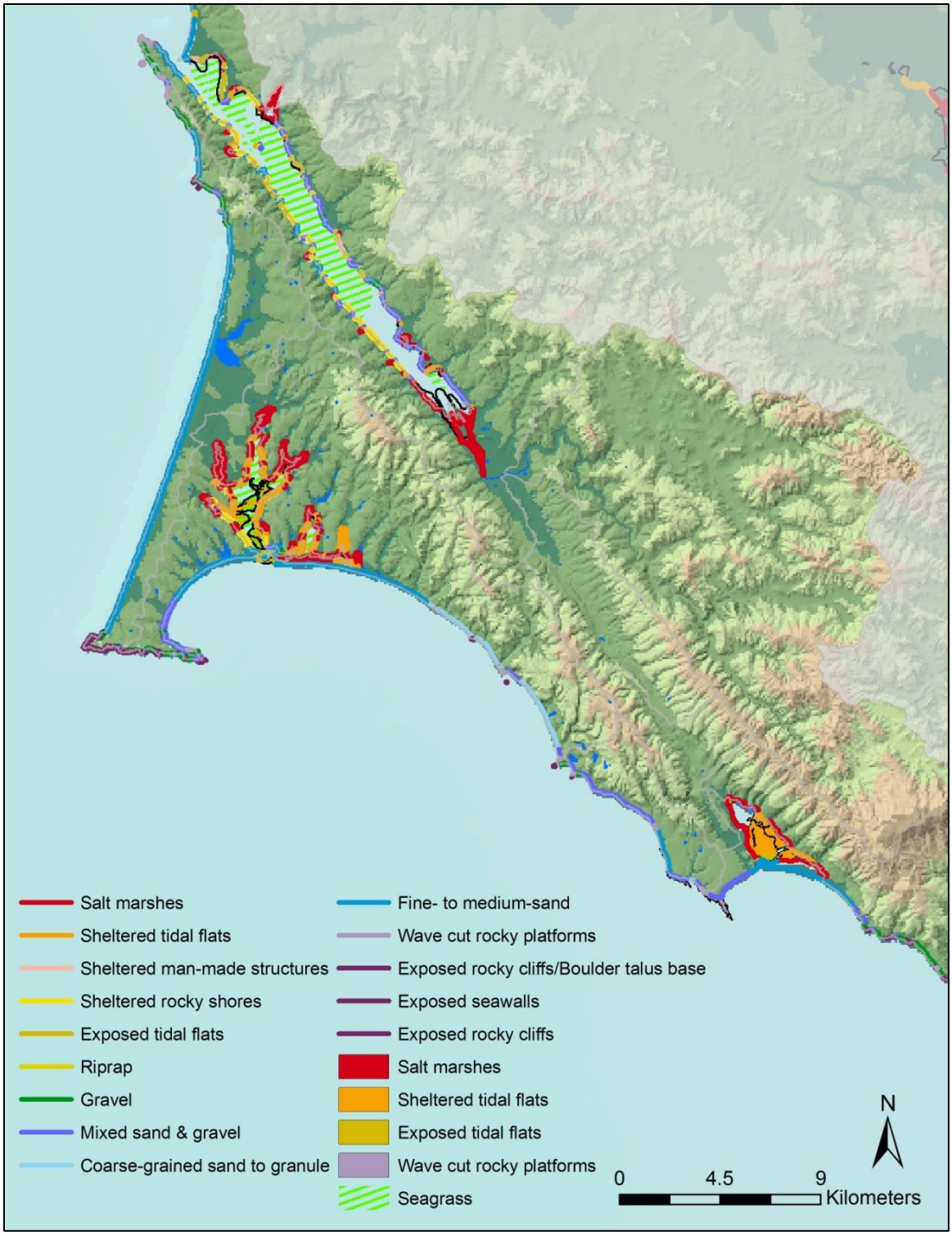


Figure 2.1.4. PORE coastal shoreline substrate and habitats. Park boundaries not shown. Reproduced from Pawley and Lay (2013).

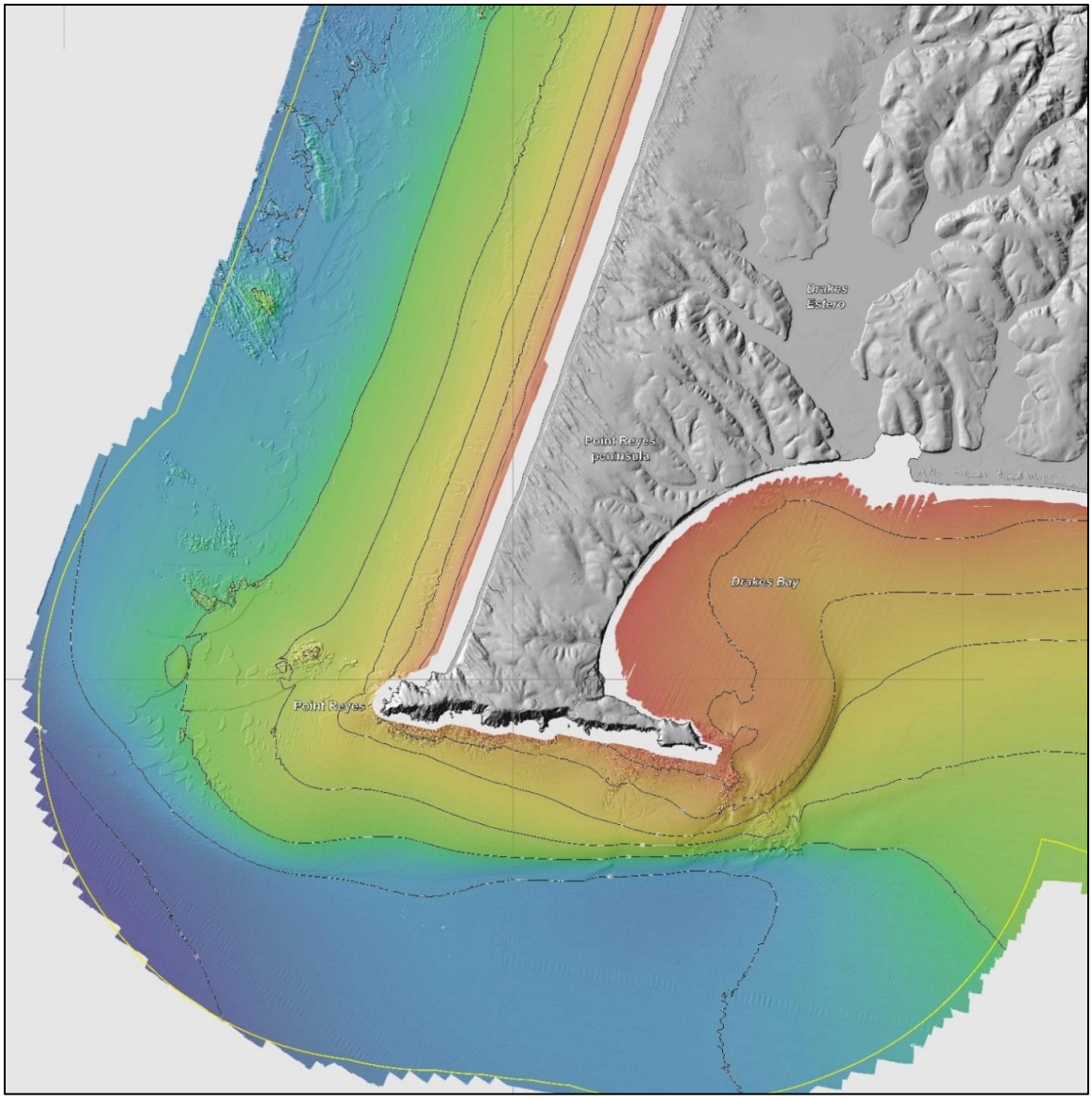


Figure 2.1.5. Colored shaded-relief bathymetry offshore of Point Reyes National Seashore. Bathymetric contour interval of 10 meters. Source: Dartnell and Kvitek (2015).

2.1.3. Visitation Statistics

Since 1985, Point Reyes National Seashore has consistently attracted approximately 2.0 to 2.5 million visitors each year (NPS 2017a Figure 2.1.6). The National Park Service staff greets over a half million people per year in the Seashore's three visitor centers, and provides interpretive talks and walks for tens of thousands of visitors annually. In addition, the Seashore's education program, coordinated out of four educational facilities, hosts about 6,800 elementary school children per year with programs about the Seashore's natural and cultural resources led by interpretive rangers. Each year, the Point Reyes National Seashore Association offers additional education and outreach programs for nearly 6,000 students and adults.

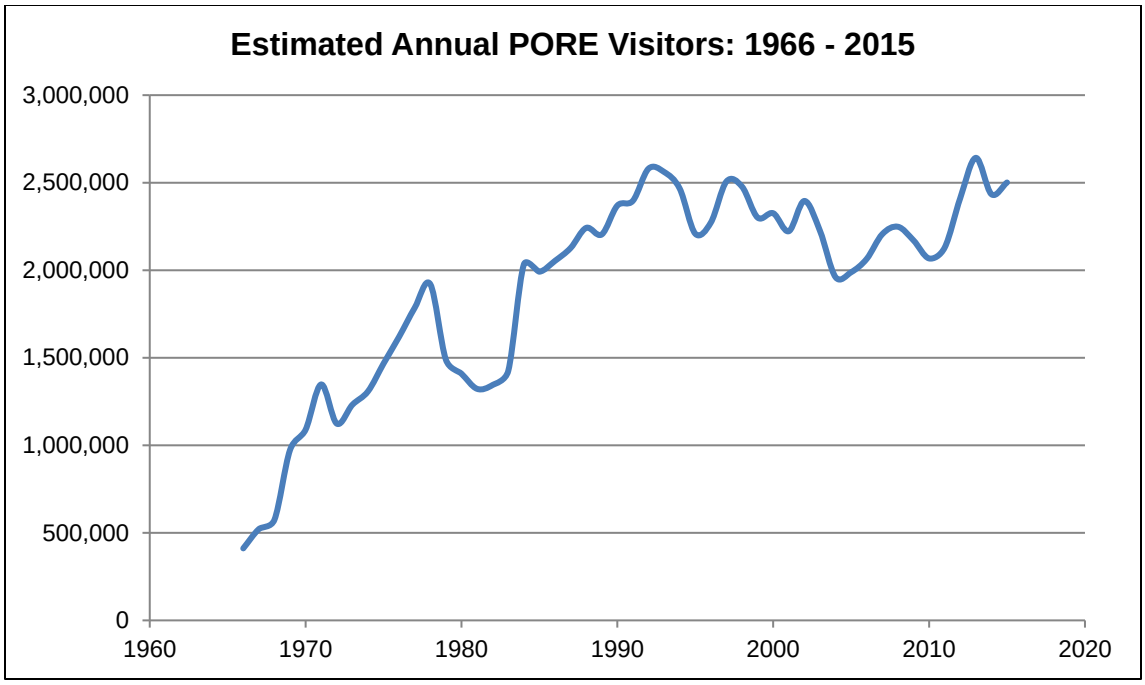


Figure 2.1.6. Annual visitation statistics from traffic counter data.

2.2. Natural Resources

Point Reyes National Seashore 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 gradient 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 2.2.1). 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.

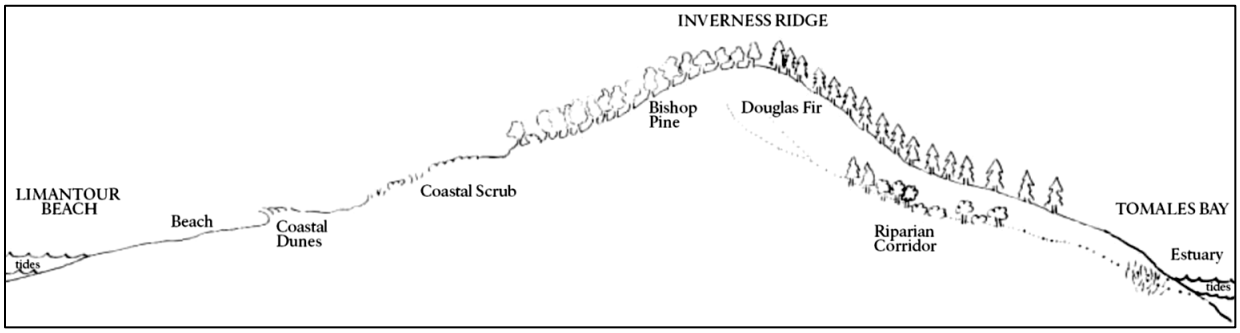


Figure 2.2.1. Example of typical PORE habitats illustrated by a transect from Limantour Beach to Tomales Bay (Pawley and Lay 2013).

2.2.1. Ecological Units at Point Reyes National Seashore

The PORE and GOGA Coastal Watershed Assessment (Pawley and Lay 2013) provides detailed descriptions, history, important species, and management issues related to most of PORE's habitats. We list these major habitats, but do not repeat detailed descriptions 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 (Figure 2.2.2)
  - Tidal Flats (Figure 2.2.3)
  - Tidal Salt Marshes
  - Brackish Marshes (Figure 2.2.4)
- Freshwater Habitats
  - Streams (Figure 2.2.5)
  - Lakes, Ponds, and Lagoons
  - Freshwater Wetlands (Figure 2.2.6)
- Upland Habitats
  - Coastal Dunes
  - Grasslands
  - Coastal Scrub
  - Riparian Forest/Shrubland
  - Hardwood Forest
  - Douglas-fir/Coast Redwood Forest
  - Bishop Pine Forest



Figure 2.2.2. Eelgrass (*Zostera marina*) in Drakes Estero. NPS Photo.



Figure 2.2.3. Tidal mudflat in Tomales Bay. NPS Photo.



Figure 2.2.4. Tidal brackish marsh along Lagunitas Creek. NPS photo.

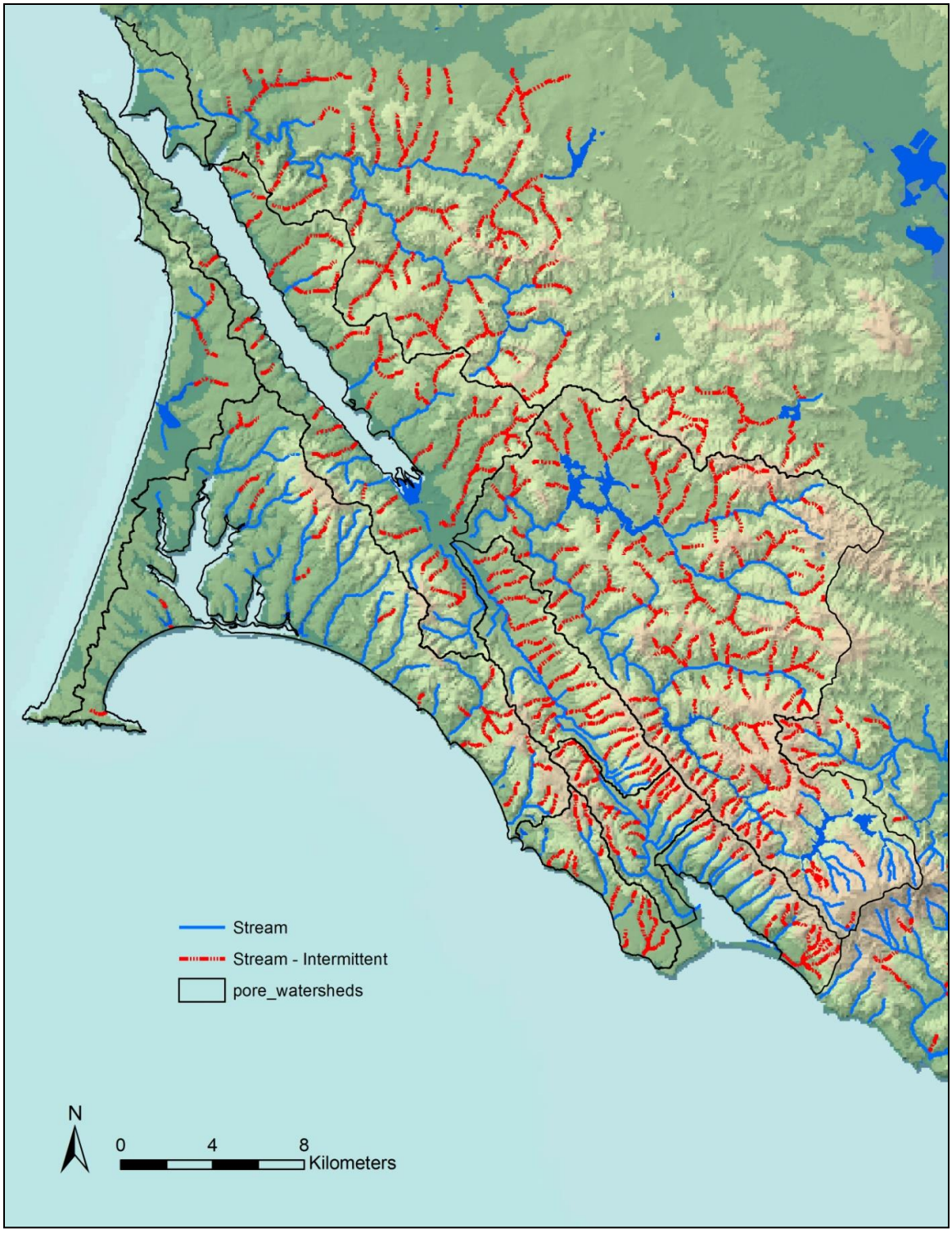


Figure 2.2.5. Watershed map of perennial and intermittent streams in the region. Reused from Pawley and Lay (2013).



Figure 2.2.6. Clumps of tall emergents such as cattails and bulrush amidst a blanket of low-growing species such as hydrocotyle and water parsley in the Giacomini West Pasture's Freshwater Marsh. NPS Photo.

2.2.2. Resource Issues Overview

The Coastal Watershed Assessment (Pawley and Lay 2013) identified and discussed PORE'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)
  - Aquaculture (Not currently occurring in park but may occur nearby)
- Resource Extraction
  - Mining (Not currently occurring in park but may occur nearby)
  - Oil Development (Not currently occurring in park but may occur nearby)
  - Oil Spills
  - Logging (Not currently occurring in park but may occur nearby)

  - Fishing and Harvesting
  - Hydrologic and Geomorphic Alteration
- Erosion/Sedimentation
- Water Quality Pollution
- Invasive Species

Ocean acidification may also present a future stressor on park marine and estuarine resources (Gazeau et al. 2007). The impacts of stressors on specific resources are addressed in Chapter 4.

2.3. Resource Stewardship

2.3.1. Management Directives and Planning Guidance

The Point Reyes National Seashore Foundation Statement (NPS 2017b) which specifies the most important characteristics and values of the park reads:

> *Established for public benefit and inspiration, the Point Reyes National Seashore protects a rugged and wild coastal peninsula and surrounding waters, connecting native ecosystems, enduring human history, and recreational, scientific, and educational opportunities.*

And in reference to the Northern Lands of Golden Gate NRA:

> *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:

- The Phillip Burton Wilderness at Point Reyes National Seashore offers an extraordinary opportunity for solitude and unconfined recreation in untrammeled terrestrial and marine environments immediately accessible to a large urban community.
- Point Reyes National Seashore 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 productive coastal grassland ecosystem supported by the fog driven climate of the Point Reyes Peninsula was the basis for the development of the historic dairy and beef ranch tradition.
- Representing more than 8,000 years of human history, Point Reyes National Seashore contains one of the most intact and well preserved landscapes of American Indian history and a material record of one of the earliest instances of culture contact between American Indians and European explorers on the west coast of the United States. The Coast Miwok, federally recognized as the Federated Indians of Graton Rancheria, maintain cultural ties to the Point Reyes Peninsula.

- The geography of the Point Reyes Peninsula, reaching almost 10 miles into the Pacific Ocean, both necessitated and facilitated the development of innovative maritime and radio communications technologies that influenced the history of the region and the nation.
- The geology of the Point Reyes Peninsula inspires both visitors and scientists. The coastal bluffs expose an intersection of sedimentary deposits rich in paleontological history, while vistas of Tomales Bay and the Olema Valley, shaped by the San Andreas Fault, provide an exceptional opportunity to visualize and study plate tectonics. Studies here have helped geologists refine our understanding of Earth's history.

With its proximity to the San Francisco Bay metropolitan area, the undeveloped scenic coastal landscapes and rich biodiversity of Point Reyes National Seashore offer opportunities to visitors from around the world for inspiration, recreation, education, and research.

2.3.2. Status of Supporting Science

PORE has strong internal and external research, inventory and monitoring programs. Approximately 95 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 & Elephant 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 PORE websites.

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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 principles 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 staff outlined a list of priority natural resources for consideration in the NRCA (Table 3.1.1).

Table 3.1.1. Priority resources selected by PORE/GOGA staff. Level 1 refers to classification of resources 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	1.00	Biotic integrity
T&E Plant Species*	Vegetation/terrestrial	1.00	1.00	Biotic integrity
Breeding landbird diversity*	Vertebrates/birds	1.00	1.00	Biotic integrity
Amphibians*	Vertebrates/land	1.00	1.00	Biotic integrity
T&E salmonids (coho, steelhead)*	Vertebrates/fish	1.00	1.00	Biotic integrity
Coastal dune	Vegetation/terrestrial	1.00	3.00	Biotic integrity
Native coastal prairie, serpentine grassland	Vegetation/terrestrial	1.50	1.00	Biotic integrity
Forests (Bishop pine, Doug fir, bay, oaks, redwood)	Vegetation/terrestrial	1.75	1.00	Biotic integrity
Rocky intertidal	Invertebrates	1.50	1.50	Biotic integrity
Snowy plovers	Vertebrates/birds	2.00	1.00	Biotic integrity
Shorebird and waterbird	Vertebrates/birds	1.50	1.50	Biotic integrity
Northern spotted owls	Vertebrates/birds	1.50	1.50	Biotic integrity
Bat diversity	Vertebrates/land	1.50	1.50	Biotic integrity
Water quality – freshwater	Water	1.50	1.50	Water
Tidewater goby	Vertebrates/fish	2.00	1.00	Biotic integrity
Invasive plants	Vegetation/terrestrial	–	1.00	Biotic integrity
Bank swallow	Vertebrates/birds	–	1.00	Biotic integrity
Mission blue and other endangered butterflies	Invertebrates	–	1.00	Biotic integrity
Land cover and use, fragmentation	Spatial Ecology	–	1.00	Landscapes

* Resource ranked first by both parks (also shown in yellow shading).

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.

3.2. Study Design

3.2.1a. Assessment Framework Used in This Study

PORE 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 priority natural resources selected for inclusion in this NRCA were all in the biological integrity category. The NPS Ecological Monitoring Framework is included here for reference (Table 3.2.1).

Table 3.2.1. The Ecological Monitoring Framework is a systems-based, hierarchical, 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	–
	Air Quality	Wet and Dry Deposition	–
	Air Quality	Visibility and Particulate Matter	–
	Air Quality	Air Contaminants	–
	Weather and Climate	Weather and Climate	–
Geology and Soils	Geomorphology	Windblown Features and Processes	–
	Geomorphology	Glacial Features and Processes	–

Table 3.2.1 (continued). The Ecological Monitoring Framework is a systems-based, hierarchical, 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
Geology and Soils (continued)	Geomorphology	Hillslope Features and Processes	–
	Geomorphology	Coastal/Oceanographic Features and Processes	–
	Geomorphology	Marine Features and Processes	–
	Geomorphology	Stream/River Channel Characteristics	–
	Subsurface Geologic Processes	Geothermal Features and Processes	–
	Subsurface Geologic Processes	Cave/Karst Features and Processes	–
	Subsurface Geologic Processes	Volcanic Features and Processes	–
	Subsurface Geologic Processes	Seismic Activity	–
	Soil Quality	Soil Function and Dynamics	–
	Paleontology	Paleontology	–
Water	Hydrology	Groundwater Dynamics	–
	Hydrology	Surface Water Dynamics	–
	Hydrology	Marine Hydrology	–
	Water Quality	Water Chemistry	–
	Water Quality	Nutrient Dynamics	–
	Water Quality	Toxics	–
	Water Quality	Microorganisms	–
	Water Quality	Aquatic Macroinvertebrates and Algae	–
Biological Integrity	Invasive Species	Invasive/Exotic Plants	–
		Invasive/Exotic Animals	–
	Infestations and Disease	Insect Pests	–
	Infestations and Disease	Plant Diseases	–
	Infestations and Disease	Animal Diseases	–
	Focal Species or Communities	Marine Communities	Includes coral communities

Table 3.2.1 (continued). The Ecological Monitoring Framework is a systems-based, hierarchical, 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	Intertidal Communities	–
	Focal Species or Communities	Estuarine Communities	–
	Focal Species or Communities	Wetland Communities	Marshes, swamps, bogs
	Focal Species or Communities	Riparian Communities	–
	Focal Species or Communities	Freshwater Communities	Standing water (inland ponds and lakes) and flowing water (rivers and streams); emphasis on aquatic biota
	Focal Species or Communities	Sparsely Vegetated Communities	–
	Focal Species or Communities	Cave Communities	Cave flora and fauna.
	Focal Species or Communities	Desert Communities	–
	Focal Species or Communities	Grassland/Herbaceous Communities	Includes tundra and alpine meadows, lichens, fungi
	Focal Species or Communities	Shrubland Communities	–
	Focal Species or Communities	Forest/Woodland Communities	–
	Focal Species or Communities	Marine Invertebrates	–
	Focal Species or Communities	Freshwater Invertebrates	–
	Focal Species or Communities	Terrestrial Invertebrates	–
	Focal Species or Communities	Fishes	–
	Focal Species or Communities	Amphibians and Reptiles	–
	Focal Species or Communities	Birds	–
	Focal Species or Communities	Mammals	–
	Focal Species or Communities	Vegetation Complex (use sparingly)	Catch-all category to be used in rare cases

Table 3.2.1 (continued). The Ecological Monitoring Framework is a systems-based, hierarchical, 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	Terrestrial Complex (use sparingly)	Catch-all category to be used in rare cases
	Focal Species or Communities	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

Prior to the scoping meetings Point Reyes National Seashore and Golden Gate National Recreation staff outlined a list of priority natural resources for consideration in the NRCA (Table 3.1.1). 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
- Coastal Dunes
- Forests
- Grasslands

- Invasive plants
- Rare plants
- Salmonids

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 resource. 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 3.2.2 lists the reference condition selected for each assessment. More detailed explanations for each resource are found in Chapter 4.

Table 3.2.2. Point Reyes National Seashore natural resource condition assessment framework.

Ecological 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
	Coastal Dunes	Historic conditions	• Introduced species
	Forests	• Biomass: theoretical standards • Biomass: regional standards • Baseline conditions • Historic conditions	• Climate change • Pests and pathogens • Altered fire regime
	Grasslands	Not available	• Altered fire regime • Introduced species • Encroachment by shrubs/trees
	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 • Restricted expansion • Climate change
	Salmonids	Historic conditions	• Migration barriers • Lack of suitable habitat

3.2.2. Reporting Areas

Analyses for PORE are scaled up by management zones (Figure 3.2.1). Three management zones are considered: natural lands, wilderness, and pastoral lands. Summarizing resource assessments by these zones was considered the most relevant to management as each of these categories suggests a set of desired conditions for natural and cultural resources, visitor experience, and general levels of development and visitor use. These desired conditions are different in each management zone and reflect the overall focus of that particular zone. The boundaries of the management zones used for this assessment continue to shift over time and some changes have taken place in land designations

since the zones used in this analysis were established. The primary change is that some of the lands originally classified as pastoral are now considered cultural lands.

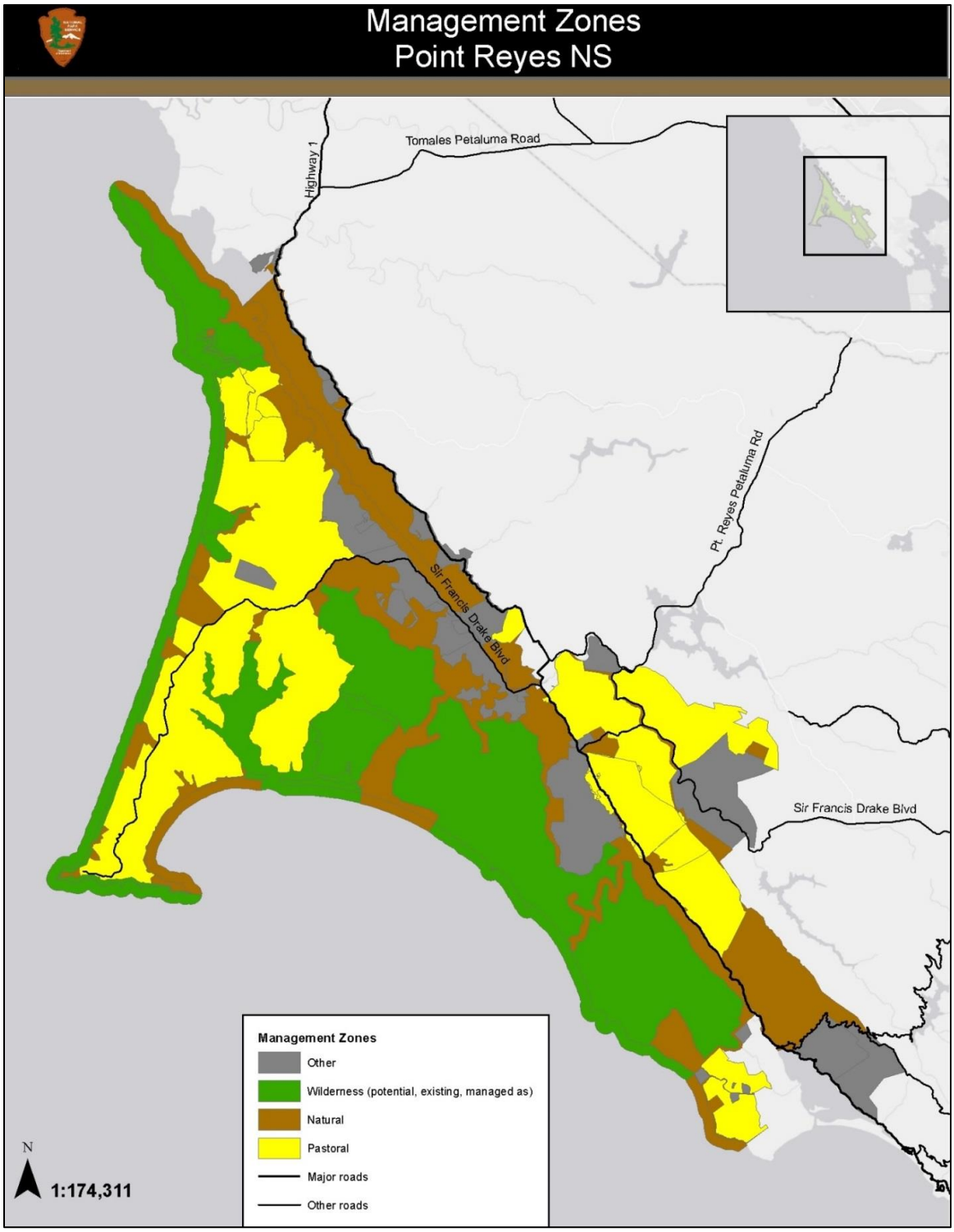


Figure 3.2.1. Map of management zones at Point Reyes National Seashore.

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 PORE 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 PORE 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.

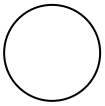
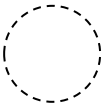
Resource Assessment Format

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

Condition Graphic

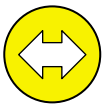
Although the PORE and GOGA NRCAs were initiated prior to 2014, both parks opted to follow the updated NPS guidelines required for newer NRCA reports by using the standard symbol set for resource condition reporting (Tables 3.2.3 and 3.2.4). The condition graphic provides a visual representation of the 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 3.2.3. 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

Where possible, 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:

Table 3.2.4. Examples of how the symbols should be interpreted:

Symbol Example	Verbal Description
	Resource is in good condition, its condition is improving, high confidence in the assessment.
	Condition of resource warrants moderate concern; condition is unchanging; medium confidence in the assessment.
	Condition of resource warrants significant concern; trend in condition is unknown or not applicable; low confidence in the assessment.
	Current condition is unknown or indeterminate due to inadequate data, lack of reference value(s) for comparative purposes, and/or insufficient expert knowledge to reach a more specific condition determination; trend in condition is unknown or not applicable; low confidence in the assessment.

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 provided below.

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 3.2.5). Open (uncolored) circles are omitted from the calculation. Once the average is calculated, apply the scale below to determine the resulting color.

Table 3.2.5. Combined condition scale.

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 PORE, 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.

Literature Cited

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. Natural 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 (Figure 4.1.1 and Figure 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 (Figure 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. Not surprisingly, most sites were also only surveyed in fewer than five years between 1993 and the present (Figure 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; Figure 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 (Figure 4.1.6 and Figure 4.1.7).

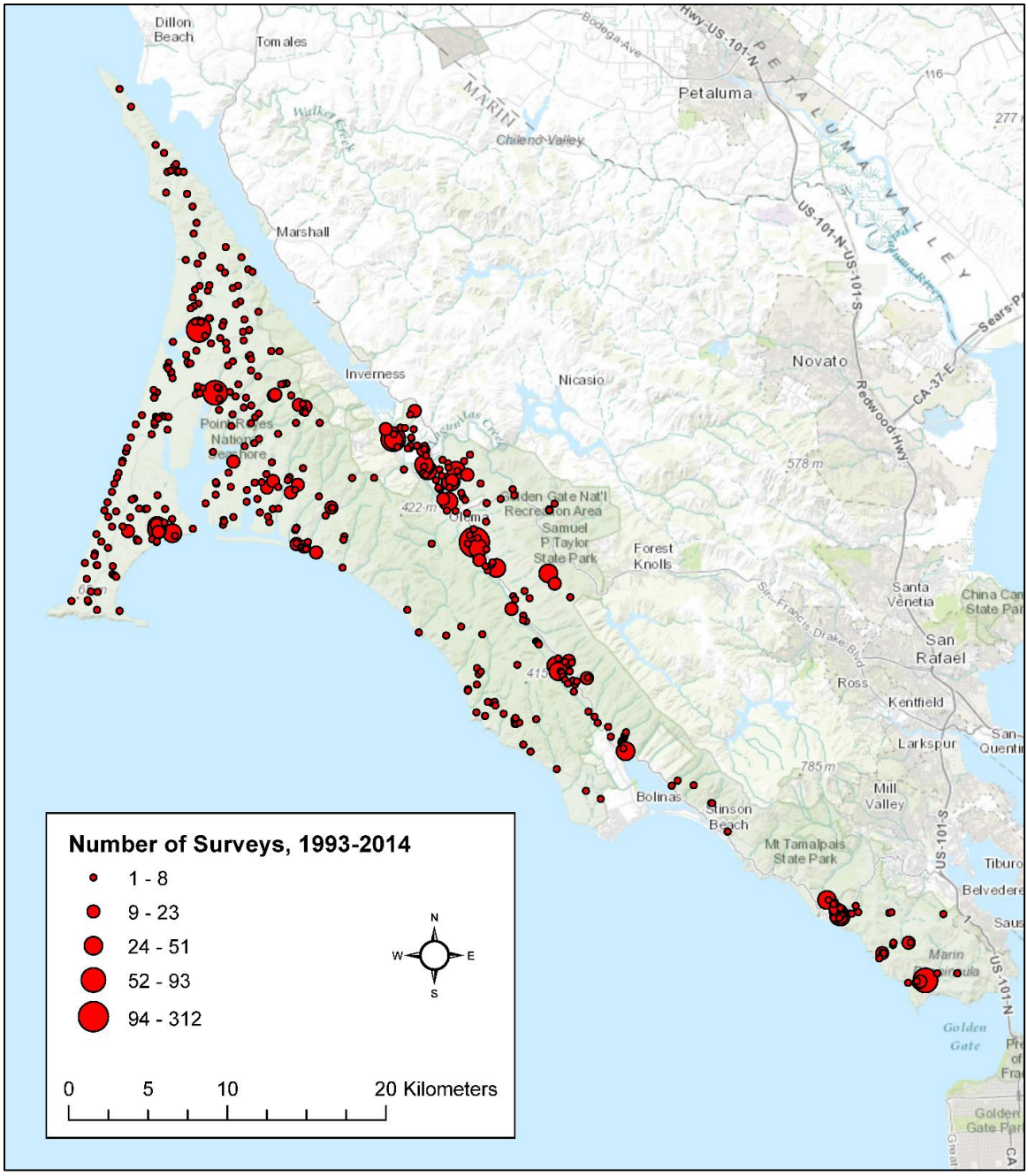


Figure 4.1.1. Distribution of survey effort for amphibians at Point Reyes National Seashore and Golden Gate National Recreation Area in Marin County, California, 1993 – 2014.

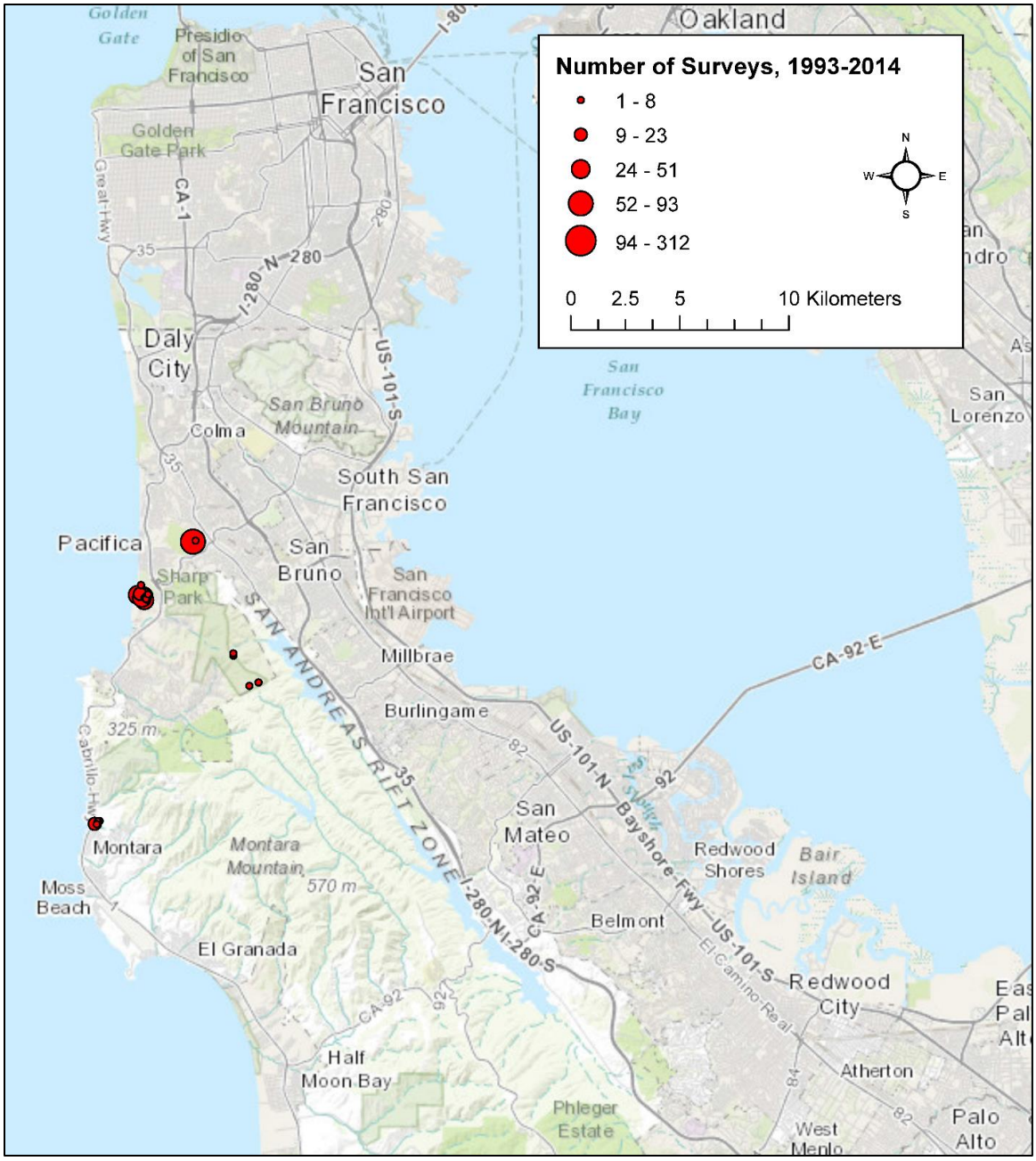


Figure 4.1.2. Distribution of survey effort for amphibians at Golden Gate National Recreation Area in San Mateo County, California, 1993 – 2014.

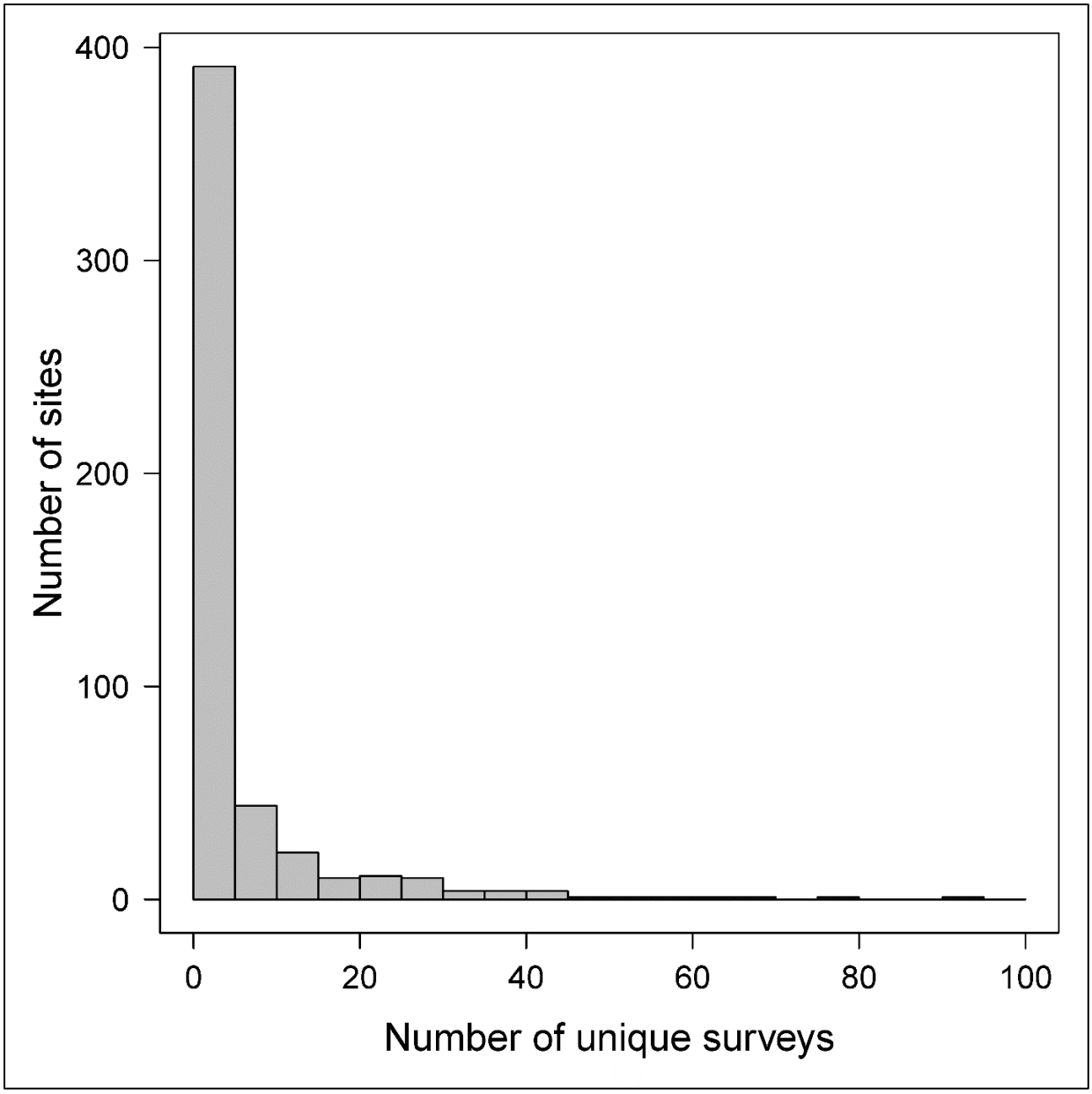


Figure 4.1.3. The number of unique surveys conducted at each individual survey site at Point Reyes National Seashore and Golden Gate National Recreation Area, 1992 – 2014. One site that was surveyed 312 times was omitted to better show sampling effort at the majority of sites, which had far fewer surveys.

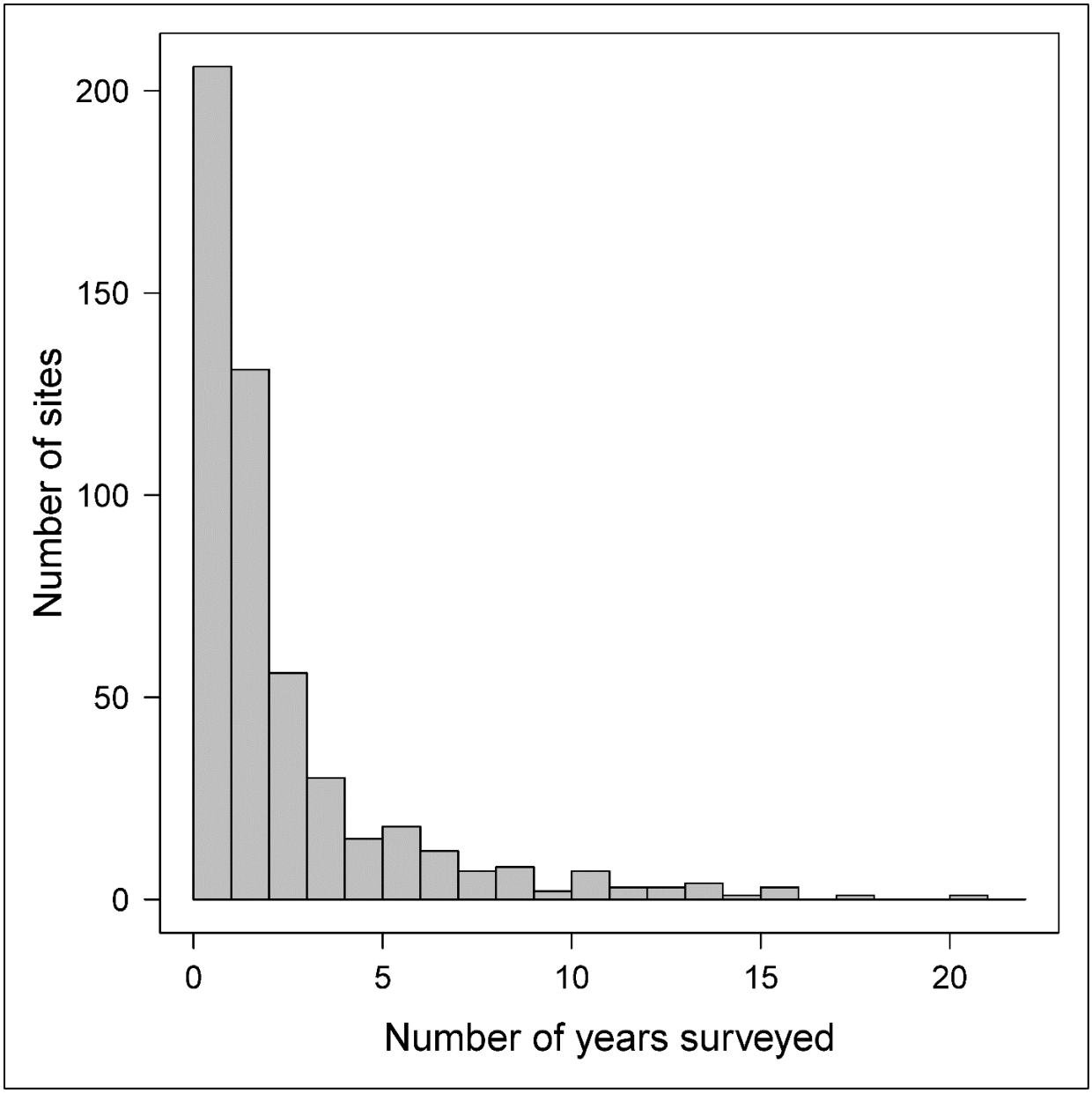


Figure 4.1.4. Number of years from 1993 through 2014 during which at least one survey was conducted at each site sampled for amphibians at Point Reyes National Seashore and Golden Gate National Recreation Area.

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.

Year	Number of Sites Surveyed	Number of Sites with Detections			Proportion of Sites with Detections			Number of Native Amphibian 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.

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

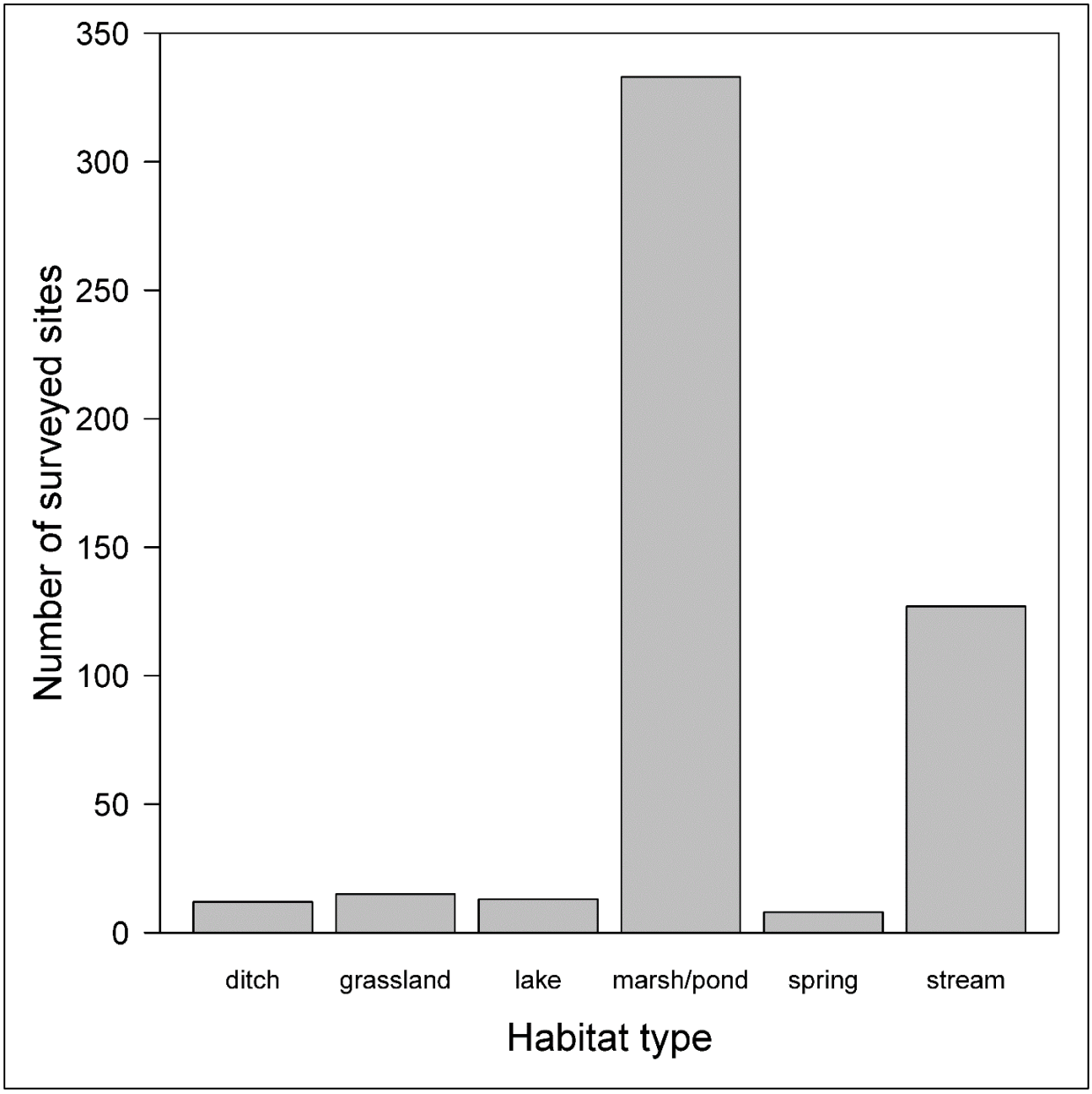


Figure 4.1.5. Number of sites of each habitat type surveyed for amphibians at Point Reyes National Seashore and Golden Gate National Recreation Area, 1993 – 2014.

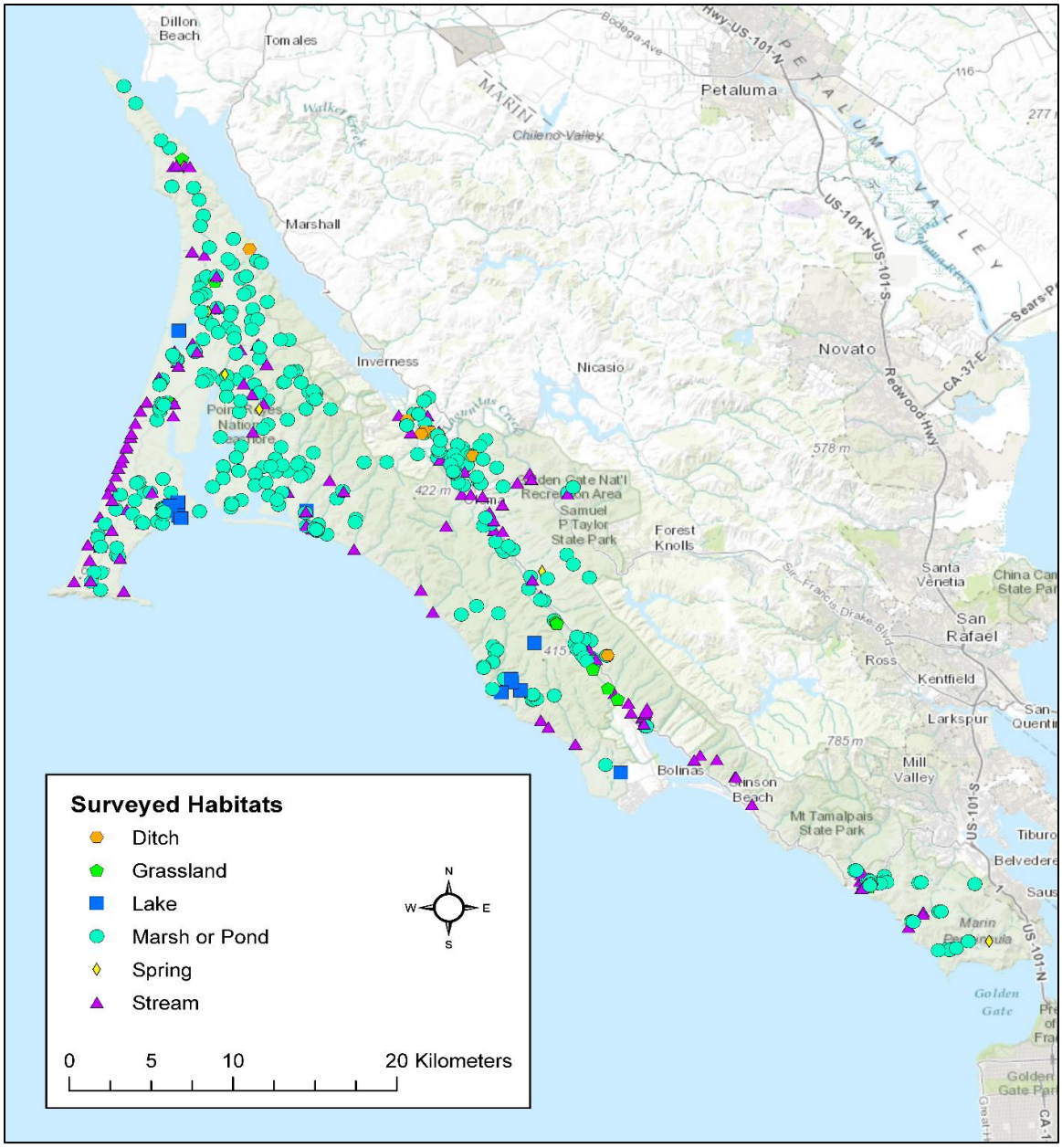


Figure 4.1.6. Spatial distribution of habitats surveyed for amphibians at Point Reyes National Seashore and Golden Gate National Recreation Area in Marin County, California, 1993 – 2014.

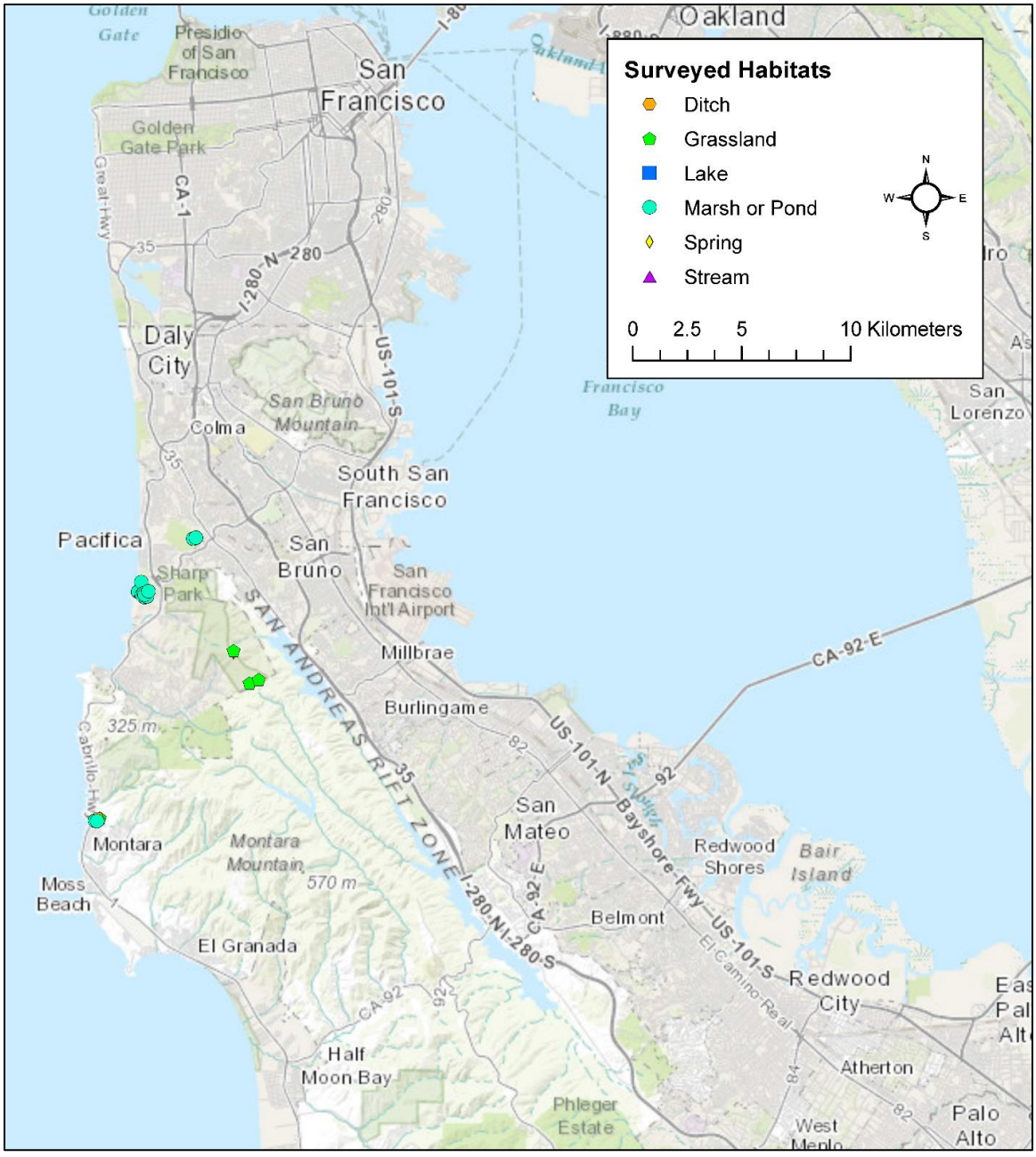


Figure 4.1.7. Spatial distribution of habitats surveyed for amphibians at Golden Gate National Recreation Area in San Mateo County, California, 1993 – 2014.

Seven aquatic-breeding amphibian species were detected during surveys: native western toads (*Anaxyrus boreas*), sierran treefrogs (*Pseudacris sierra*), California red-legged frogs, Pacific 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 being most commonly observed (Figure 4.1.8). No amphibians were observed at 15% of the sites surveyed. No clear pattern was evident in the spatial distribution of species richness (Figure 4.1.9 and Figure 4.1.10). A high proportion of most habitat types surveyed

had at least one native amphibian species detected (Figure 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 (Figure 4.1.12).

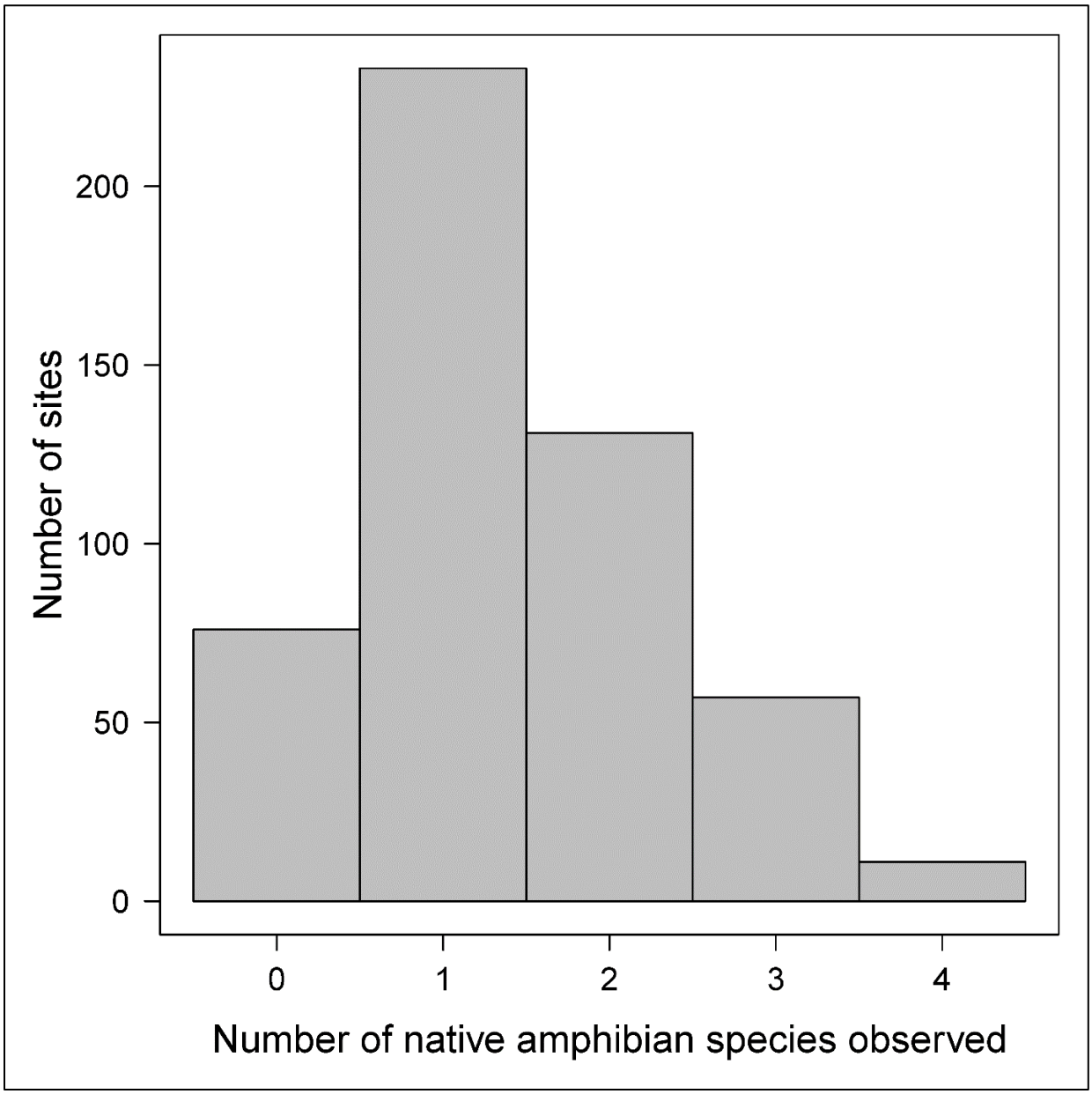


Figure 4.1.8. Distribution of species richness of native amphibians among surveyed sites at Point Reyes National Seashore and Golden Gate National Recreation Area, 1993 – 2014.

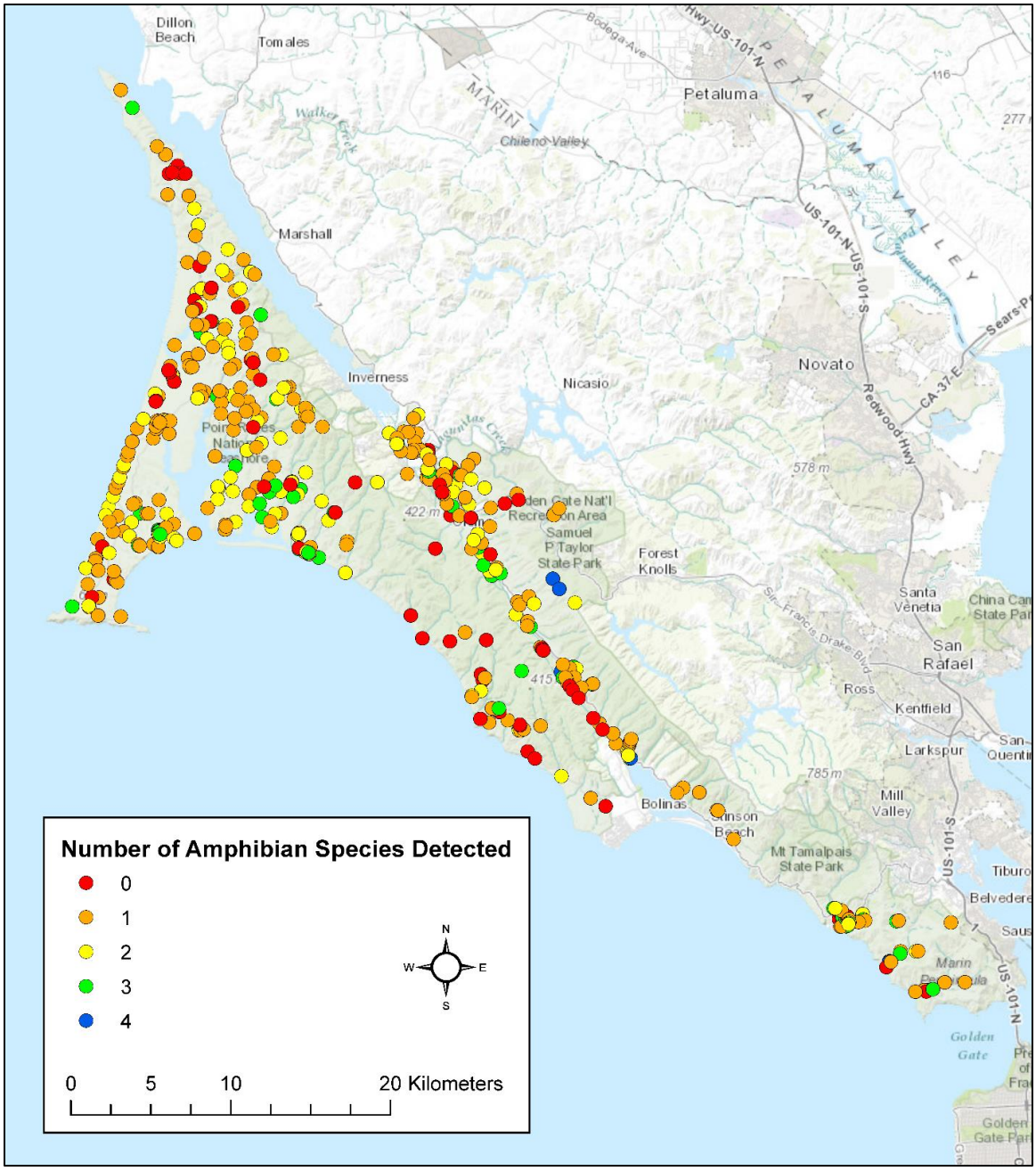


Figure 4.1.9. Spatial distribution of species richness of native amphibians at Point Reyes National Seashore and Golden Gate National Recreation Area in Marin County, California, 1993 – 2014.

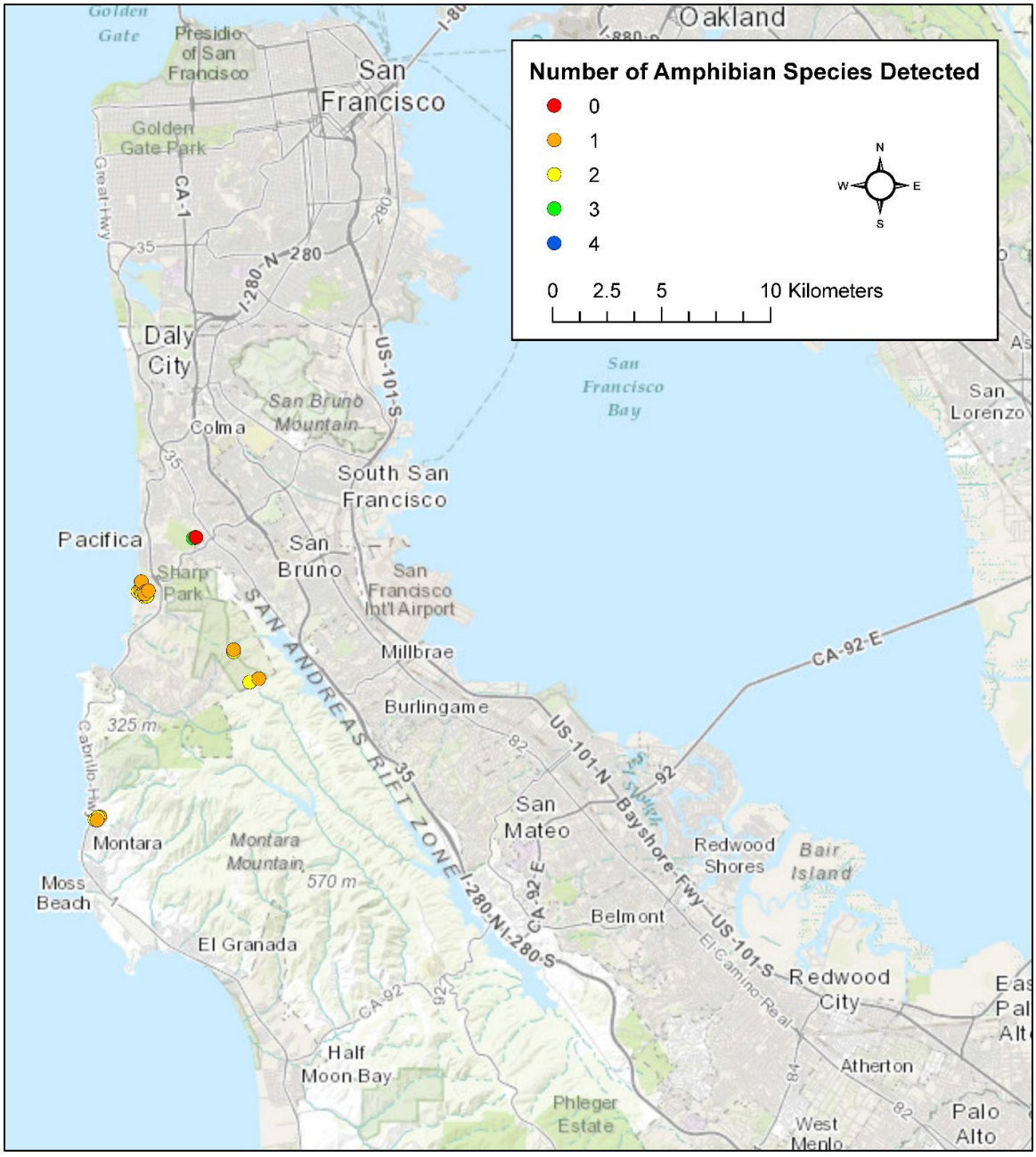


Figure 4.1.10. Spatial distribution of species richness of native amphibians at Golden Gate National Recreation Area in San Mateo County, California, 1993 – 2014.

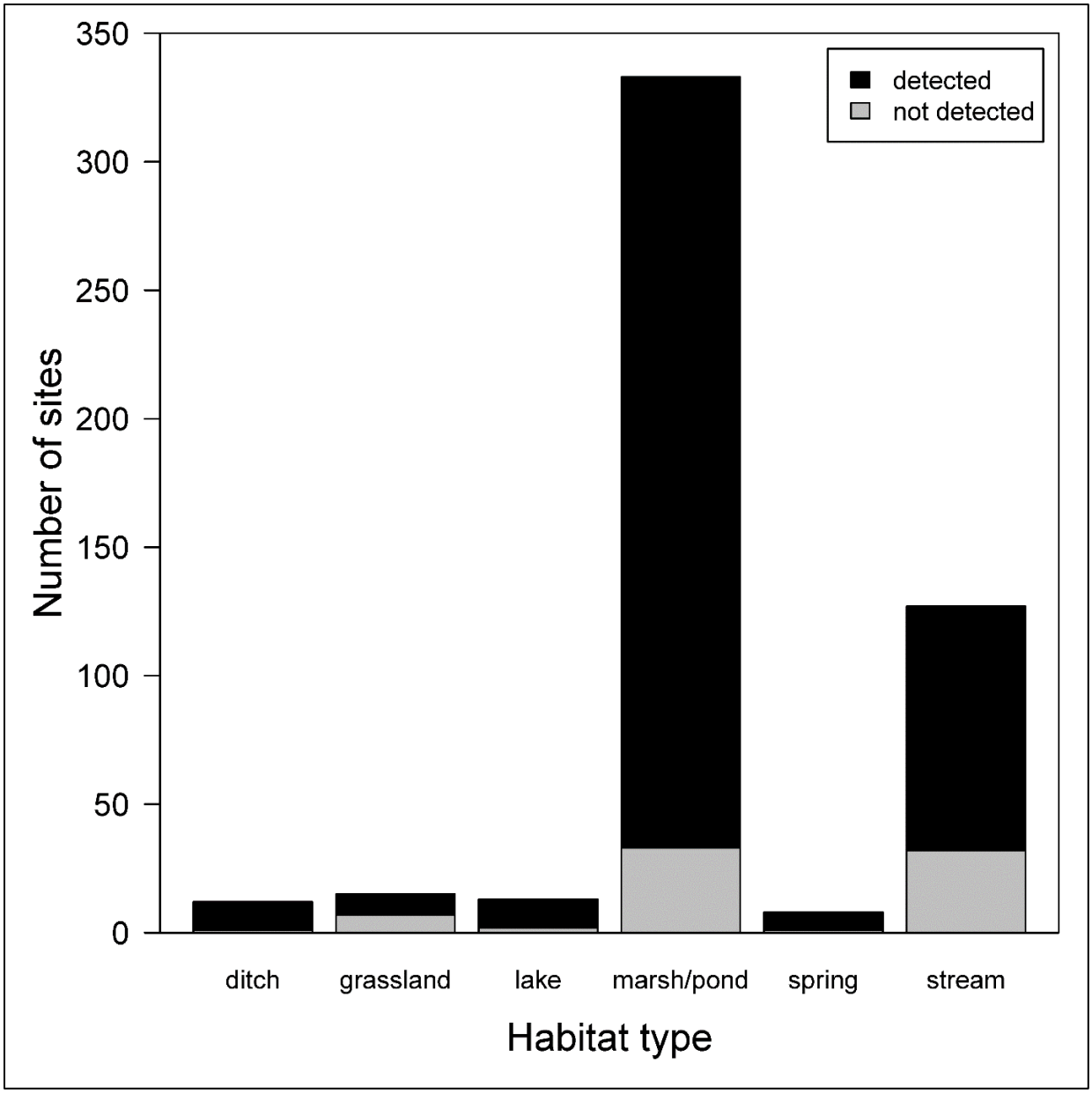


Figure 4.1.11. Distribution of detections of native amphibian species among habitats surveyed at Point Reyes National Seashore and Golden Gate National Recreation Area, 1993 – 2014.

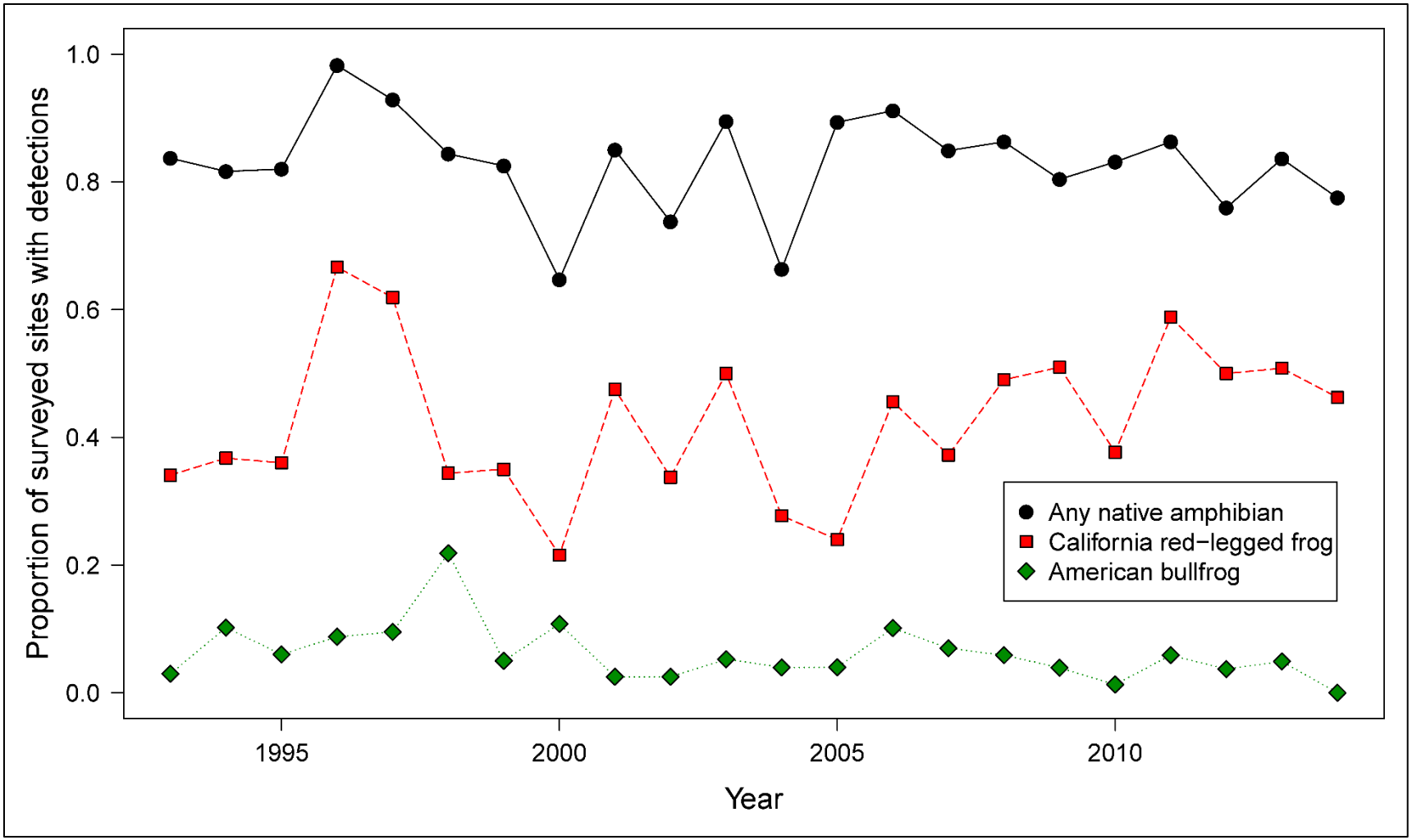


Figure 4.1.12. Annual proportion of surveyed sites with detections of at least one native amphibian species (including California red-legged frogs *Rana draytonii*; black circles), California red-legged frogs (red squares), and American bullfrogs (*Lithobates catesbeianus*; green diamonds) at Point Reyes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

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 (Figure 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 (Figure 4.1.14 and Figure 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, Figure 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, pers. comm. 2015). 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, pers. comm. 2015).

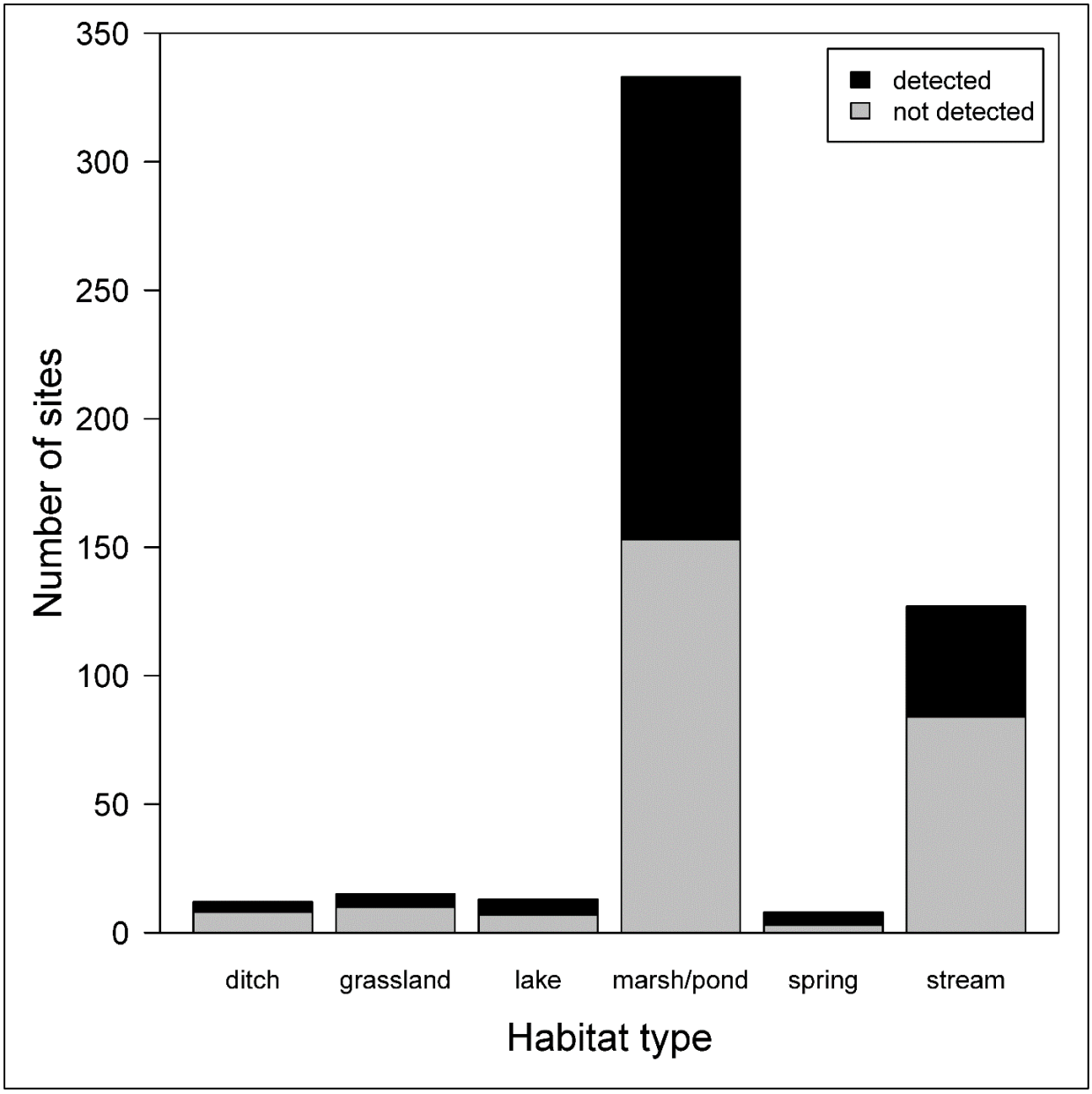


Figure 4.1.13. Proportion of sites at which California red-legged frog (*Rana draytonii*) were detected at Point Reyes National Seashore and Golden Gate National Recreation Area, 1993 – 2015, by habitat type.

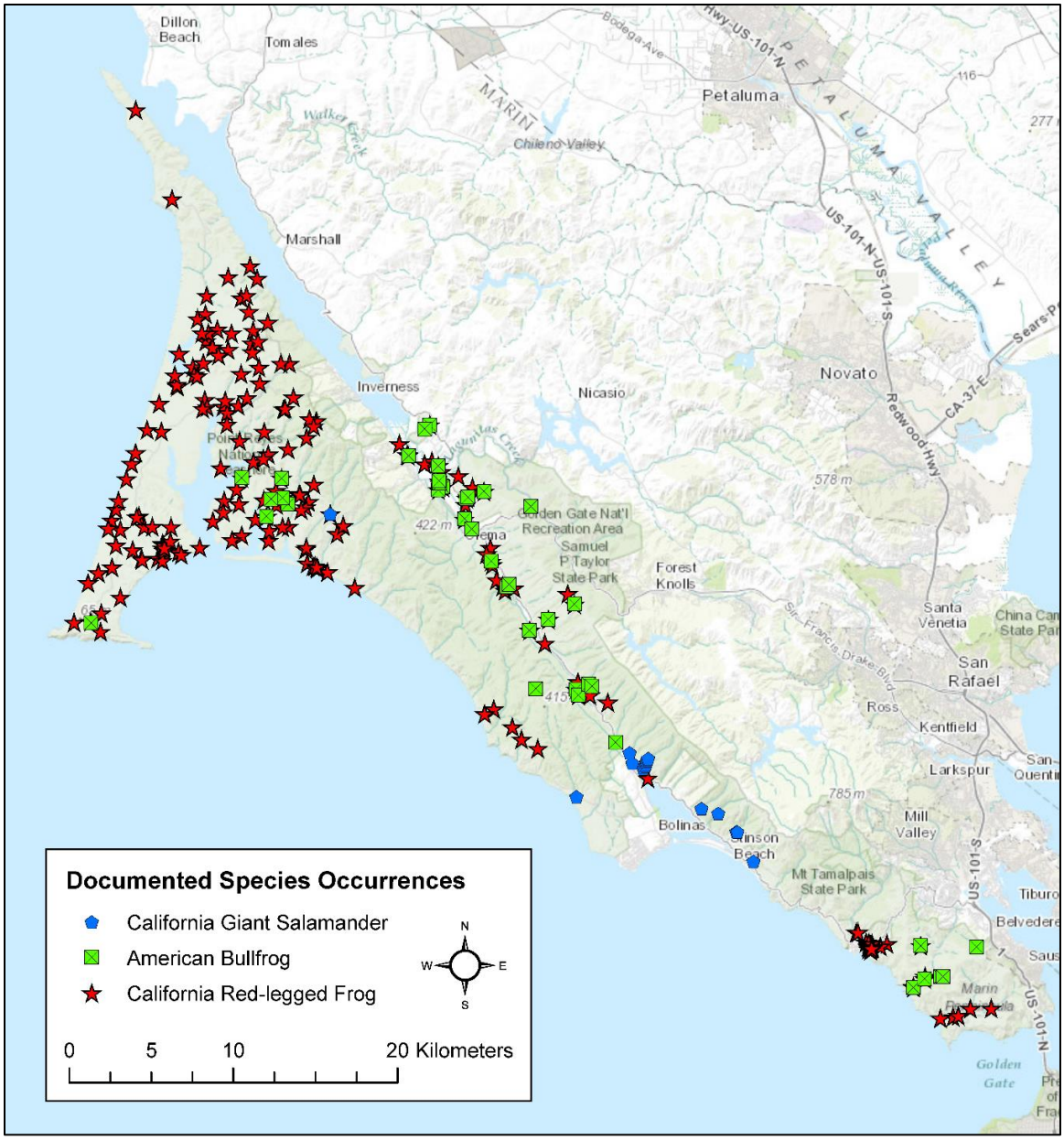


Figure 4.1.14. Spatial distribution of detections of California red-legged frogs (*Rana draytonii*; red stars), American bullfrogs (*Lithobates catesbeianus*; green squares), and California giant salamanders (*Dicamptodon ensatus*; blue pentagons) at Point Reyes National Seashore and Golden Gate National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

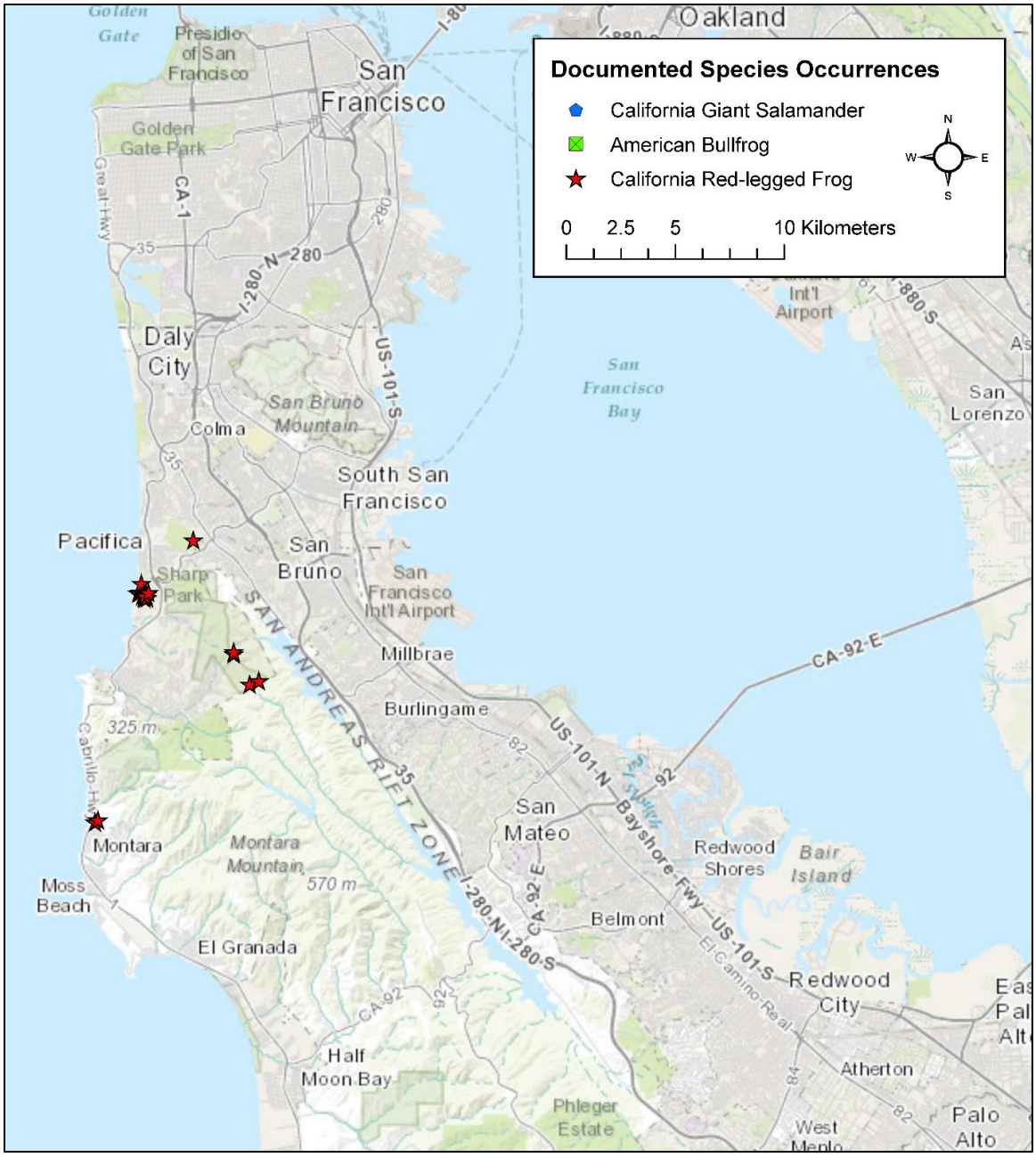


Figure 4.1.15. Spatial distribution of detections of California red-legged frogs (*Rana draytonii*; red stars), American bullfrogs (*Lithobates catesbeianus*; green squares), and California giant salamanders (*Dicamptodon ensatus*; blue pentagons) at Golden Gate National Recreation Area in San Mateo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

Pacific 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, Figure 4.1.16). Nonetheless, Pacific giant salamanders were detected in up to 100% of surveyed streams in a given year (Table 4.1.1). Reliably detecting Pacific giant salamanders is best done with targeted surveys specifically for this species, so they might have gone undetected in some occupied streams.

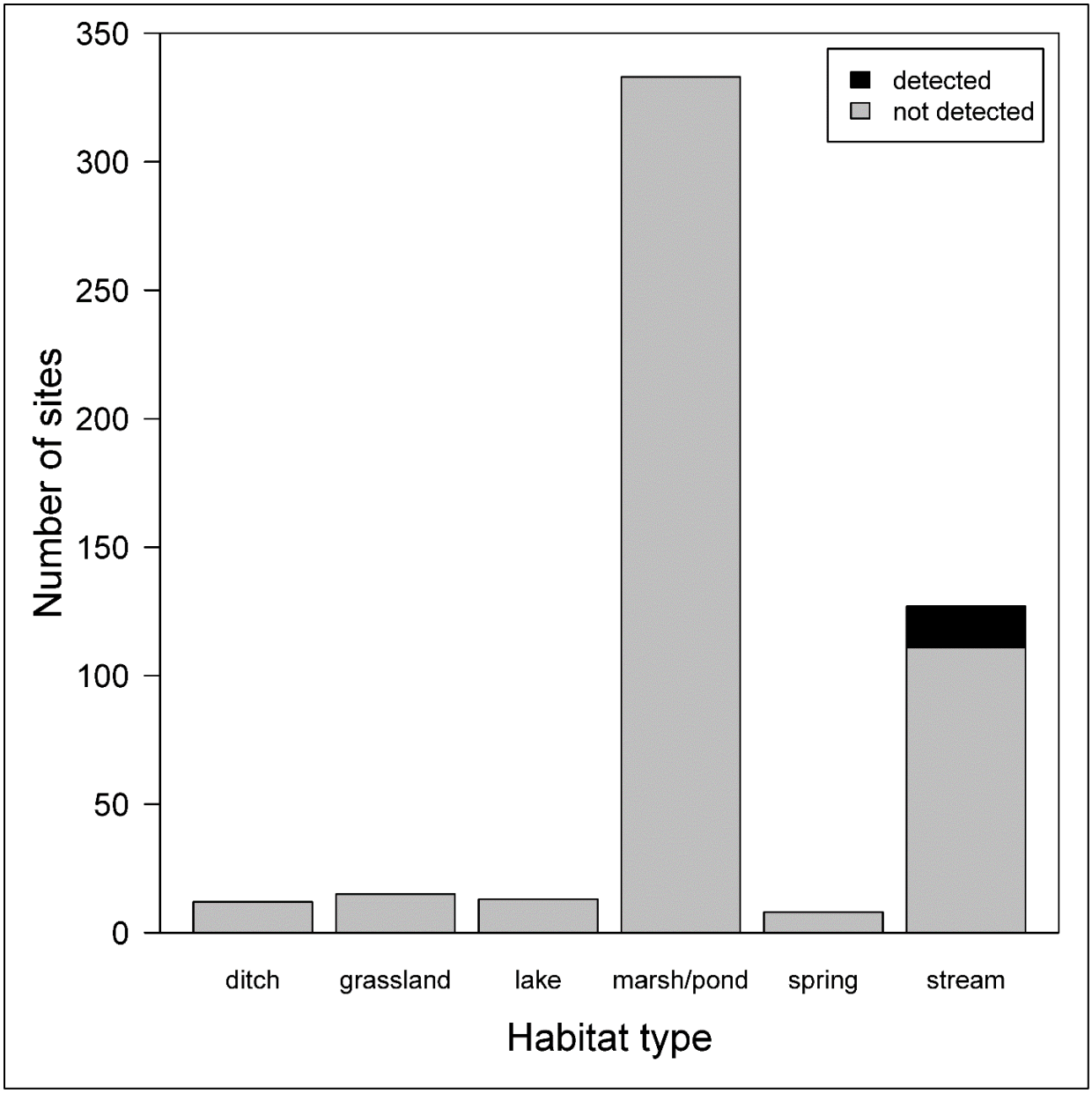


Figure 4.1.16. Proportion of sites at which California giant salamanders (*Dicamptodon ensatus*) were detected at Point Reyes National Seashore and Golden Gate National Recreation Area, 1993 – 2014, by habitat type.

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 (Figure 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 (Figure 4.1.14 and Figure 4.1.15). The latter populations in the Tennessee Valley have

been successfully eradicated (D. Fong, pers. comm. 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 4.1.2, Figure 4.1.12).

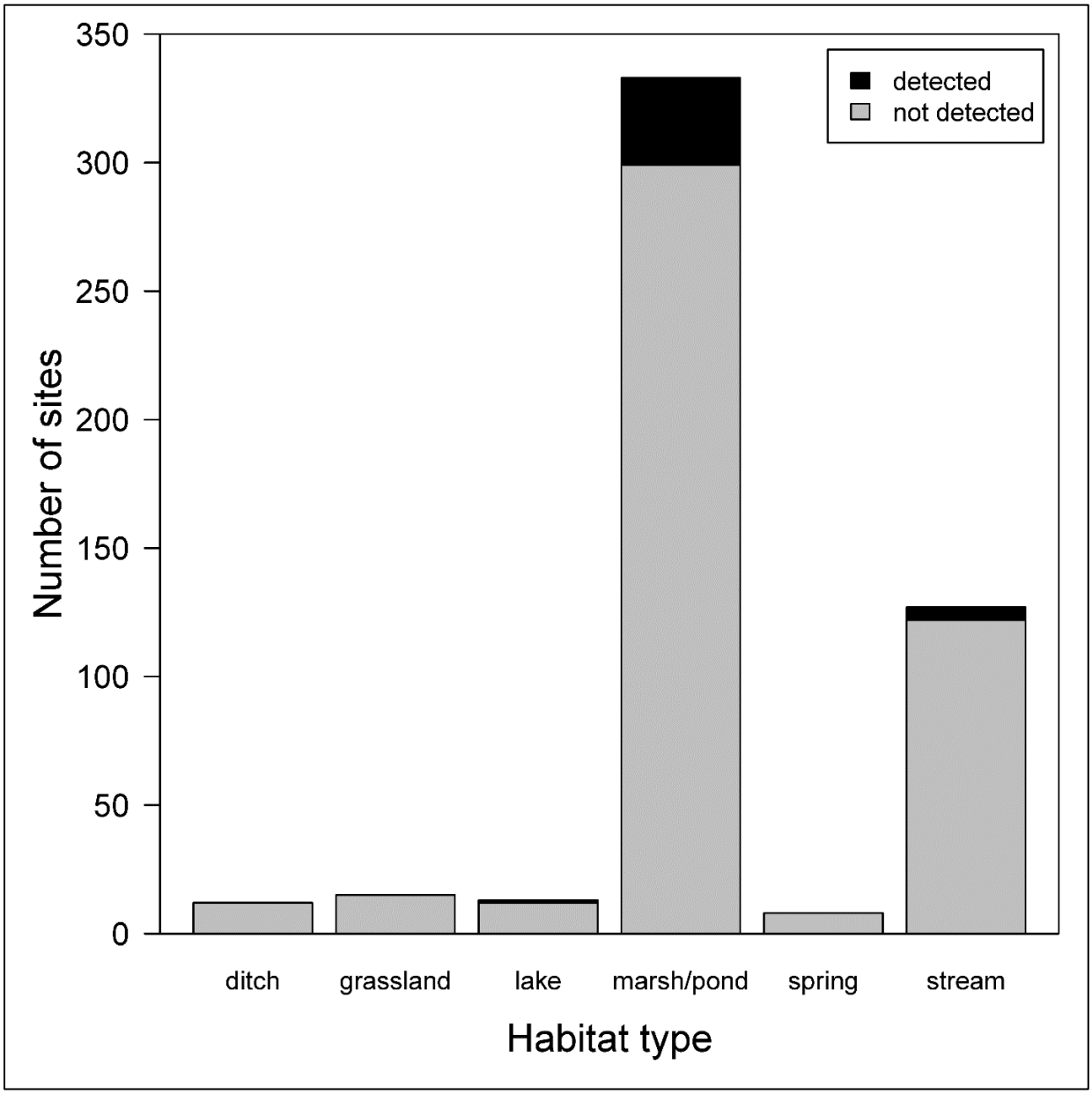


Figure 4.1.17. Proportion of sites at which American bullfrogs (*Lithobates catesbeianus*) were detected at Point Reyes National Seashore and Golden Gate National Recreation Area, 1993 – 2015, by habitat type.

The distribution of non-focal aquatic-breeding amphibians varied widely among species. Sierran treefrogs and rough-skinned newts were generally widespread (Figure 4.1.18 and Figure 4.1.19). California newts were more restricted in their distribution, and western toads were detected at only four sites (Figure 4.1.18 and Figure 4.1.19). Rough-skinned newts and western toads were not

recorded in surveys in San Mateo County (Figure 4.1.18 and Figure 4.1.19). Foothill yellow-legged frogs (*Rana boylii*), a rocky stream-specialist anuran, was notably absent from all surveys.

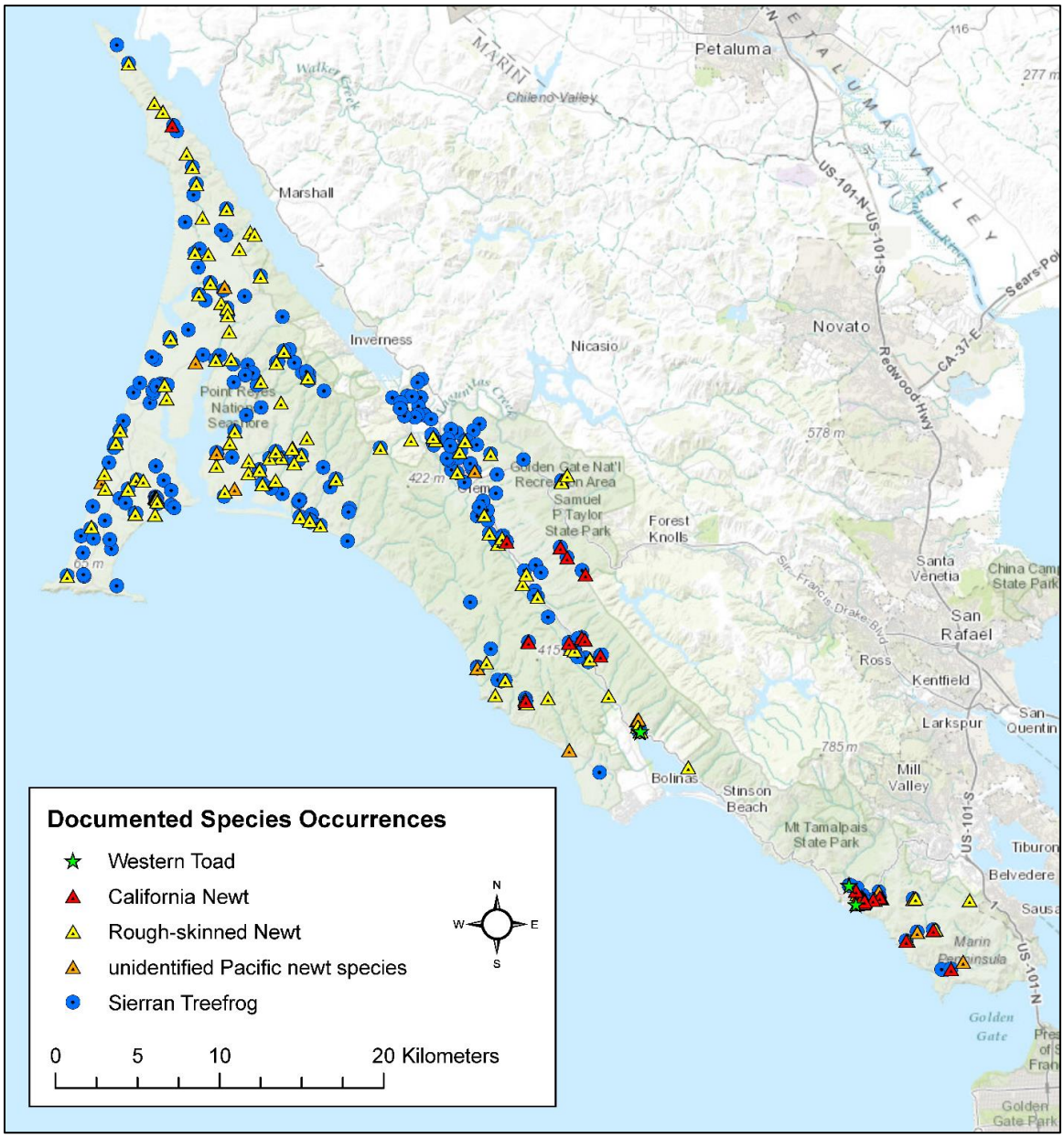


Figure 4.1.18. Spatial distribution of detections of Western toads (*Bufo boreas*; green stars), California newts (*Taricha torosa*; red triangles), rough-skinned newts (*Taricha granulosa*; yellow triangles), unidentified Pacific newts (*Taricha* spp.; orange triangles), and sierran treefrogs (*Pseudacris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

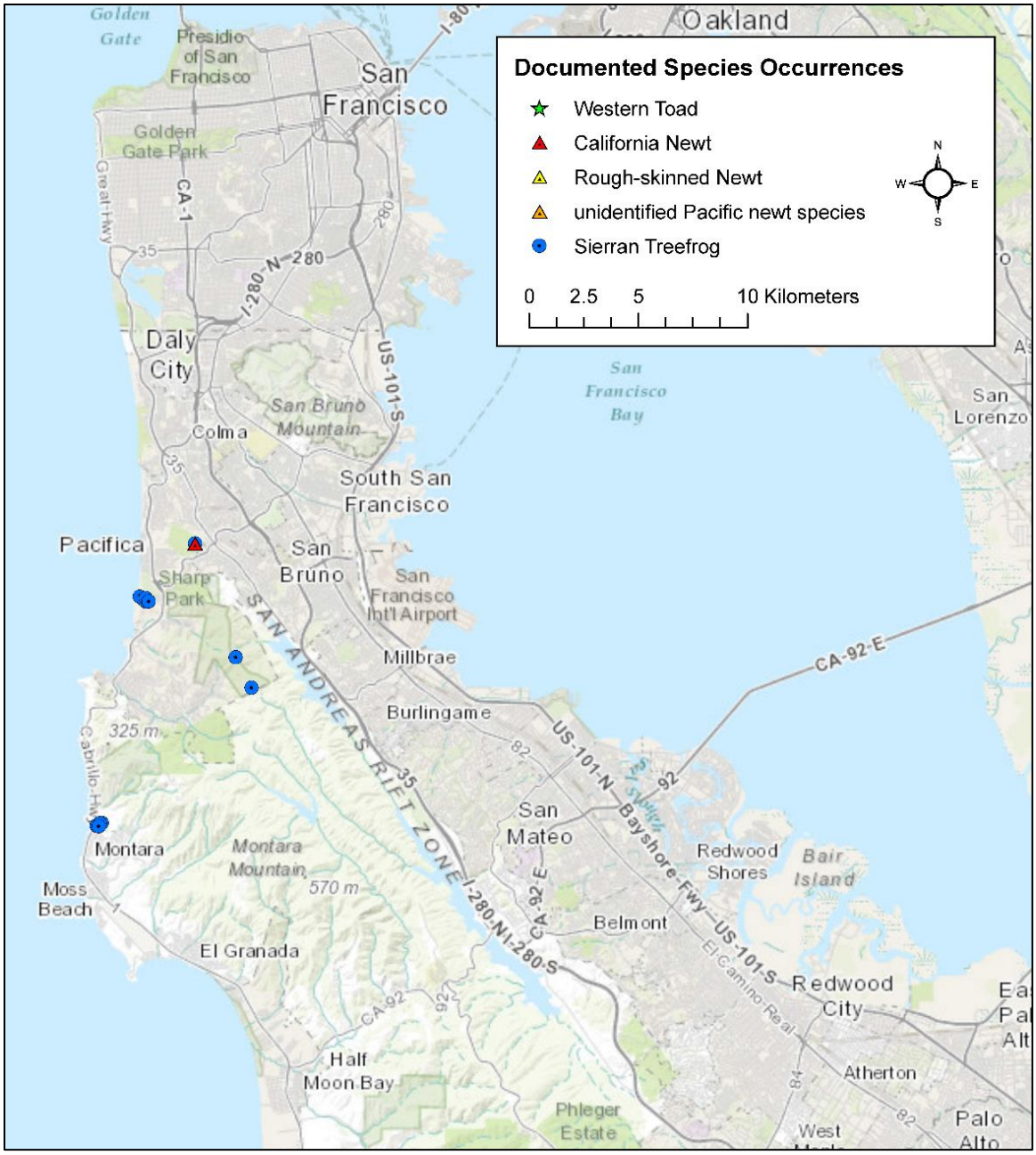


Figure 4.1.19. Spatial distribution of detections of Western toads (*Bufo boreas*; green stars), California newts (*Taricha torosa*; red triangles), rough-skinned newts (*Taricha granulosa*; yellow triangles), unidentified Pacific newts (*Taricha* spp.; orange triangles), and sierran treefrogs (*Pseudacris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

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 Pacific 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 poses 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 1997b, 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, pers. comm. 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., pers. comm. 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, pers. comm. 2015). 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.

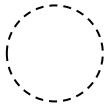
Condition Summary

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 at Point Reyes National Seashore.

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

Table 4.1.3 (continued). Resource condition summary for amphibians at Point Reyes National Seashore.

Indicators of Condition	Specific Measures	Condition Status	Rationale
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 and trend of amphibians			–

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.

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4.2. PORE Breeding Landbirds



The landbird resource for PORE 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 2005a) 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).

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) Trend (percentiles)[1]	BBS Coastal CA (1966-2013) Trend (percentiles)[1]
Species	**Slope (β)**	**p-value**	**Slope (β)**	**p-value**		
Olive-sided Flycatcher	**-0.082[2]**	**0.034[2]**	-0.15	0.175	**-2.94 (-3.53, -2.37)[2]**	**-2.85 (-3.80, -1.84)[2]**
Warbling Vireo	0.002	0.89	0.003	0.912	**-0.90 (-1.44, -0.35)[2]**	**-1.17 (-1.98, -0.37)[2]**
American Robin	**-0.057[2]**	**0.031[2]**	-0.007	0.438	**-0.47 (-0.79, -0.14)[2]**	**0.79 (0.31, 1.30)[2]**
Swainson's Thrush	-0.002	0.883	0.000	0.989	-0.60 (NS)	**-2.11 (-3.21, -1.02)[2]**
Orange-crowned Warbler	0.016	0.302	**0.035[2]**	**0.021[2]**	**-0.95 (-1.61, -0.29)[2]**	**-1.12 (-1.99, -0.22)[2]**
Wilson's Warbler	-0.004	0.738	0.000	0.994	**-1.80 (-2.61, -1.02)[2]**	0.65 (NS)
Song Sparrow	-0.023	0.09	-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)[2]**	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 Bold text indicates significant trends.

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).

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. 2005b). 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. 2005b) 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 PORE.

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. Resource condition summary for landbirds at Point Reyes National Seashore.

Indicators of Condition	Specific Measures	Condition Status	Rationale
Understanding of Status	Spatial and temporal distribution of survey effort		Survey effort and timing used replicated techniques and were distributed throughout the habitat of interest.
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 trend models are a mix of declining, increasing and neutral trends. No other population trends available.
Overall condition and trend of landbirds			–

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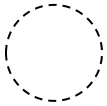
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4.3. Coastal Dunes



PORE has a significant portion of the remaining native dune vegetation in Northern California. The Seashore is continuing exotic species management on selected sites. There is a need for quantitative information in a framework that will allow for better community descriptions, assessment of condition trends, and inform adaptive management.

4.3.1. Why Focal Resource Was Assessed

Description

Coastal Dunes at Point Reyes are an important resource element with high regional conservation value. Coastal dunes also present formidable problems for conservation, management, and restoration at multiple spatial and temporal scales. Goals, management practices, and monitoring methods need careful development in a highly dynamic environment dominated by sharp physical gradients and an inherently rapidly changing biota.

Dunes have long been significantly affected by human activities. The National Park Service's central goal is clear: "Park Service Management Policies directs parks to manage, and if possible and prudent, eradicate, invasive species that interfere with natural processes and the perpetuation of natural features, native species, or habitats" (NPS 2015). This goal also contains some qualifiers ("…if possible and prudent…that interfere with natural processes…") that apply directly to Coastal Dunes at Point Reyes and will be addressed systematically below. The assumption is that the goals can be specific, and the results of any management intervention will be predictable. One way to do this is to develop ecological site descriptions (ESDs) and state and transition models (S-T Models) (Spiegal et al. 2014).

Critical questions

- Can the existing data be used to develop good ecological site descriptions and associated state and transition models for coastal dunes?
- Are these models likely to offer good predictions for the effects of management and environmental change on coastal dunes?
- What are the critical data and knowledge gaps for coastal dunes that PORE needs to address?
- How are invasive species influencing the condition of coastal dunes and dune habitats in PORE?
- What are the opportunities for management intervention in these systems to maintain long term viability?

4.3.2. How Focal Resource Was Assessed

Measures

We used a qualitative approach to address the above critical questions for PORE coastal dunes. A detailed recent report *Coastal Dunes Restoration Environmental Assessment* (NPS 2015) was

available. This document contained extensive qualitative information about PORE coastal dunes and some quantitative information about invasive and threatened and endangered species. Our conclusions are limited both because we were not provided access to the data used in the EA and also because the EA focused primarily on exotic plant control. Although the EA includes goals for enhancement of threatened and endangered plants and animals and includes a statement about the desirability of adaptive management there were no data that would directly inform quantitative assessment of site specific conditions or effects of adaptive management.

We use an ecological site description (ESD) framework to assess condition of the Coastal Dune focal resource. Because original data were not available, we were restricted to qualitative ESDs for this report. ESDs are widely used by Federal agencies as a way to organize and predict the effects of management, develop realistic conservation objectives, and inform adaptive management decisions and recommendations (USDA 2014). An Ecological Site is defined as "a distinctive kind of land with specific characteristics that differs from other kinds of land in its ability to produce a distinctive kind and amount of vegetation" (Caudle et al. 2013). It assumes that geomorphic features like soil, geology, and local environment support a distinctive vegetation and habitat for associated fauna. The spatial and temporal scales vary, but are often tied to soil mapping units and vegetation community types. Identified ESDs have associated state and transition models (S-T Models), which may offer useful predictions about the consequences of management interventions, conservation activities, exotic plant control, or even response to climate change (Spiegal et al. 2015). This exercise can range from a broad assessment of environmental characteristics and biota, to more intensive inventories of soils, vegetation, and fauna, long-term monitoring, through direct experimentation and hypothesis testing, and varies with the complexity and scale of the landscape and the specific goals. There is currently an on-going evaluation and development of ESDs nationwide and in California (Spiegal et al. 2014) with excellent results for grasslands and significant progress toward applications to conservation of other ecosystems, such as riparian (Ratcliff et al. 2015).

There was enough qualitative information to initiate development of coastal dune ESDs and associated S-T Models but more accurate models will require more evaluation and data collection with the goal of developing quantitatively based predictive ESDs. These models could provide good information with a minimal amount of analysis of existing data already collected by NPS. We recommend testing the use of the ESD framework for developing the kind reliable predictions needed to inform adaptive management under achievable community conservation goals.

Data Sources and Methods

Literature review

The research base for understanding Californian dune vegetation structure has improved enormously over the past few decades. This has culminated in the comprehensive treatment of coastal dunes in the recently published volume *California Ecosystems* (Alpert 2015). We expected that information about dune fauna, flora, and the physical environment would also be available from products produced for coastal zone planning, especially the recently completed Coastal Dunes Restoration Environmental Assessment (CDREA; NPS 2015). We reviewed available publications and reports related to the distribution and species composition of dune vegetation within PORE (Appendix A).

We refer to a key subset of those references and from Alpert (2015) in this report. Note that the CDREA reviewed both the existing dune literature and internal NPS information.

Data Analysis and production of ESDs

We developed useful qualitative ESDs and associated S-T Models that provide a theoretical framework that will support more quantitative predictive models when data become available.

Reference Conditions/Values

As stated above, the existing qualitative information was sufficient to create general ESDs and S-T Models (Figure 4.3.1). We believe that available internal monitoring information would be sufficient for evaluating the potential for qualitative changes either under environmental or management influences but did not have access to those data.

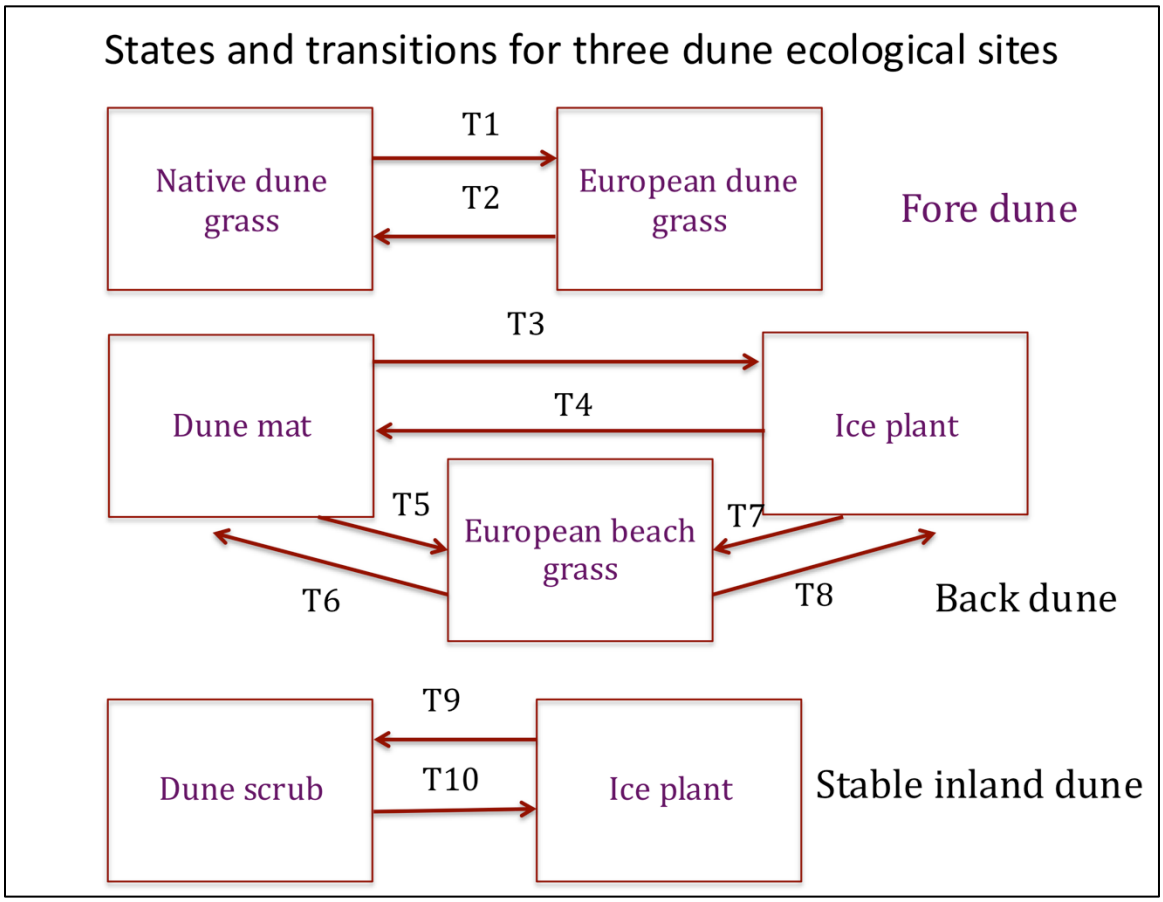


Figure 4.3.1. Ecological site descriptions and state and transition models for three coastal dune ecological sites (Fore dune, Back dune, and Stable inland dune) at Point Reyes. The Dune swale ESD is not described. Arrows represent hypothesized but likely transitions T1-T10 between Vegetation States (boxes). Detailed descriptions of States and Transitions are in text.

Based on mostly subjective and anecdotal information in the CDREA (NPS 2015) and the review by Alpert (2015), there appears to be good information available on climate, geology, and soils that would allow refinement and modification of draft ESDs for coastal dunes. We incorporated and

summarized published information about plant community structure and dynamics into the S-T Models for the coastal dune ESDs in Figure 4.3.1 (see Pickert and Barbour 2007, Holton and Johnson 1979, and Appendix A). However, the information available for Point Reyes can only generally and qualitatively link vegetation processes to the temporal and spatial structure of the dune systems. There is mention of work on monitoring dune restoration as noted above, but we did not have access to data that would have allowed further evaluation.

Reference states are arranged on the left side of Figure 4.3.1. The Fore Dune Ecological Site historically was a state dominated by native American beachgrass along with associated native species adapted to that environment. Back Dune Ecological Sites historically supported diverse dune mat plant communities. The Stable Inland Dune Ecological sites historically supported Dune scrub vegetation, a state with diverse native species.

The current Holocene environment is not typical, representing a short and probably temporary departure from the normal ice-dominated Pleistocene (Bartolome and Spiegal 2014) with cooler temperatures and a local coastline at Point Reyes much farther to the west due to a lowered global sea level. The underlying geology is complicated with the collision of the Pacific and North American plates but current dunes in Northern California variably date mostly from quite recent to some pre glacial (Pickert and Barbour 2007, Alpert 2015). Another important consideration is that the combinations of subsidence and sea level change have commonly resulted in a landscape gradient from very old and stable sands on older coastal terraces dominated by woody vegetation (Jenny et al. 1969) to the less stable modern dunes.

4.3.3. Condition Assessment

Condition and Trend

Dune systems at Point Reyes are highly dynamic but commonly form predictable patterns with associated differences in vegetation structure. The strongest influence on biota, including people, is the physical substrate of mobile sand. The primary fore dune is sparsely vegetated, originally by the native American dune grass (*Leymus mollis*) but more recently occupied by European beachgrass (*Ammophila arenaria*) (T1), which produces deep rhizomes and is favored by less substrate mobility. This species was widely planted in the mid-20th century in an attempt to stabilize coastal dunes but is now recognized as a major threat to natural processes and native species (see Figure 15 in NPS 2015). Aggressive management intervention is required to reverse T1 with T2. Farther inland, back dunes internally stabilize and remobilize sand and commonly support European beachgrass or iceplant states (Baye 2008, NPS 2015). The Coastal Dunes Restoration Environmental Assessment (CDREA) lists several references noting reduction in sand movement in areas with increase of European beachgrass (T5) and iceplant (T8) (NPS 2015), which could result in a transition to Dune scrub and a shift in Ecological site. Dune restoration projects that remove exotic plants have a major goal of producing transitions T2, T4, T6, and T9 (Johnson 2013). Where near surface water is present, back dunes support marsh habitats. NPS (2015) lists 36 federally listed species of plants and animals as occurring on or near dune habitats at Point Reyes; the named plant community types include Native American Dune Grass, Dune Mat, Dune Scrub, European Beachgrass, and Ice Plant, which correspond to the States in Figure 4.3.1. Some of those named types have been partially

mapped and according to the CDREA (NPS 2015) include unpublished data, which were not made available for this report.

General qualitative information is available for the abundance of exotics (NPS 2015), native plant distributions (NPS 2015, Alpert, 2015), threatened and endangered plants and animals (NPS 2015). PORE Coastal dunes near Abbott's Lagoon have been cited as the best examples of native dune vegetation in Northern California (Barbour and Johnson 1988; Alpert 2015), which would make them a sources of quantitative information on baseline conditions. However, this kind of information is of limited value without the perspective of a quantitative ESD model.

Stressors

As described above, the strongest influence on biota is the physical substrate of mobile sand. The primary fore dune is sparsely vegetated and recently occupied by European beachgrass, which produces deep rhizomes and is favored by less substrate mobility. This species is now recognized as a major threat to natural processes and native species (see Figure 15 in NPS 2015). The CDREA notes a reduction in sand movement in areas with European beachgrass and iceplant (NPS 2015).

Control of the two most common exotic plants, European beachgrass and iceplant, is feasible and justified as part of the preferred alternative the CDREA (NPS 2015). Control should be implemented and followed through effectiveness monitoring and adaptive management. This monitoring will work best if directly tied to ESDs and well-developed State and Transition models (Spiegal et al. 2016).

Level of confidence in assessment

There is widespread support for the notion that exotic species, especially European beachgrass and iceplant, now dominate some parts of the Dune environment. There is some evidence that this has been at the expense of native plant species. The available evidence for native animals is lacking.

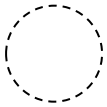
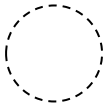
Gaps in understanding

Spatially and temporally explicit quantitative ESDs and S-T Models would help better guide management and decision making in Dune systems.

Condition Summary

The strongest influence on coastal dune biota is the physical substrate of mobile sand. European beachgrass (*Ammophila arenaria*), which produces deep rhizomes, was widely planted in the mid-20th century in an attempt to stabilize coastal dunes but is now recognized as a major threat to natural processes and native species. There is widespread support for the notion that exotic species, especially European beachgrass and iceplant, now dominate some parts of the Dune environment. Control of the two most common exotic plants is feasible. Control should be implemented and followed through effectiveness monitoring and adaptive management. This monitoring will work best if directly tied to Ecological Site Descriptions and well-developed quantitative State and Transition Models.

Table 4.3.1. Resource condition summary for coastal dunes at Point Reyes National Seashore.

Indicator of Condition	Specific Measure	Condition Status	Rationale
Are Ecological Site Descriptions with associated state and transition models likely to offer good predictions for the effects of management and environmental change on coastal dunes?	Ecological Site Descriptions with associated state and transition models		Data not available sufficient to initiate development of quantitative ESDs and S-T Models
Overall condition and trend of coastal dunes	n/a		–

4.3.4. Information Sources

Sources of Expertise

This report incorporates information from a literature review and as reported in the Coastal Dunes Restoration Environmental Assessment (NPS 2015).

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4.4. 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.

4.4.1. Why Focal Resource Was Assessed

Description

Forests account for 32% of the 280 km^2 of the terrestrial landscape managed by Point Reyes National Seashore (PORE). Grassland (29%), coastal scrub (27%), managed pastures (6%), shrublands (3%), and dunes (3%) constitute the remaining elements of the complex vegetation mosaic (Schirokauer et al. 2003). Part of this complexity is due to the steep environmental gradients typical of the North Coast Range of California (Barbour et al. 2014). Indeed PORE is a good example of the adage: "Great environmental variation and associated vegetation change occur within very limited geographical areas in California (Waring and Major 1964)." Consider the pattern across Mount Wittenberg (Figure 4.4.1). From the summit (428 m elevation) down to the coast a mere 6 km to the southwest, the structure of the vegetation changes from a tall, closed-canopy evergreen forest near the summit (Figure 4.4.2) though coastal scrub along the midslope (Figure 4.4.3) to coastal dune vegetation before the beach (Figure 4.4.4).

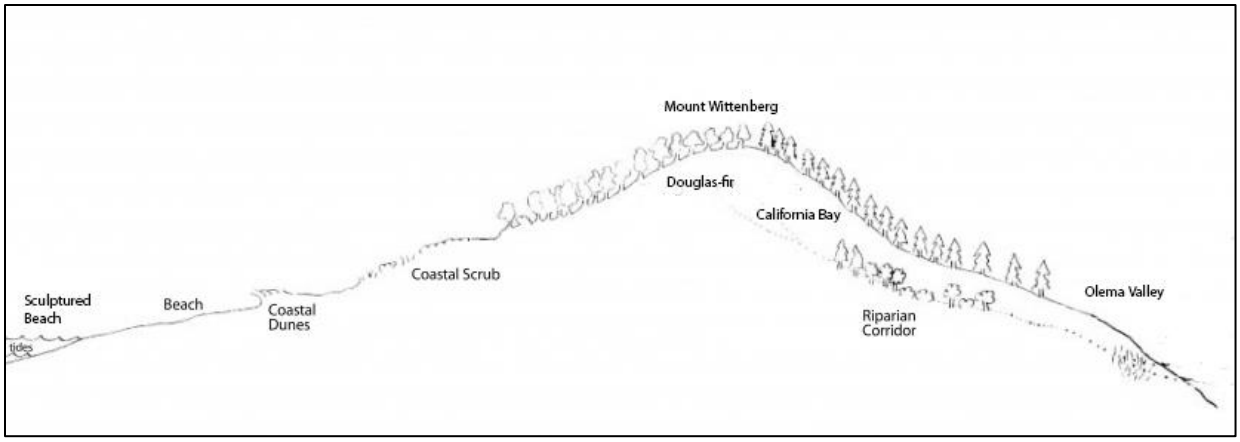


Figure 4.4.1. Idealized vegetation transect across Mount Wittenberg. Diagram adapted from Point Reyes National Seashore Association (http://www.ptreyes.org/activities/plant-communities).



Figure 4.4.2. Mature Douglas-fir forest near the summit of Mount Wittenberg. Photo credit: John Battles



Figure 4.4.3. Coastal scrub community on the west slope (coast side) of Mount Wittenberg. Photo credit: John Battles.



Figure 4.4.4. Coastal dune vegetation near Sculptured Beach. Photo credit: John Battles.

As is typical for coastal uplands in northern California (Sawyer 2007), the mixed evergreen forest is by far the most abundant tree community covering 74 km^2 (76% of all forests, Schirokauer et al. 2003) of PORE. This community is characterized by shared dominance between the evergreen gymnosperm, Douglas-fir (*Pseudotsuga menziesii*), and three evergreen angiosperms: California bay laurel (*Umbellularia californica*), tanoak (*Notholithocarpus densiflorus*), and coast live oak (*Quercus agrifolia*). Also present are two less common forests typified by the dominance of a single conifer tree species – the bishop pine (*Pinus muricata*) forests along Inverness Ridge (8 km^2) and the coast redwood (*Sequoia sempervirens*) forests in the southern end of the management district along Bolinas Ridge (6 km^2). In addition, riparian forests consisting largely of willows and alders line the stream corridors (8 km^2). Scattered throughout are small non-native stands (< 1 km^2) of eucalyptus

(*Eucalyptus* spp.), Monterey cypress (*Hesperocyparis macrocarpa*), and Monterey pine (*Pinus radiata*). The plant taxonomic reference follows Calflora (2016).

Collectively the forests at PORE provide essential structure and function to the ecosystem. The trees along the slopes of Inverness and Bolinas ridges greatly diversify the available habitat that in turn supports a wide range of organisms including threatened and endangered species like the northern spotted owl (*Strix occidentalis*, Forrestel et al. 2015) and the Point Reyes mountain beaver (*Aplodontia rufa phaea*, Fellers et al. 2004). 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). The forests account the vast majority (95%) of the 910 Gg of carbon stored in the aboveground live vegetation at PORE (Gonzalez et al. 2015). This carbon represents 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 the entire Seashore.

Primary risks to the forest at PORE include climate change, an altered fire regime, and the spread of exotic pathogens. By one account, shifts in vegetation resulting from projected changes in climate could result in the near elimination of the mixed evergreen forest by 2100 (Hameed et al. 2013, Appendix A, Figure DC-5). Fire is a major driver of vegetation in the American West and the natural fire regime has been greatly disrupted (Stephens and Ruth 2005) but its role in these coastal forests is complex (Forrestel 2013). In fire-dependent communities like the bishop pine, the occurrence of fire is closely linked to population dynamics (Forrestel et al. 2011). In others, like the coast redwood, the role of fire is more ambiguous (Lorimer et al. 2009). Moreover, the response to an altered fire regime can be context dependent. For example, in absence of fire, Douglas-fir can expand into adjacent coastal scrub vegetation (Russell and McBride 2003) while a large, hot fire like the 1995 Vision Fire greatly reduced the extent of Douglas-fir (Forrestel et al. 2011). Both scenarios (no fire and a large hot fire) are atypical for Douglas-fir forests (Brown et al. 1999). In contrast, there is no doubt regarding the impact of the introduced pathogen, *Phytophthora ramorum*, the causal agent of Sudden Oak Death (SOD). It has resulted in the widespread mortality of tanoak at PORE (Ramage et al. 2011) and has the potential to impact coast live oak as well (McPherson et al. 2010). More recently, another exotic forest pathogen has arrived. Pitch canker (*Fusarium circinatum*) has spread to the bishop pine forests (Harvey et al. 2014). Given that pitch canker disperses widely in coastal regions (Ganley et al. 2009) and the susceptibility of bishop pine (UC IPM 2013), the disease has the potential to not only hasten the demise of the older stands but also to disrupt the ongoing recovery from the Vision Fire (Harvey and Holzman 2014).

This assessment will first consider the status of the entire forest community at PORE and then focus on the three most abundant forest types (Figure 4.4.5). Forest types were defined using the "community" designation from the PORE 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.

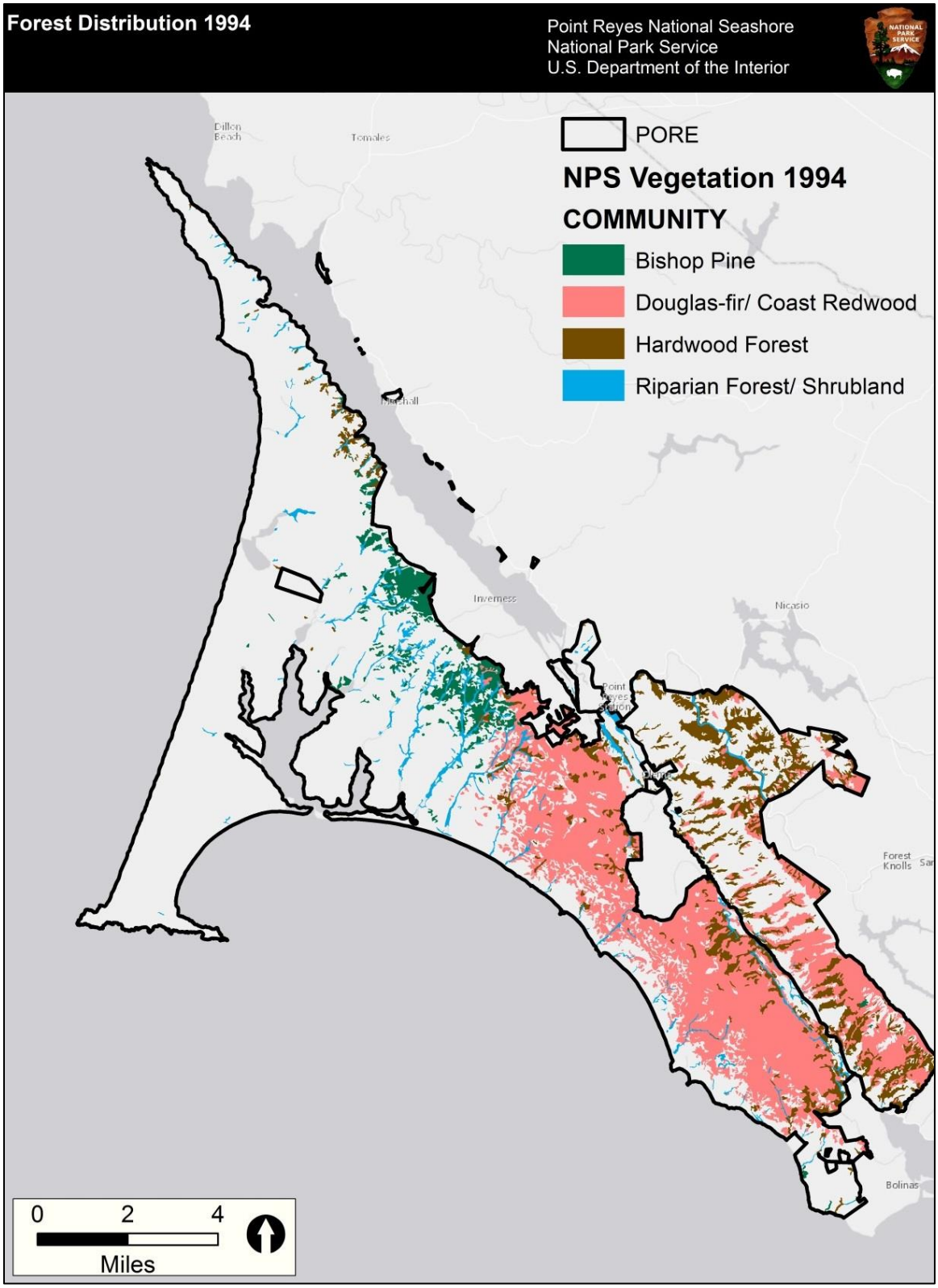


Figure 4.4.5. Distribution of forest communities included in the resource condition assessment. Vegetation map from Schirokauer et al. 2003

The key difference with the purely ecological association is that the community splits components of the mixed evergreen forest as defined by Sawyer (2007). It combines Douglas-fir stands with redwood stands in one class, Douglas-fir/Coast Redwood (59 km^2). Patches dominated by the two angiosperms, California bay and coast live oak, form the Hardwood Forest (21 km^2). Tanoak is a component of both these classes but more prevalent in the Douglas-fir/Coast Redwood. The third most type is Bishop Pine (8 km^2). The three communities vary in their inherent dynamics given the differences in the life histories of the canopy trees. While they face similar stressors (e.g. climate change, altered fire regime, and exotic pathogens), differences in their responses require that their condition be assessed separately. Also the lumping of the relatively small and isolated patch of redwood dominated forest (10% of the Douglas-fir/Coast Redwood community clustered along the Bolinas Ridge) with the more ubiquitous Douglas-fir forest risks obscuring important differences in between these two forest types. Thus when relevant to the condition assessment, the differences are noted.

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 informing management decisions and evaluating 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. Their work provides a template for the condition assessment of the PORE forests. Thus our 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 at PORE?
- What is the impact of projected changes in climate on the distribution of forests at PORE?
- What is the impact of the altered fire regime on the forests at PORE?
- What is the impact of exotic forest pathogens on the forests at PORE?

4.4.2. 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 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) not only provide insights into the future ecologies of natural systems but also their current vulnerabilities (Lenihan et al. 2008, Stralberg et al. 2009). Thus despite their limitations, they are a valuable aspect of a multi-faceted condition 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 PORE can lead to the build-up of fuels and thus change the behavior of wildfires. To the extent that this behavior exceeds the natural fire regime, it represents a threat to the integrity of the forests (Donato et al. 2008, 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 were quantified trends at PORE 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 relies on 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 tree communities at PORE. 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, specific results for PORE were obtained from the report: Climate Change Vulnerability Assessment: Point Reyes National Seashore (included as Appendix A in Hameed et al. 2013). As noted above, these projections consider results from two global circulation models assuming a medium-high emissions scenario. To obtain specific predictions for PORE from the Ackerly et al. (2015) results, the baseline climate was estimated for Point Reyes Station. The baseline climate was defined from the 30-yr normals (1980-2010) reported by the PRISM Climate Group. 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).

To assess the potential impact of wildfire, results from two different analyses were compared. In collaboration with the Marin County Fire Department, PORE developed a wildland fire risk model (PRNS 2006). Potential fire behavior was used to determine the degree of hazard based topography and fuels under extreme weather conditions. The Fire Ecology and Fire Effects Program of the National Park Service Bay Area Network produced a more detailed fire hazard analysis for PORE that explicitly incorporated spatial variation in fuel loads and topography (Forrestel no date). To quantify the impact of the altered fire regime, the distribution of forests at PORE was compared to the fire hazard classifications, with fire hazard defined as the probability of a given set of fire behaviors (Finney 2005).

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) PORE, provided the primary means to assess the impact of exotic forest pathogens. Most of the work focuses on the impact of *P. ramorum* in the Douglas-fir/Coast redwood forest. The assessment also relied on reviews of the literature to more specifically assess the condition of the three forest types and evaluate the threat posed by interacting perturbations.

Reference Conditions/Values

Two reference conditions were developed to evaluate the trends in biomass accumulation: a theoretically based standard and a regional standard. The vast majority of the forests at PORE are second-growth stands that developed following logging completed in the late 18th or early 19th century (Brown et al. 1999, Forrestel et al 2015). Most have not experienced fire for more than a century (Brown et al. 1999, PRNS 2006). 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 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 in the Seashore 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 1994 vegetation map, Schirokauer et al. 2003) 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.

4.4.3. Condition Assessment

Condition and Trend (with Stressors included)

What is the current trend (2001-2010) in forest biomass accumulation at PORE?

Between 2001 and 2010, aboveground live biomass (AGL) in the forests at PORE accumulated at rate of 0.3%/yr. The greatest biomass density was observed on the upper slopes (Figure 4.4.6) -- habitats that support mature, intact, conifer-dominated forests (Figure 4.4.1). Overall the average AGL density of 213 Mg/ha did not change with time. The increase in AGL was due to expansion of the tree-dominated area at PORE. Assuming that 1 g biomass contains 0.47 g carbon on average (Gonzalez et al. 2015), the amount of forest carbon stored in aboveground live vegetation increased from 918 GgC to 943 GgC. Note: the carbon pools reported here include the forests on Bolinas Ridge managed by PORE. The estimate reported by Gonzalez et al. (2015) did not. In contrast to PORE, AGL declined regionally at the rate of 0.9%/yr (Figure 4.4.7). Again 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 uncertainty associated with the Landfire-based estimator of biomass change (Battles et al. 2014) precludes an analysis of change by forest type at PORE. However, the literature provides clues to the underlying processes. The bishop pine trees that established following the Vision Fire (Forrestel et al. 2011) have continued to mature. Harvey and Holzman (2014) documented a significant increase in tree cover in post-fire monitoring plots with a corresponding decrease in the relative abundance of shrubs. By 2008 (14 years after fire), bishop pine accounted for 35% of the canopy – an 8%/yr increase in bishop pine growth from 2000 (growth rate estimated from data reported in Appendix D, Harvey and Holzman 2014). In contrast, plots established along Inverness and Bolinas ridges (i.e., outside of the Vision Fire perimeter) to monitor the progression of *P. ramorum* in the Douglas-fir/Coast Redwood forest show continued losses of tanoak with limited regeneration/expansion of associated species (Ramage et al. 2012, Forrestel et al. 2015). The observed declines in the live tanoak basal area undoubtedly are associated with declines in live biomass as documented by Waring and O'Hara (2008) for similar forests in the Marin Municipal Water District. Results from a Landsat-based disturbance index designed to track changes in perennial vegetation structure (Potter 2013)

support the conclusion that between 1999 and 2009, the forest is regrowing inside the perimeter of the Vision Fire and declining in areas infected with *P. ramorum.* Finally, given the absence of a wildfire at PORE since 1995 (PRNS 2006), it is likely that there has been expansion of Douglas-fir trees into the coastal scrub (sensu Russell and McBride 2003) between 2001 and 2010. Local resource management (A. Forrestel pers. comm. 2015) confirms that there has been expansion of Douglas-fir into the scrub vegetation.

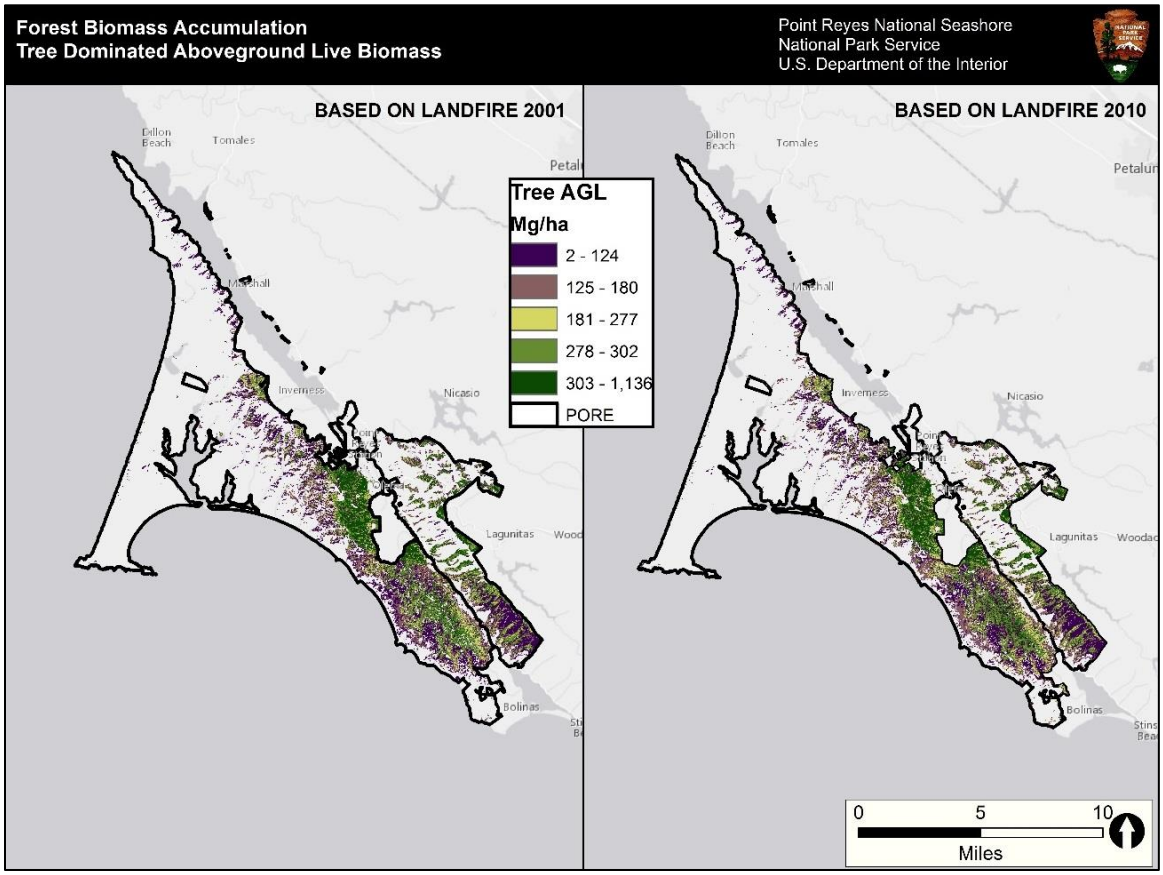


Figure 4.4.6. Changes in the aboveground live biomass in the tree-dominated landscape of PORE between 2001 and 2010 (LANDFIRE data).

Collectively, these patterns and processes suggest that the forests at PORE have sustained their biomass capital. While these second-growth forests do not appear to be accumulating biomass at the rate predicted by theory, apparently due to the progression of an exotic disease, they are clearly outpacing the regional forest. While the Seashore and region share the same suite of stressors, the protection afforded by the Seashore not only restricts the harvest or conversion of forests but also allows processes like tree encroachment into the rangelands to proceed.

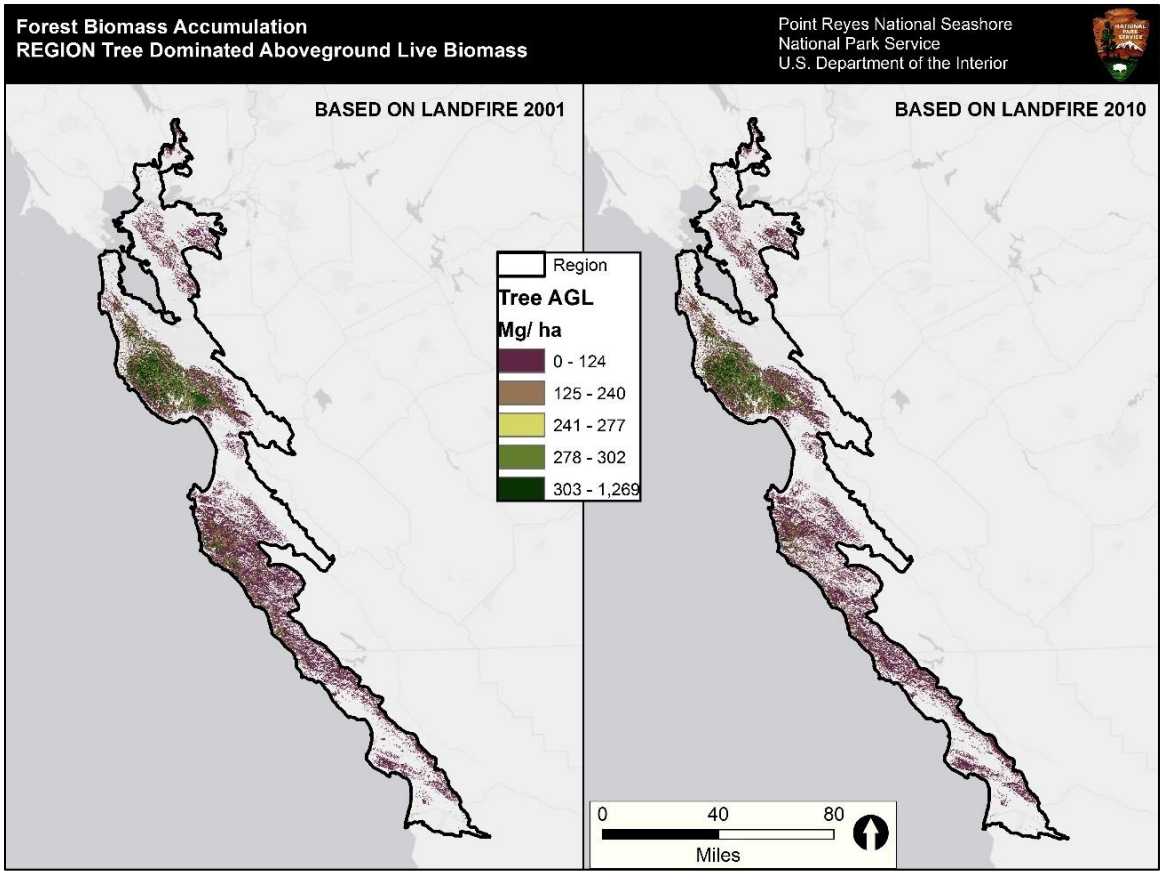


Figure 4.4.7. Changes in the aboveground live biomass stored in the tree-dominated landscape of the region (Marin, San Francisco, and San Mateo counties) between 2001 and 2010 (LANDFIRE data).

What is the impact of projected changes in climate on the distribution of forests at PORE?

Based on the projections reported by Hameed et al. (2013) from models developed by Stralberg et al. (2009), climate change will cause a dramatic contraction of the forests at PORE. Two of the three simulations predict that no climate niches will be present in 2100 that support Douglas-fir/Coast Redwood forests. The most optimistic model identifies only small patches with suitable conditions (Figure DC-4 in Appendix A, Hameed et al. 2013). The Bishop Pine community shares a similar fate (Figure BP-2 in Appendix A, Hameed et al. 2013) – little to no habitat is predicted to exist in 2100. In contrast, future distributions of the Hardwood Forest type diverge widely. Two models suggest no suitable climate niches will exist while a third suggests that Hardwood Forest will dominate the Seashore (Figure BO-3 in Appendix A, Hameed et al. 2013).

Results from Ackerly et al. (2015) also suggest that by the end of the century, given the expected warming (Figure 4.4.8, top panel), there will be very little climatically suitable habitat at PORE for the Douglas-fir/Redwood forest and the Bishop Pine forest (Figure 4.4.9).

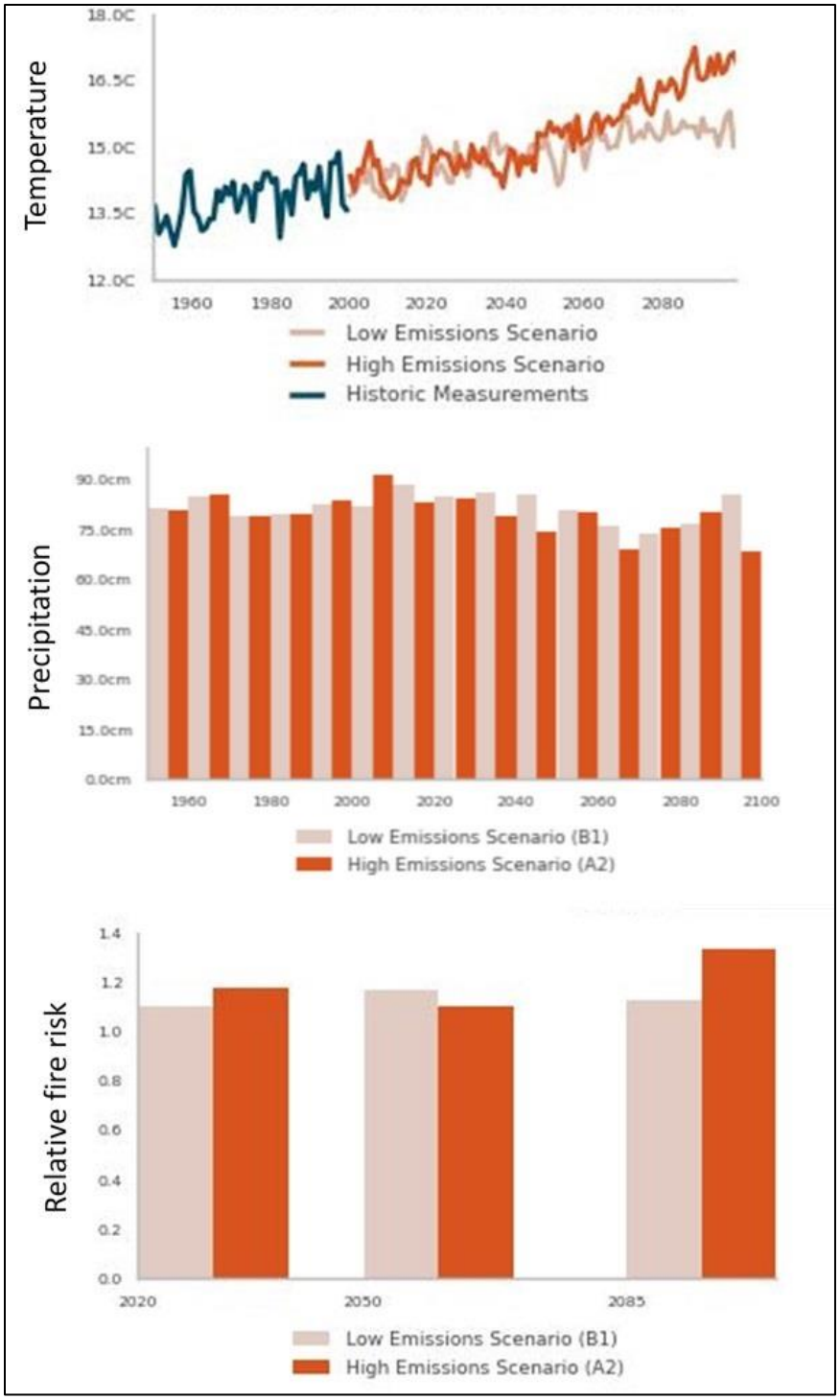


Figure 4.4.8. Potential interactions between climate change and future wildfire risk for PORE. Projections for Cal-adapt (http://cal-adapt.org/) for Point Reyes Station. Upper panel is the predicted average annual mean air temperature from four global circulation models under a low and high emission 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.

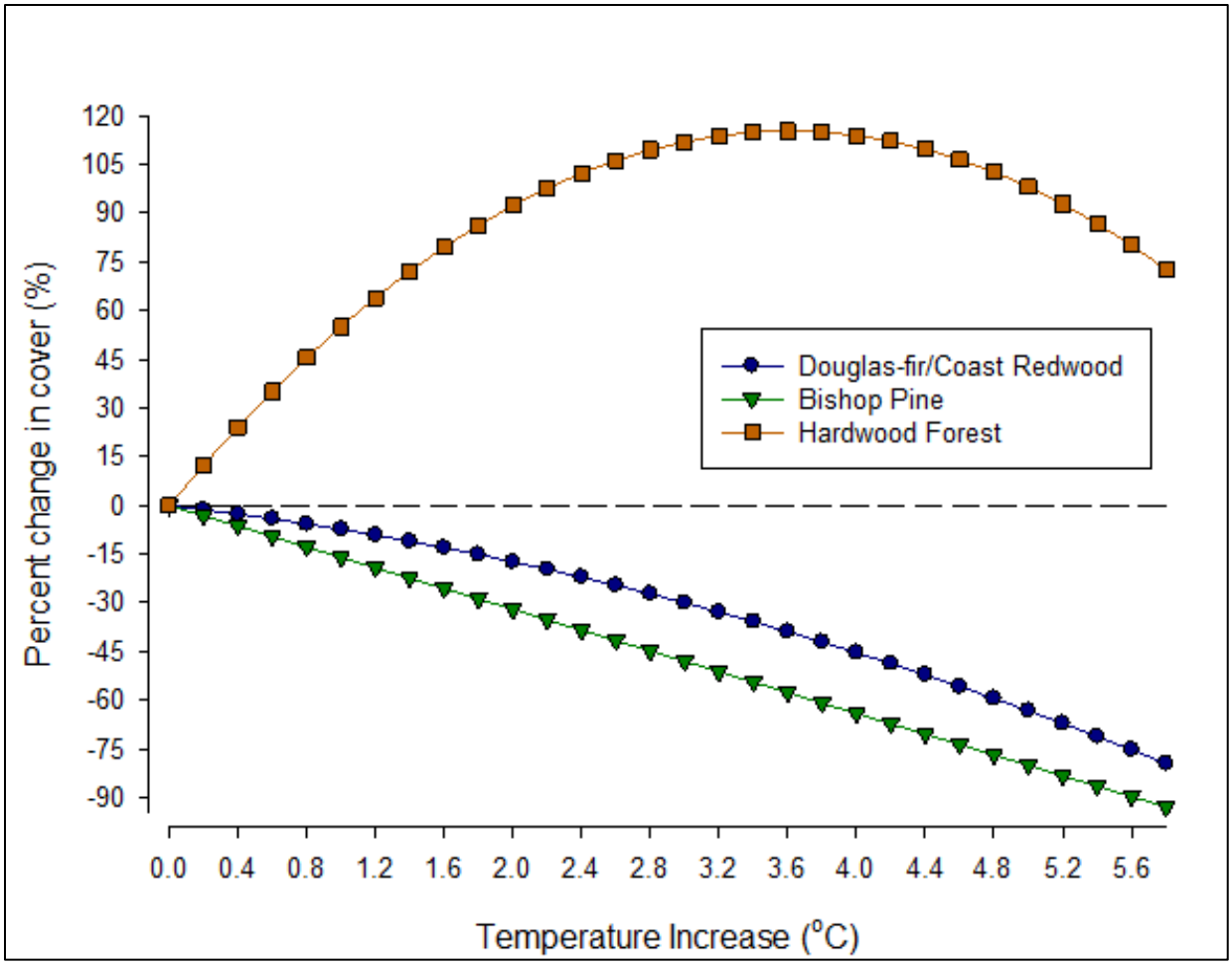


Figure 4.4.9. Projections of percent change in vegetation cover associated with increases in mean annual temperature for the forest vegetation types at PORE. The baseline conditions were calculated for a pixel near the south end of Inverness Ridge (38.0523 °N; 122.8343 °W; elevation = 232 m). The interpolated 30-yr mean for annual temperature was 14.1°C. For these projections, annual precipitation was held constant at the 30-yr mean of 1076 mm. To match the vegetation types used in this analysis, projections for the Douglas-fir/Redwood forest combined Ackerly et al. (2015) predictions for the Douglas-fir Forest and Redwood Forest. The Hardwood Forest projections combined Ackerly et al. (2015) predictions for the Coast Live Oak Forest/Woodland and California Bay Forest.

For both conifer forest types, there is steady decline in cover with increasing temperature. In contrast, there is large overall increase in cover expected for the Hardwood Forest. These results are consistent across 54 future climate scenarios that represent a range of temperature and precipitation predictions (Ackerly et al. 2015). The increase in the Hardwood Forest is driven by the expansion of the Coast Live Oak Forest/Woodland; the California Bay Forest changed little across the t climate scenarios examined (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 decades (Bishop Pine) to centuries (Douglas-fir/Coast Redwood) and forest migrations do not necessarily track climate change (Zhu et al., 2012). 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. 2013); the expected future climate is unlikely to be favorable to conifer tree species at PORE.

What is the impact of the altered fire regime on the forests at PORE?

The extent of the hazard posed by wildfires to the forests at PORE varies by assessment and forest type. The Marin County report (PRNS 2006) ranked most of the forest land at PORE as high or very high hazard. The behavior of fire in high and very high hazard areas is expected to burn hot under fire weather conditions and result in widespread mortality of canopy trees (PRNS 2006). In contrast, the Forrestel report assigned much of the Douglas-fir/Redwood forest and Hardwood Forest to low or moderate fire hazard (Figure 2 in Forrestel report.) However both assessments identified the dense stands of bishop pine regenerating in the perimeter of the Vision Fire as areas of extreme hazard.

The variation in the fire hazard assessment at PORE is due to the challenge of measuring and modeling surface and ladder fuels as well as the uncertainty regarding the role of fire in the most abundant forest type at PORE, the Douglas-fir/Coast Redwood type. The representation of surface fuels in the fire models used in both assessments is the most influential determinant of fire behavior (Hall and Burke 2006). Appropriately characterizing surface fuel loads and canopy base height is critical and should be based as much as possible on direct measurements for robust results (Collins et al. 2013). But even with direct measures, there is an element of expert opinion in translating reality to model. In addition, the natural fire regime in the Douglas-fir/Coast Redwood forest remains obscured by a long history of human ignitions that predate European settlement (Brown et al. 1999). Nevertheless, it is clear that these forests did not develop with a high intensity fire regime (Hunter and Parker 1993, Lorimer et al. 2009). Moreover, the results of even a hot fire in these forests would not result in complete removal of the canopy (A. Forrestel, pers. comm. 2015). These difficulties and differences result in divergent expectations for fire behavior and fire effects for much of the forests at PORE.

In contrast, the models and experts agree on the role of fire in Bishop Pine forest. Regeneration in the Bishop Pine Forest is strongly tied to severe fire where the heat of the fire is needed to open the closed cones of the pine (Sugnet 1981). Forrestel et al. (2011) reported an 85% increase in the extent of bishop pine following the Vision Fire. However the current severe fire hazard in these 20 year-old stands poses a transient threat to their future development. Furthermore, the observed increase in dead trees (see below) would likely increase the intensity of any fire in these stands (A. Forrestel, pers. comm. 2015).

The goal of fire management plan at PORE continues to be to prevent fires and reduce fuels (PRNS 2006). Success in this regard would limit the consequences of the altered fire regime for the forests with the exception of the mature stands of bishop pine. To date, fire suppression has been effectively deployed. Aside from the Vision Fire, no fires have escaped since 1950 (Brown et al. 1999, PRNS 2006). Thus one aspect of 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 forests at PORE?

The progression of *P. ramorum* disease in the Douglas-fir/Coast Redwood forest at PORE has resulted in the sustained and steep decline of the most susceptible species, tanoak (Ramage et al. 2012, Forrestel et al 2015). Tanoak is a major canopy constituent of Douglas-fir/Coast Redwood association at PORE (Ramage et al. 2012) and typically accounts for 20% of the total tree basal area in this forest type (Hunter 1997). The disease and its impact has been well-documented by a network of repeatedly measured paired-plots along the Inverness and Bolinas ridges at PORE. Since the presence of *P. ramorum* was first documented at PORE in 2004, it has dramatically increased the mortality rate of tanoak. For example, in plots observed to be healthy in 2007 (i.e., all tanoaks alive), 40% of the tanoak component had died by 2011 in plots dominated by Douglas-fir (Forrestel et al. 2015). Although the tanoak death rate is markedly lower in plots dominated by coast redwood, the decline in tanoak is still inexorable. Hayden et al. (2011) found limited population-level resistance to the disease and among populations tested, the tanoak population at PORE had the most susceptible individuals. These results suggest that individual stands in invaded landscapes are unlikely to escape the disease (Cobb et al. 2013).

For the Hardwood Forest, coast live oak is the most susceptible species. Coast live oak is the canopy dominant in this association and typically accounts for more than half of the total tree basal area (Brown et al. 1999). The disease progression in the Hardwood Forest is not monitored in the Seashore, but it is in similar and nearby forests in Marin Municipal Water District. There, *P. ramorum* has accounted for an annual mortality rate in coast live oak of 2.6%/yr (data from 2000-2008, McPherson et al. 2010). However in contrast to tanoak, coast live oak has shown more quantitative resistance to the disease (McPherson et al. 2014).

For both the Douglas-fir/Coast Redwood Forest (Forrestel et al. 2015) and the Hardwood Forest (Brown and Allen-Diaz 2009), 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 and at least temporary reducing canopy cover, it seems unlikely to catalyze a regime shift (sensu Folke et al. 2004).

In the Bishop Pine Forest, pitch canker has recently infected young stands (Harvey et al. 2014). In dense stands, the impact of this exotic disease can be severe. In combination with moisture stress, the disease can lead to extensive mortality of bishop pine (T. Gordon, pers. comm. 2015). As yet, not enough information is available to assess quantitatively the threat pitch canker represents to the Bishop Pine Forest.

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). 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 at PORE (Forrestel et al. 2015).

Metz et al. (2013) also noted the potential for a warming climate to further exacerbate the disease-fire interaction. At PORE, 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 1.5 to 2.6 °C (Figure 4.4.8).

The synergy among this combination of stressors does pose a threat to the ecological integrity of the forest at PORE. 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 (Figure 4.4.8). Thus the critical question regarding the fate of the forest resource is the probability of a wildfire occurring while fuel loads are elevated.

Level of confidence in assessment

The assessments of biomass accumulation and exotic disease progression are grounded in site-specific, data-driven, research 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. None of these results attain a high level of confidence since in no case was their sufficient information to estimate uncertainty. For example, the monitoring plots set-up to track the progression of sudden oak death at PORE (Ramage et al. 2012, Forrestel et al. 2015) follow an exemplary paired-plot sampling design and are stratified between two forest types. They represent the best data used in this report. However it is stretch to infer conditions in a forest that spans 54 km^2 from a sample that totals 0.15 km^2 (29 plots each 0.05 ha in size).

Gaps in understanding

The value of a forest monitoring network that is measured repeatedly over time cannot be overstated. The paired-plot study established to monitor the impact of sudden oak death is a good example (Ramage et al. 2012, Forrestel et al. 2015): it has provided essential, Seashore-specific details on this region-wide perturbation. However, forest data from PORE was limited to the Ramage/Forrestel plots and the Vision Fire monitoring plots (Harvey and Holzman 2014). The nationwide inventory effort, the US Forest Inventory and Assessment Program, maintains no more than 4 plots at PORE. This absence of data creates gaps in knowledge. For example, since there was no site-specific information on the disease progression in the Hardwood Forest, the analysis was based on data collected in Marin County and the East Bay. Potter (2013) inferred locations of forest growth (young bishop pine stands on Inverness Ridge) and degradation (tanoak on Bolinas Ridge) using a novel, satellite-based method to detect change. But given the absence of ground-based data to validate these inferences, managers had little confidence in Potter's (2013) results (A. Forrestel, pers. comm. 2015). 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. Direct measures are essential to inform fire models, particularly when the goal is to assess fire hazard across the landscape and over time (Collins et al. 2013). As noted above, the available assessments diverge greatly in the extent of the hazard at PORE. 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 forest communities at PORE. Currently the main species of concern is *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). At PORE, *E. erecta* has been observed in the understory of Douglas-fir/Redwood forests. There is at least one case (near Sky Camp at PORE) where *E. erecta* has completely taken over the understory of a Douglas-fir dominated stand (A. Forrestel, pers. comm. 2015). The existing invasive plant monitoring system at PORE should consider including efforts to track spread invasive plants in forested areas with particular attention focused on locations that have been recently disturbed.

The detailed vegetation map for PORE is a wonder of precision and accuracy (Schirokauer et al. 2003) that is absolutely indispensable for management and research. However it is more than two decades old and needs to be updated, on a regular basis if possible. Forrestel et al. (2011) demonstrated the value of re-mapping vegetation to quantify the expansion and contraction of different communities following a disturbance. 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).

Climate change clearly has the potential to transform the forest landscape at PORE. Species like coast redwood and bishop pine 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, are difficult to simulate reliably. Fernández 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. However in contrast to the more inland sites, the redwoods at PORE

were not particularly sensitive to climatic instability (Figure 7 in Fernández et al. 2015). They speculated that the forests near the coast, even at the southern end of the range, may be buffered against future temperature increases. 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) (Table 4.4.1). At PORE, the progression of *P. ramorum* in the Douglas-fir/Coast Redwood Forest and the Hardwood Forest is having a widespread impact via the increased mortality of susceptible tree species. The declines in tanoak and coast live oak 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. The available evidence suggests that 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 grounded in empiricism but PORE lacks the comprehensive site-specific data needed to assign high confidence to this assessment.

Table 4.4.1. Resource condition summary for forests at Point Reyes National Seashore.

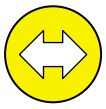
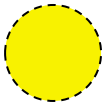
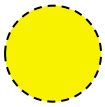
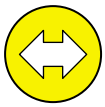
Indicators of Condition	Specific Measures	Condition Status	Rationale
Biomass accumulation	Aboveground live biomass (AGL) accumulation (theoretical expectation)		Small increase in forest biomass from 2001 to 2010
	AGL accumulation (regional comparison)		Biomass trends improving relative to regional forests 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 high intensity fire	Fire hazard model		Existing models differ on the extent of the hazard posed but agree that the dense stands of bishop pine established after the Vision Fire face severe fire hazard. Impacts of wildfire mitigated by suppression
Exotic disease progression	Tree mortality and growth as measured in field plots		Susceptible species continue to die but community wide collapse unlikely

Table 4.4.1 (continued). Resource condition summary for forests at Point Reyes National Seashore.

Indicators of Condition	Specific Measures	Condition Status	Rationale
Potential for compounding perturbations	Fuel load and future fire risk		Transient risk of more severe fire behavior associated with pathogen mortality
Overall condition and trend of forests			–

4.4.4. Information Sources

Sources of Expertise

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

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4.5. Coastal Grassland



Exotic plants have increased in frequency and abundance in the coastal prairie. The shrub coyote brush may be encroaching into the coastal grassland. A coastal prairie indicator species, California oatgrass, has declined in frequency and abundance.

4.5.1. Why Focal Resource Was Assessed

Description

Coastal grasslands form a major landscape component at Point Reyes National Seashore. Grasslands are the primary resource for sustaining authorized pastoral activities and are also of high conservation interest and value. California's coastal prairie has been subjected to many disturbances including burning by Native Americans and European ranchers, cultivation, land development, invasive species, and livestock grazing (Keeley 2002, Ford and Hayes 2007). These factors have had variable effects on resource condition, which need assessment and should inform updating of older plans (e.g., Shook 1990). Statewide, coastal grasslands have been considerably reduced in general extent, and the National Park Service (NPS) has an important role to play in protecting and enhancing this resource (Ford and Hayes 2007, Hopkinson and Bartolome 2009).

Point Reyes is an unusual unit in the NPS in that it incorporates livestock grazing and associated agriculture into goals for the protection, management, and restoration of the pastoral zone. Since the mid-1980s, NPS has monitored vegetation, soils, and livestock grazing, primarily in the grasslands. We have reviewed available publications, reports, and data to produce summaries of the condition (species composition and productivity) of grasslands within Point Reyes. Available monitoring data proved adequate for an initial assessment of the effects of livestock grazing and associated rangeland practices on current vegetation and the potential for changes either under environmental or management influences. Existing information may be sufficient to initiate development of better and more specific Ecological Site Descriptions (ESDs) and state-and-transition models for Point Reyes grasslands.

Critical questions

- Can the existing data from pastoral zone monitoring be used to develop useful Ecological Site Descriptions and associated state-and-transition models?
- Are these models likely to offer good predictions for the effects of management and environmental change?
- What are the critical data and knowledge gaps that Point Reyes needs to address in grasslands?
- How are invasive species influencing the condition of the grasslands in Point Reyes?

4.5.2. How Focal Resource Was Assessed

Measures

Below is a list of indicators and specific measures used to determine the condition of coastal grasslands (Table 4.5.1).

Table 4.5.1. Indicators and measures used in assessment of coastal grasslands.

Indicator of Condition	Specific Measure	Condition Categories	Confidence Categories
Invasion of exotic plant species into the coastal grasslands.	An increase in exotic plant species on 51 transect plots in grazed areas of Point Reyes.	Condition categories based on expert opinion.	No existing Ecological Site Descriptions (defined below) that allow for better prediction of trends.
Encroachment of shrub/tree species into coastal grasslands.	An increase in shrub frequency/abundance on 51 transect plots in grazed areas of Point Reyes.	Condition categories based on expert opinion.	No existing Ecological Site Descriptions (defined below) that allow for better prediction of trends.
Decrease in frequency /abundance of desired native plant species in coastal grasslands.	A decrease in frequency/abundance of desired native plant species on 51 transect plots in grazed areas of Point Reyes.	Condition categories based on expert opinion.	No existing Ecological Site Descriptions (defined below) that allow for better prediction of trends.

Data Sources and Analytical Methods

Dataset

PORE staff provided a grassland plant community monitoring dataset. These data have been curated by Robert Steers and used for an analysis described in a presentation entitled *20 Years of Rangeland Monitoring in Point Reyes National Seashore* (Steers et al. 2012). This NPS range monitoring dataset comprises information from 51 transect plots located on key areas in grazed grassland in the Point Reyes pastoral zone and on Point Reyes-managed grazed lands in the Golden Gate National Recreation Area, spanning the period 1988 through 2013 (Figure 4.5.1).

Each transect included a 100-m baseline with eight 30-m point line-intercept transects of 50 sampling points per line arranged perpendicularly on either side of the baseline. In total, 400 hits were recorded per plot (50 point hits * 8 transects). Only the first hit in vertical space was recorded.

Each transect plot was visited for spring sampling during multiple, but typically non-consecutive, years (Table 4.5.2). There were 344 transect sample years (N=344), and 244 plant taxa were hit on transect and, in most cases, identified to species level. Additionally, bare ground, “cow pie” (fecal pat), gravel, litter, moss, and rock were recorded when they were the first hit. The species with the highest frequency are listed in Table 4.5.3.

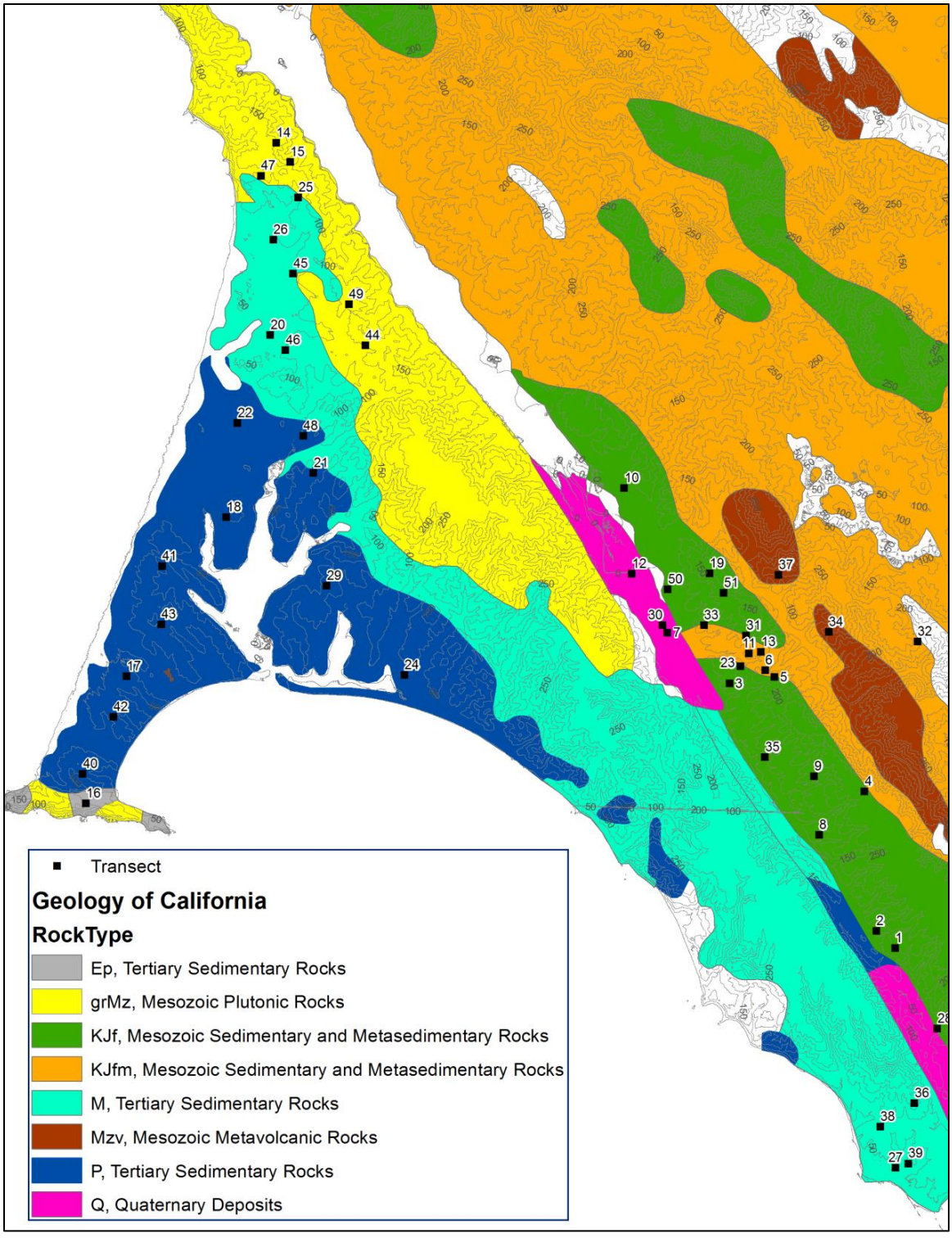


Figure 4.5.1. 51 transect plots and geologic substrate (California Geological Survey).

Table 4.5.2. Point Reyes National Seashore coastal grassland transect plots and sample year, N=344 (data provided by NPS).

Transect	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2007	2009	2010	2011	Total
1	1	1	1	1	1	1	1	1	1	–	–	–	–	–	1	–	10
2	1	1	1	1	–	1	1	1	1	–	–	–	–	1	–	–	9
3	–	–	1	–	–	1	1	1	1	–	1	–	–	–	1	–	7
4	–	1	1	1	1	1	1	1	1	–	–	–	–	1	–	–	9
5	1	1	1	1	–	–	–	1	1	1	–	–	–	1	–	–	8
6	1	1	1	1	1	1	1	1	1	1	1	–	–	1	–	–	12
7	–	–	–	–	–	–	–	1	1	–	1	1	–	–	–	1	5
8	–	1	1	1	1	1	1	1	1	–	–	–	–	1	–	–	9
9	–	–	–	–	–	–	1	1	–	–	–	1	–	1	–	–	4
10	1	–	1	–	–	1	1	1	1	–	–	–	–	1	–	–	7
11	1	–	–	1	1	1	1	1	1	1	–	–	–	–	1	–	9
12	1	–	–	–	–	–	–	–	–	–	1	1	–	–	–	–	3
13	1	1	1	1	1	1	1	1	1	1	1	–	–	1	–	–	12
14	–	–	–	–	–	–	–	–	–	–	1	–	1	–	–	1	3
15	–	–	1	1	1	1	1	1	1	–	–	–	–	–	1	–	8
16	–	–	–	–	–	–	–	1	1	1	–	–	–	–	–	1	4
17	–	–	–	–	–	–	–	1	–	–	1	–	–	–	1	–	3
18	–	1	1	1	1	1	1	1	1	–	–	–	–	–	1	–	9
19	1	–	–	–	–	1	1	1	–	–	–	1	–	1	–	–	6
20	–	1	1	1	1	1	1	1	1	–	–	–	–	–	1	–	9
21	–	–	1	–	–	–	1	1	–	–	–	1	–	–	1	–	5
22	–	1	1	1	1	1	1	1	1	–	–	–	1	–	–	1	10
23	–	1	–	1	1	1	1	1	1	1	–	–	–	–	1	–	9
24	–	1	–	1	1	1	1	1	1	–	1	–	–	–	1	–	9
25	–	–	–	–	–	1	1	1	1	–	–	1	1	–	–	1	7
26	–	–	–	–	–	1	1	1	–	–	–	–	1	–	–	1	5

Table 4.5.2 (continued). Point Reyes National Seashore coastal grassland transect plots and sample year, N=344 (data provided by NPS).

Transect	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2007	2009	2010	2011	Total
27	–	–	–	–	–	–	–	–	–	–	1	–	1	–	–	1	3
28	–	–	–	–	–	–	–	1	1	–	1	–	–	1	–	–	4
29	–	1	1	1	1	1	1	1	1	–	1	–	–	–	1	–	10
30	1	–	–	–	–	–	–	–	–	–	1	1	–	1	–	–	4
31	1	1	1	1	1	1	1	1	1	1	1	–	–	1	–	–	12
32	1	–	1	–	–	1	1	1	–	–	–	–	1	–	–	1	7
33	1	–	–	–	–	–	–	1	–	–	1	–	–	1	–	–	4
34	1	1	1	1	1	1	1	1	1	1	1	–	–	1	–	–	12
35	1	–	–	–	–	–	1	1	1	1	1	–	–	1	–	–	7
36	1	–	–	–	–	1	1	1	1	–	–	1	1	–	–	1	8
37	1	1	1	1	1	1	1	1	1	–	–	–	–	–	1	–	10
38	1	–	1	–	–	–	–	1	1	–	–	–	–	–	–	1	5
39	1	–	–	–	–	1	1	1	–	–	–	1	–	–	1	–	6
40	1	–	–	–	–	–	–	–	–	–	1	–	–	–	–	1	3
41	1	–	–	–	–	1	1	1	–	–	–	1	–	–	–	1	6
42	–	1	–	–	1	1	1	1	1	–	–	1	–	–	1	–	8
43	1	–	1	–	–	–	–	1	–	–	1	–	–	–	–	1	5
44	1	–	–	–	–	–	–	1	–	–	1	1	1	–	–	1	6
45	1	–	–	–	–	–	–	1	–	–	1	–	–	–	–	1	4
46	1	–	–	–	–	1	1	1	–	–	–	1	–	–	1	–	6
47	1	–	–	–	–	–	–	–	–	–	1	–	–	–	1	–	3
48	1	–	–	–	–	1	1	1	–	–	–	–	–	–	1	–	5
49	1	–	–	–	–	–	–	1	–	–	1	–	–	–	–	1	4
50	–	1	–	–	–	–	1	1	1	1	–	–	–	1	–	–	6
51	–	1	–	–	–	–	–	1	1	–	1	–	–	1	–	–	5
Grand Total	**28**	**19**	**21**	**18**	**17**	**29**	**33**	**45**	**30**	**10**	**23**	**13**	**8**	**17**	**17**	**16**	**344**

Table 4.5.3. Plant species with highest percent frequency and their percent absolute cover on Point Reyes National Seashore coastal grassland transects.

Species name	Origin	% frequency in transect sample years[1]	% absolute cover over all transect sample years[2]
Festuca perennis (*Lolium multiflorum*)	exotic	99	19
Festuca (*Vulpia*) *bromoides*	exotic	96	8
Plantago lanceolata	exotic	90	10
Bromus hordeaceus	exotic	89	5
Hypochaeris radicata	exotic	80	3
Danthonia californica	native	76	6
Trifolium subterraneum	exotic	66	3
Aira caryophyllea	exotic	61	2

[1] Possible n=344

[2] Possible total of 137,600 (400 hits * 344 samples)

We compiled environmental data for the 51 transect plots, comprised five variables:

- geologic substrate from the *Geologic Map of California* (Jennings et al. 2010, Table 4.5.4);
- elevation,
- slope,
- northness (USDA/NRCS 2010; northness after Zar 1999); and
- "marine influence," a 1-3 scale representing the degree to which the plot is influenced by maritime climatological patterns with 1 = low, 2 = medium, and 3 = high.

Table 4.5.4. Geology relevant to Point Reyes National Seashore coastal grassland from Jennings et al. 2010.

Rock Code	Rock Type	Rock Type Description
Ep	Tertiary Sedimentary Rocks	Sandstone, shale, and conglomerate; mostly well consolidated.
grMz	Mesozoic Plutonic Rocks	Mesozoic granite, quartz monzonite, granodiorite, and quartz diorite.
KJf	Mesozoic Sedimentary and Metasedimentary Rocks	Franciscan Complex: Cretaceous and Jurassic sandstone with smaller amounts of shale, chert, limestone and conglomerate. Includes Franciscan melange, except where separated -see KJfm.
KJfm	Mesozoic Sedimentary and Metasedimentary Rocks	Melange of fragmented and sheared Franciscan Complex rocks.
M	Tertiary Sedimentary Rocks	Sandstone, shale, siltstone, conglomerate, and breccia; moderately to well consolidated.

Table 4.5.4 (continued). Geology relevant to Point Reyes National Seashore coastal grassland from Jennings et al. 2010.

Rock Code	Rock Type	Rock Type Description
Mzv	Mesozoic Metavolcanic Rocks	Undivided Mesozoic volcanic and metavolcanic rocks. Andesite and rhyolite flow rocks, greenstone, volcanic breccia and other pyroclastic rocks; in part strongly metamorphosed. Includes volcanic rocks of Franciscan Complex: basaltic pillow lava, diabase, greenstone, and minor pyroclastic rocks.
P	Tertiary Sedimentary Rocks	Sandstone, siltstone, shale, and conglomerate; mostly moderately consolidated.
Q	Quaternary Deposits	Alluvium, lake, playa, and terrace deposits; unconsolidated and semi-consolidated. Mostly nonmarine, but includes marine deposits near the coast.

Questions and Analytical Methods

Ecological sites

Every landscape has a set of probable controls over plant species distribution. Identifying the strongest controls is critical to strategic placement of effective management, monitoring, and study (Naveh and Whittaker 1979).

Although the California coastal prairie is regarded as a distinctive plant community type (Spiegal et al. In Press), it presents problems for classification and mapping because of its dynamic relationship with associated coastal shrub vegetation. There have been many vegetation types identified within the coastal prairie solely based on vegetation structure (Sawyer and Keeler-Wolf 1995). Within areas with shrub cover low enough to be considered coastal prairie, several factors may influence herbaceous species distribution. Major factors include degree of invasion by exotic annual and perennial grasses and forbs, fire, grazing by wild and domesticated animals, marine climate influence, topography, and soils (reviewed in Hatch et al. 1999, Hayes and Ford 2007).

One current conceptualization of the probable controls over plant species distribution in the coastal prairie of Pt. Reyes is that "[h]istoric and current ranching practices have the largest influence on rangeland composition." This was a major conclusion of a study conducted by Robert J. Steers, *20 Years of Rangeland Monitoring in Point Reyes National Seashore*, presented at the San Francisco Bay Area Science and Learning Science Symposium of 2012. Our analysis evaluates the utility of augmenting such current conceptualizations of the Point Reyes grassland landscape with ecological site concepts.

Ecological sites are conceptual divisions of a landscape within a singular regional climate. An ecological site is defined by the US Department of Agriculture as "a distinctive kind of land based on recurring soil, landform, geological, and climate characteristics that differs from other kinds of land in its ability to produce distinctive kinds and amounts of vegetation and in its ability to respond similarly to management actions and natural disturbances" (USDA 2014). Ecological sites are predicated on the basic notion that patterns in the plant community within a particular landscape are strongly controlled by the underlying topographic and edaphic (topo-edaphic) characteristics of the

landscape. Assuming the veracity and applicability of this approach in a landscape, if a land management team wants to make predictions about the distribution of species, the team should understand variation in the underlying topo-edaphic characteristics.

For this analysis, we asked whether an ecological site approach is appropriate for describing, understanding, and predicting dynamics for the coastal grasslands of Point Reyes: Are there multiple ecological sites, or is the landscape better conceptualized as a single ecological site?

We sought to determine how well the Point Reyes grasslands' species composition splits along landscape divisions defined by climatic, topographic, and edaphic-proxy lines. We used these factors to estimate whether a more formal Ecological Site Description effort, which could include soils as they are mapped in the park unit, would be a worthwhile undertaking. We asked whether the grasslands comprise multiple ecological sites, or whether the grasslands are better conceptualized as a single ecological site. As geographic distance increases, community similarity likely decreases due to decreased ability of seeds to disperse to maintain community similarity (Nekola and White 1999) so we used geographic distance among plots as an informal test of the veracity of ecological sites on the landscape.

We ran a Non-metric multidimensional scaling (NMDS) ordination in PC-ORD 5 (750 runs with real data, 250 runs with shuffled data, Sorensen distance measure) on absolute cover values for 195 taxa in the 344 sample years (any taxon observed only once in all 344 samples was omitted). A secondary matrix of the five topo-edaphic variables: geology, elevation, slope, aspect, and marine influence, helped depict divisions of the plant community along topo-edaphic lines. Although no edaphic variables *per se* were included, geologic parent material and topographic factors are critical factors of soil formation (Jenny 1941), and we used these to estimate whether a more formal Ecological Site Description effort that included soil variables would be worthwhile. The two categorical variables (geology, marine influence) were used as symbolic overlays on the plots in species ordination space, and the three continuous variables (elevation, slope, northness) were candidates for drawing as vectors if the correlation to an ordination axis was greater than 0.3 ($r > 0.3$). Arrangement of the symbology and the angle and direction of the vectors were considered when interpreting the ordination axes.

Ecological states

Our next question was whether the plant community's spatial and temporal patterns represent repeatable and useful states and/or transitions. Temporal change at an ecological site can be depicted with a state-and-transition model. State-and-transition modelers customarily portray states as stable (on a management time-scale), resilient regimes separated by threshold-based transitions (Bestelmeyer et al. 2003, Knapp et al. 2011, USDA 2014). Thresholds help describe causes of change, attune users to warning signals of imminent change in states, or signify that a transition to an alternative state would be expensive or perhaps impossible to achieve (Walker 1993, Bestelmeyer et al. 2009, Knapp et al. 2011). Within this framework, community phases are dynamic sub-components of state regimes. Unlike the states they compose, community phases are not considered to be resilient. Accordingly, the "community pathways" between community phases are typically

associated with interannual weather or regular management of the ecological site (Bestelmeyer et al. 2009, Knapp et al. 2011).

An Ecological Site Description (ESD) describes the abiotic environment of an ecological site as well as its associated states and transitions (USDA 2014). Good Ecological Site Descriptions form the basic reference for understanding history, management, and environmental influences, and predicting future condition.

To investigate the existence of ecological states and community phases, we looked in detail at species patterns in ordination space. Spatial and temporal patterns of key species' abundance identified from the ordination were assessed to determine the validity and predictive value for Ecological Site Descriptions. To get a better picture of temporal changes, we determined whether the abundance of 16 taxa on the 51 transects changed from the first sample (usually in the later 1980s) to the most recent (around 2010). Changes were recorded as positive, none, or negative and subjected to a sign test for significance.

Transitions and phase shifts

We also investigated potential drivers of temporal community phase shifts and/or transitions using residual dry matter (RDM) data sampled at the plots. RDM levels served as an index for livestock grazing intensity.

We used a subset of 246 transect samples that had both spring species composition sampling and RDM measurements (from the previous fall) to try better linking species patterns to livestock grazing use.

Reference Conditions/Values

The PORE grassland plant community dataset contained extensive temporal and spatial data but did not encompass all the variation exhibited by Point Reyes coastal grassland (see Synthesis below for further details). Information on reference conditions were missing, as were Ecological Site Descriptions.

4.5.3. Coastal Grassland Condition Assessment

Condition and Trend

Ecological sites

In the NMDS ordination of the plant community data, the first two axes had a stress of 20, while the first three axes had a stress of 14. Although stress was lower for a 3-dimensional solution, a 2-dimensional solution enhanced visual interpretation.

In the rotated ordination graph (Figure 4.5.2 and Figure 4.5.3), ***elevation*** and ***slope*** were continuous variables significantly correlated with the axes, as depicted by the arrows facing left. Northness (a proxy for aspect) was not significantly correlated with either axis. Elevation was correlated with Axis 1 at -0.507. Slope was correlated with Axis 1 at -0.415 and Axis 2 at -0.204. These correlations indicate that the gradient represented by Axis 1 represents a gradient in the community on the landscape as elevation and slope change. The correlation of this gradient in species ordination space

and environmental space on the landscape lends support to the notion that the species composition is at least partially controlled by topography. In addition, the ordination with the geologic substrate overlay (Figure 4.5.2) suggests that the coastal grassland is at least loosely organized along ***geologic*** lines. Several sets of plots share geologic substrate and similar species composition. The plots within four of the eight geologic substrates share similar species composition, and the among-plot geographic distribution within each of these four subsets of plots suggests that their species composition is similar despite geographic distance. On the other hand, plots within three of the geologic types are somewhat dissimilar. One geologic type, '**Ep, Tertiary Sedimentary Rocks,**' was represented only by a single plot (gray squares in Figure 4.5.2; plot 16; n=4), so no inferences were made about relationships between community composition and geologic composition for that plot.

Plots on the geologic substrate '**grMz, Mesozoic Plutonic Rocks**' (yellow circles in Figure 4.5.2; plots 14, 15, 44, 47, 49; n=24) not only share the same geologic substrate but also similar vegetation. All plot samples on grMz are ordinated in the middle of Axis 1, in the top half of the ordination graph. While some plots on this geologic substrate (yellow grMz polygon) are adjacent to each other (plots 14, 15, 47; and plots 44, 49), these two sets of adjacent plots are geographically separated (Figure 4.5.1). This pattern suggests that underlying geology may be an important control over community similarity among plots.

Plots underlain by '**KJfm, Mesozoic Sedimentary and Metasedimentary Rocks**' (orange squares in Figure 4.5.2; plots 6, 11, 13, 32, 33; n=44) also share geologic substrate as well as similarity in the plant community. The vegetation of all KJfm plot samples (except plot 11 in one year) ordinate to the same region on the left half of the ordination graph. In this case, several plots with this geologic substrate are close together in geographic space (orange KJfm polygon); however, one plot (plot 32) is quite separated by geographic distance yet still retains the same plant community.

In a broad sense, plot samples on '**KJf, Mesozoic Sedimentary and Metasedimentary Rocks**' and the plot samples on '**M, Tertiary Sedimentary Rocks**' differ with respect to geologic substrate *and* community composition. All but 17 of the 112 KJf plot samples (green circles on Figure 4.5.2; plots 1, 2, 3, 4, 5, 8, 9, 19, 23, 28, 31, 35, 50, 51; n=112) are located to the left of the vegetation ordination. In contrast, all of the M plot samples (aquamarine squares on Figure 4.5.2; plots 20, 25, 26, 27, 36, 38, 39, 45, 46; n=81) are on the right side of the vegetation ordination graph.

In contrast, plots on '**Mzv, Mesozoic Metavolcanic Rocks**' (burgundy triangles in Figure 4.5.2; plots 34 and 37; n=22) share the same geologic substrate, but their vegetation differs. This geologic substrate contains only two plots, each sampled in multiple years. These two plots are somewhat far apart in geographic space (burgundy Mzv polygon in Figure 4.5.1), and though they share underlying geology and both sit at about 200 m elevation, they are separated by a valley. Geographic distance, topographic distance, or another factor contributed to distance in ordination space of these two plots that share the same geologic substrate.

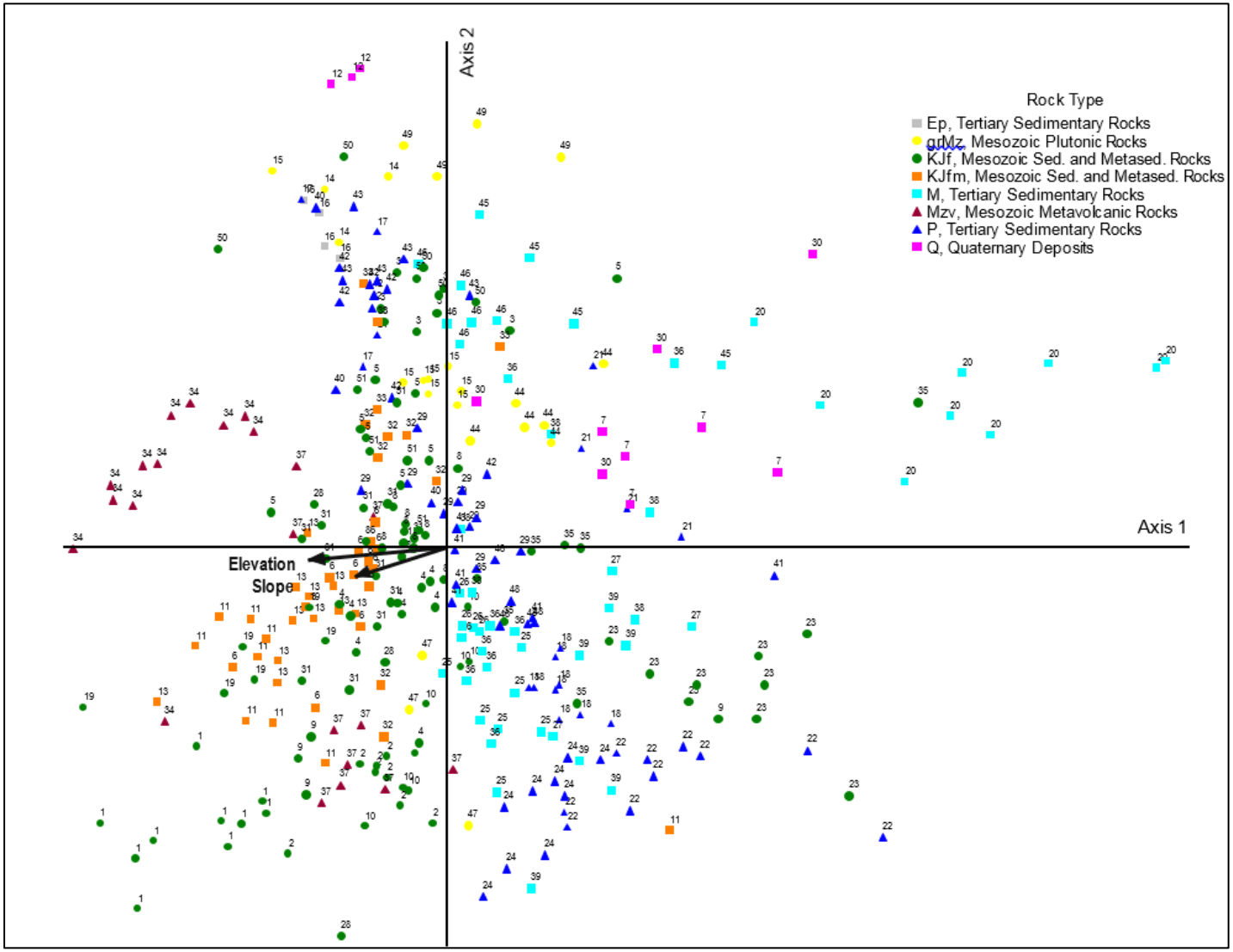


Figure 4.5.2. Point Reyes National Seashore coastal grassland plots in species ordination space, with geologic substrate overlay; numbers adjacent to the symbols represent plot numbers; sample year not represented.

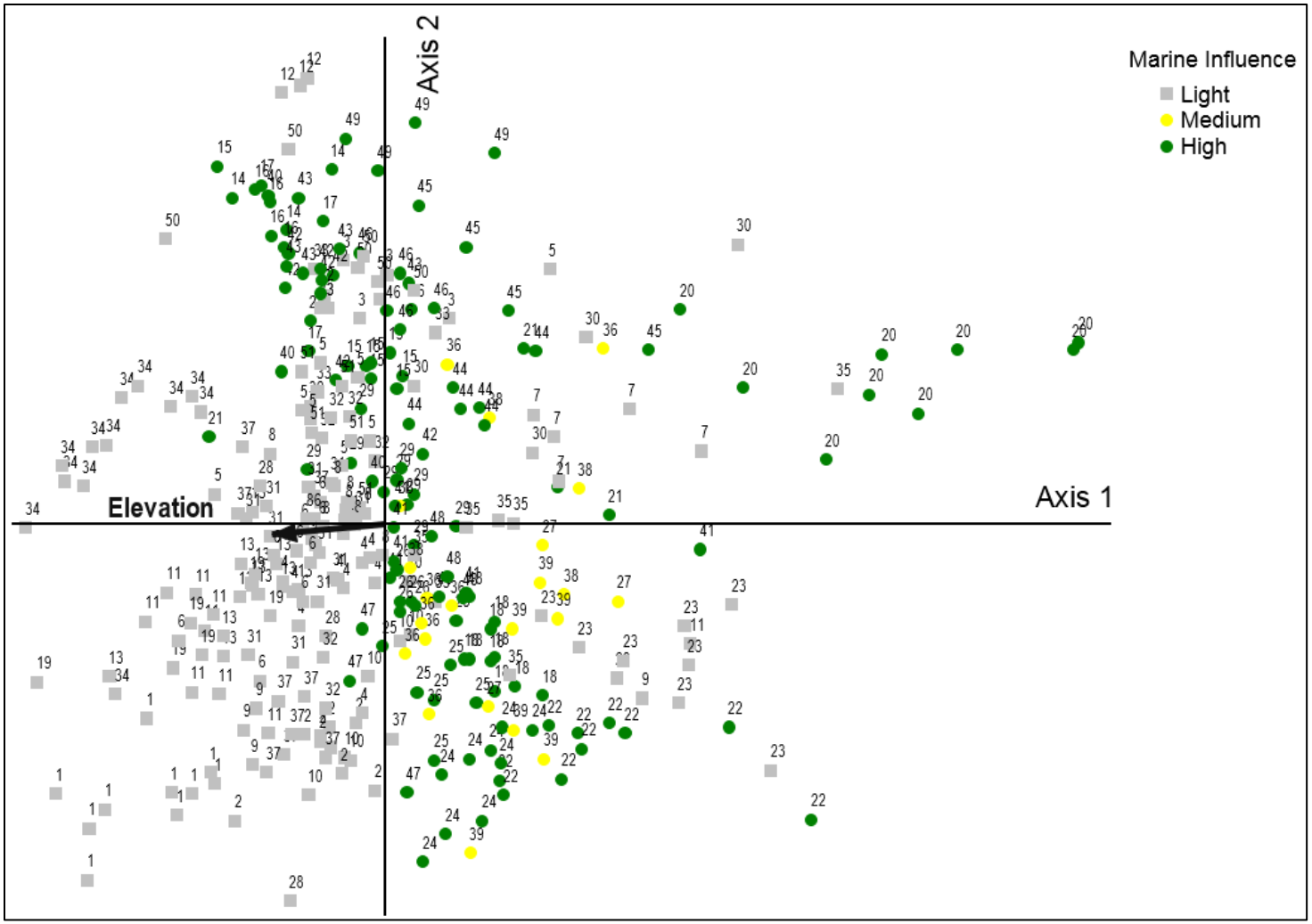


Figure 4.5.3. Point Reyes National Seashore coastal grassland plots in species ordination space, with marine influence overlay.

Likewise, the species composition of the plot samples on '**P, Tertiary Sedimentary Rocks**' does not appear to be organized along geologic lines. Species composition measured at these 11 plots (blue triangles in Figure 4.5.2; plots 17, 18, 21, 22, 24, 29, 40, 41, 42, 43, 48; n=73) is not limited to any quadrant or half of the ordination. These are close to the coast (blue polygon in Figure 4.5.1).

Finally, the plots on '**Q, Quaternary deposits**' also do not group together in species ordination space (pink squares in Figure 4.5.2; plots 7, 12, 30; n=12). Samples from Plot 12 are found on the top left quadrant of the ordination; however, the samples from the other two plots (7 and 30) are in the top right quadrant and separated to a large degree from Plot 12 in ordination space. Likewise, plots 30 and 7 on the pink Q polygon in 4.5.1 are close together, whereas plot 12 is relatively separated from the other two.

Following the same lines of reasoning, community structure as measured at the plots also appears to be at least somewhat correlated with degree of ***marine influence*** (Figure 4.5.3). The clearest example is all samples from plots with Medium marine influence (yellow circles in Figure 4.5.3) being located on the right half of the ordination.

Synthesizing topographic, geologic, and climatological factors gives rise to at least two distinct ecological sites. One ecological site encompasses plots on **KJfm, Mesozoic Sedimentary and Metasedimentary Rocks'** (orange squares in Figure 4.5.2; plots 6, 11, 13, 32, 33). All plots on this geologic substrate have a slope ranging from 5-25%, elevation of 70-230 m, and light marine influence. Another comprises the plots on **grMz, Mesozoic Plutonic Rocks**' (yellow circles in Figure 4.5.2; plots 14, 15, 44, 47, 49). These plots range in elevation from 100 to 150 m, and all have heavy marine influence.

Elevation and slope influence community structure on this landscape. Community patterns also strongly match geologic pattern but less strongly match marine influence pattern. Although geologic substrate and marine influence may be correlated, we did not calculate the correlation between these two factors.

Seed dispersal may also have an influence on species arrangement in the grasslands; however, not all of the plots that share the same geologic substrate and similar species composition are close together in geographic space. Thus, proximity on the ground, and seed dispersal related to that geographic proximity, does not fully explain proximity in ordination space.

An ecological site approach would likely be useful for describing, understanding, and making predictions for management in the grasslands of Point Reyes. In light of the conclusions made by Steers and his collaborators that current and historic ranching practices are strong controls over species distribution, we recommend that NPS investigate the relationships between management history and geologic, topographic, and climatic factors. Currently, the location of transects only in key grazed areas within grasslands, the lack of good soils information at the transect scale, and the irregular sampling limits the conclusions that can be drawn about the number and structure of ecological sites on Point Reyes.

Ecological states

As noted above, the NMDS revealed significant structure in the data, much of which can be interpreted as influenced by environmental gradients including geologic substrate, elevation, and degree of marine influence, and demonstrated that there would be discernable species patterns for groups of transects. The previous section assessed transect locations in ordination space in relation to topo-edaphic environment; this section examines species patterns in ordination space. In the 344 samples, 195 taxa were present on more than 1 transect-year. Once axes are determined, the abundance of taxa can be evaluated as a correlation with each major axis, the NMDS providing a correlation coefficient to assess the significance of the relationship. Those taxa with an axis with at least one r-value greater than 0.3 were further examined. The large suite of common naturalized annual species were eliminated from further analysis because these species did not strongly influence the ordination results. The location of species centroids in ordination space also showed the relative influence of species on transects located in nearby space.

Exotic annual plants have extensively invaded Point Reyes grassland (and in some instances have also been seeded into the grassland to improve forage values). Of the eight most common species in the dataset, seven were exotic grasses and forbs (Table 4.5.3); the sole native species in the top eight, California oatgrass (*Danthonia californica*), was only the 6th most frequent on the transects. The most abundant taxon was the exotic annual/perennial grass ryegrass [*Festuca perennis* (*Lolium multiflorum*)], which was only absent from a few transect years, followed in abundance by several other exotic grasses and forbs (Table 4.5.3). Abundance of ryegrass was highly correlated with axis 2, but because the species was so widespread, it was of little use in distinguishing spatial or temporal patterns. Ryegrass was seeded into the Point Reyes grassland by ranch operators (Dylan Voeller, pers. comm. 2015).

The two most common native grasses, California oatgrass and purple needlegrass (*Stipa* (*Nassella*) *pulchra*), showed different patterns. Although these perennial bunchgrasses co-occurred on many transects, California oatgrass was associated with greater marine influence than purple needlegrass. The most abundant native taxon was California oatgrass, which showed a significant relationship to axis 2 and, as noted, appeared to be more abundant under higher marine influence (Figure 4.5.4). The second most abundant native perennial bunchgrass, purple needlegrass, was significantly related to both axes 1 and 2 and appeared to be more abundant with less marine influence (Figure 4.5.5).

The invasive exotic perennial grass common, velvet grass (*Holcus lanatus*), was significantly associated with axis 1 and dominated a few transects (Figure 4.5.6). Another species of interest, the native but potentially encroaching shrub, coyote brush (*Baccharis pilularis*), was significantly associated with axis 1 but common on only a few plot years (Figure 4.5.7).

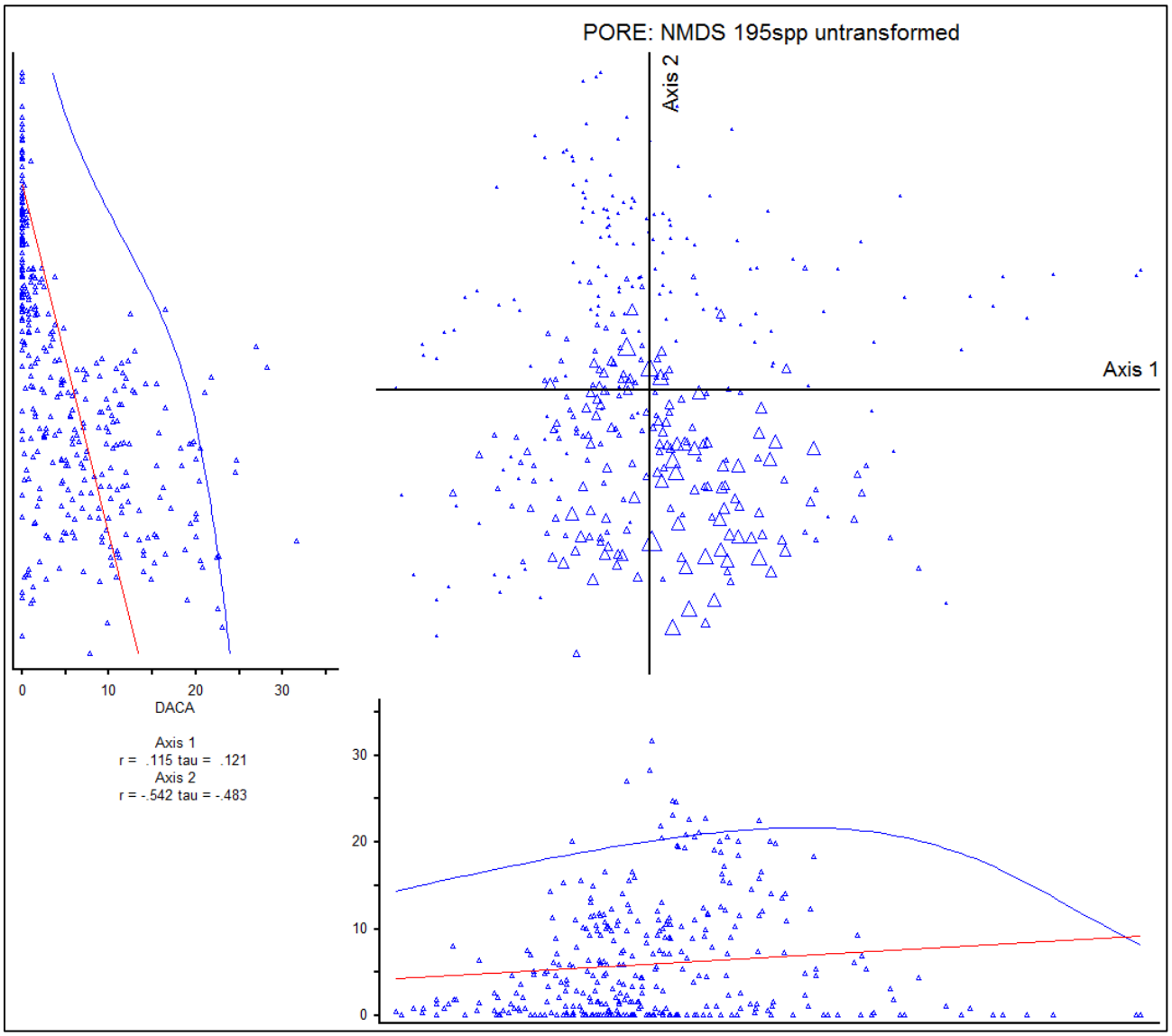


Figure 4.5.4. Location and abundance of *Danthonia californica* in ordination space, Point Reyes National Seashore coastal grassland transects. Symbol size is proportional to abundance of species; red line=linear regression line; blue curve=95% of points envelope.

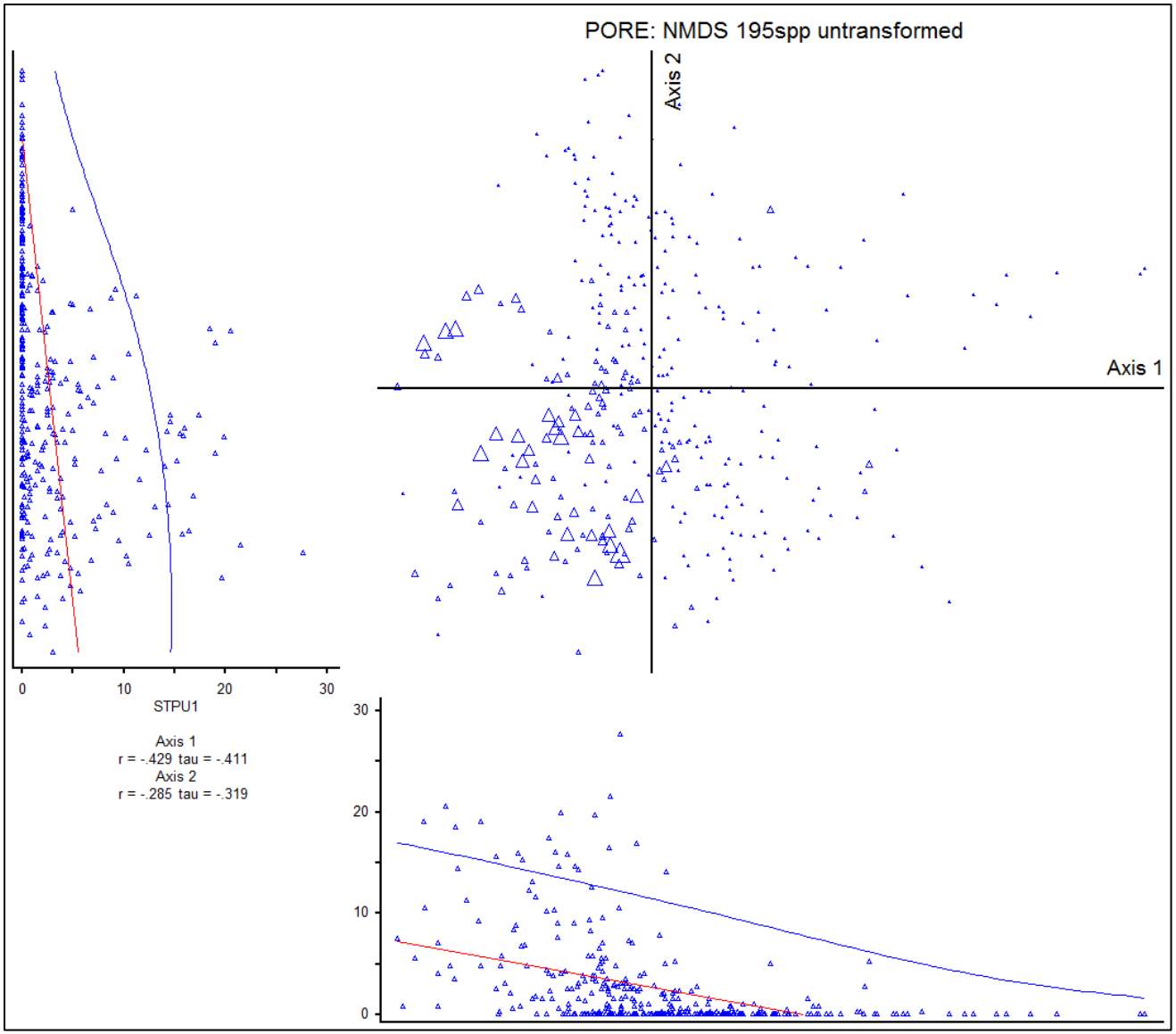


Figure 4.5.5. Location and abundance of *Stipa* (*Nassella*) *pulchra* in ordination space, Point Reyes National Seashore coastal grassland transects. Symbol size is proportional to abundance of species; red line=linear regression line; blue curve=95% of points envelope.

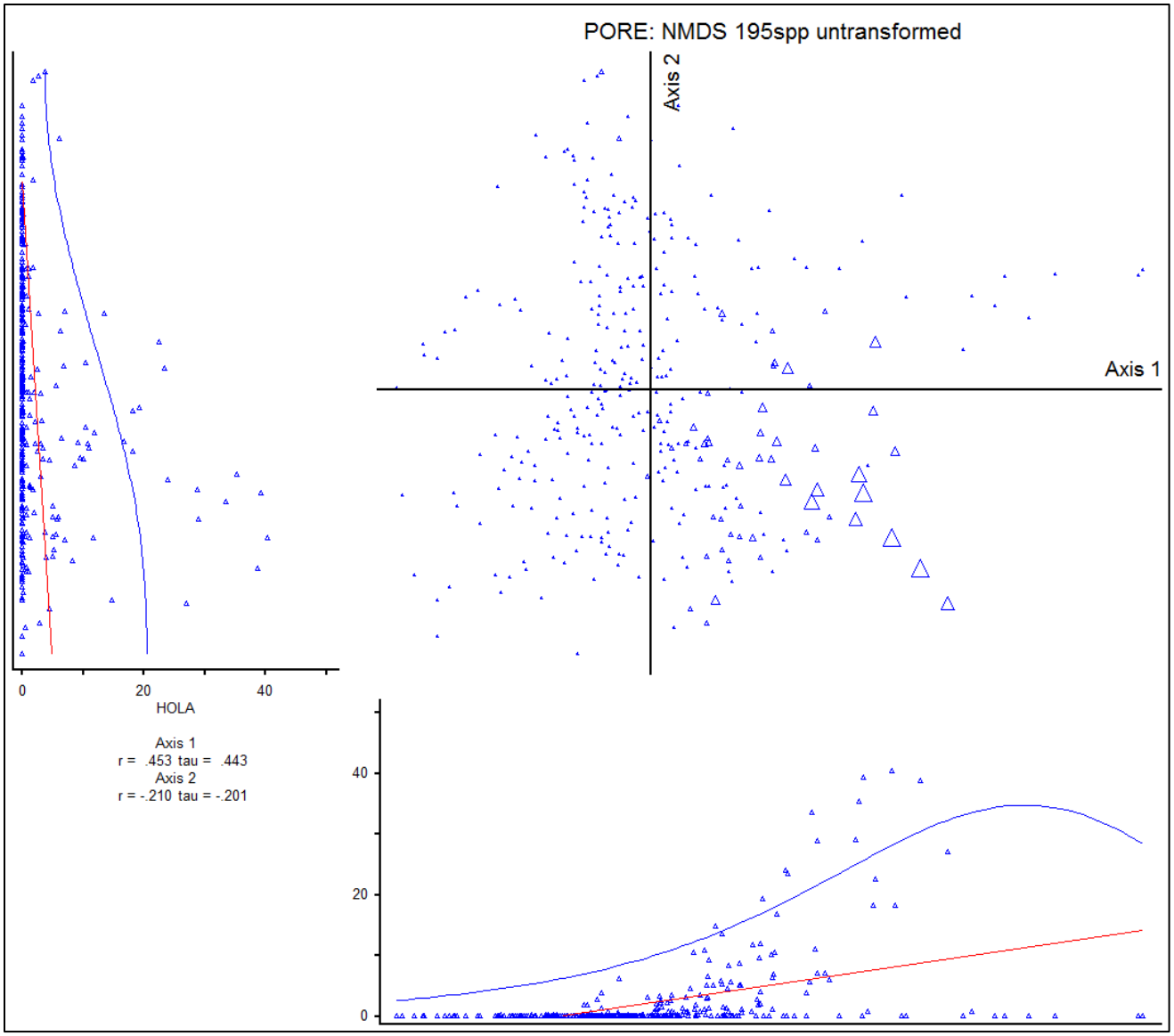


Figure 4.5.6. Location and abundance of *Holcus lanatus* in ordination space, Point Reyes National Seashore coastal grassland transects. Symbol size is proportional to abundance of species; red line=linear regression line; blue curve=95% of points envelope.

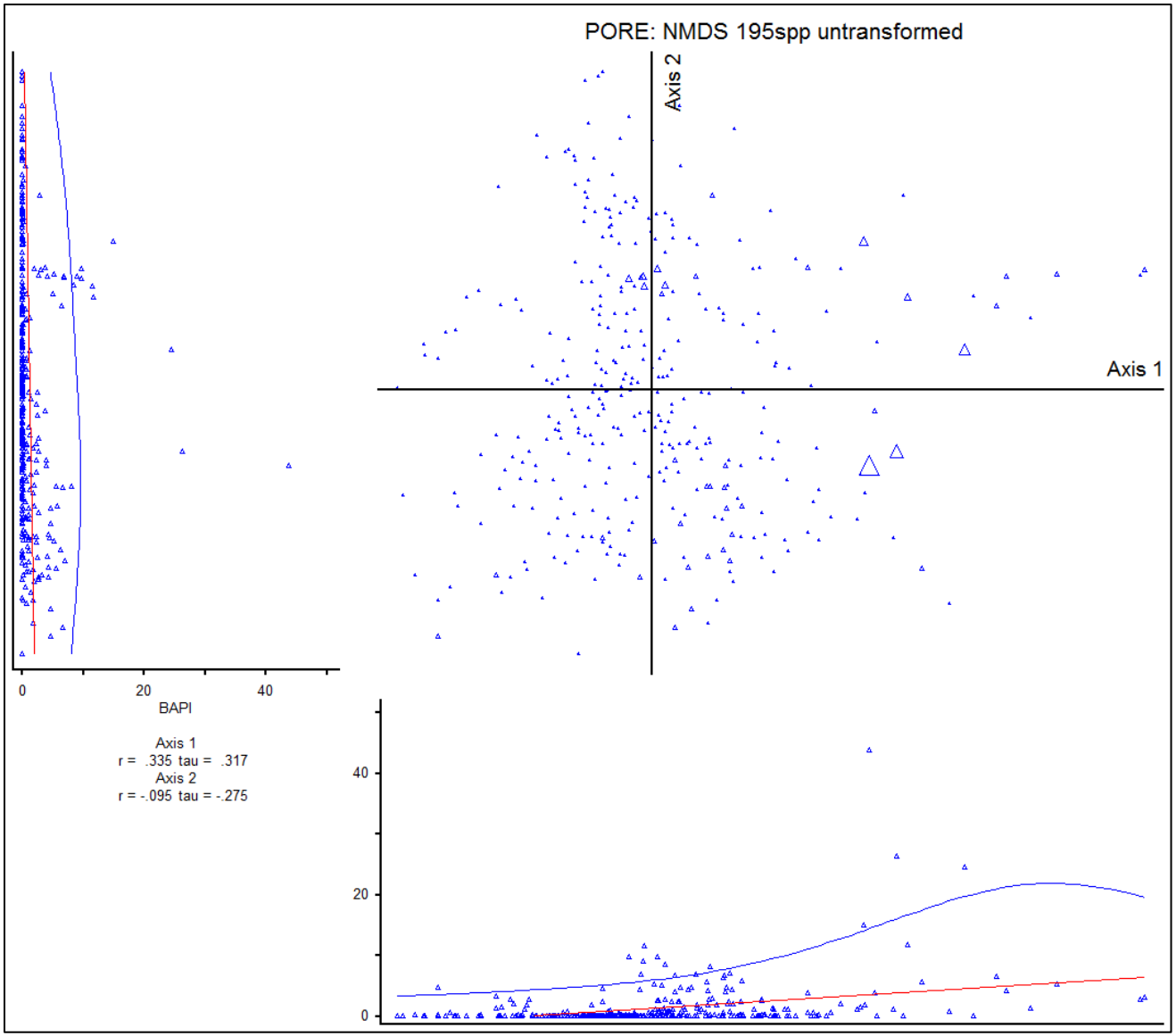


Figure 4.5.7. Location and abundance of *Baccharis pilularis* in ordination space, Point Reyes National Seashore coastal grassland transects. Symbol size is proportional to abundance of species; red line=linear regression line; blue curve=95% of points envelope.

Meaningful temporal patterns were difficult to interpret directly from ordination results because of irregular sampling between years. To get a better picture of temporal changes, we determined whether the abundance of 16 taxa on the 51 transects changed from the first sample (usually in the later 1980s) to the most recent (around 2010). Changes in abundance were recorded as positive, none, or negative and subjected to a sign test for significance (important species are shown in Table 4.5.5).

Table 4.5.5. Direction of change in selected species on 51 Point Reyes National Seashore coastal grassland transects between 1988 and 2011; significance determined by binomial sign test.

Species	Origin	Increase 1988 - 2011	Decrease 1988-2011	Transects present between 1988-2011	Probability that increase or decrease was not significant
Danthonia californica	native	10	24	38	P < 0.04
Stipa (*Nassella*) *pulchra*	native	11	9	25	NS
Holcus lanatus	exotic	15	4	23	P < 0.01
Brachypodium distachyon	exotic	12	3	19	P < 0.01
Festuca perennis (*Lolium multiflorum*)	exotic	25	25	51	NS
Baccharis pilularis	native but potentially encroaching into grasslands	10	8	23	NS

The most common species ryegrass did not show a trend in abundance. The exotic annual grass, false brome (*Brachypodium distachyon*), significantly increased. Significant patches of exotic perennial grasses were present, such as common velvet grass, which occurred on 23 transects and increased between 1988 and 2011 on 15 of those transects but without a discernable link to native species abundance. The native bunchgrass, California oatgrass, declined significantly between 1988 and 2011, decreasing on 24 of the 37 transects on which it occurred.

Transitions and phase shifts

The ordination of the subset of 246 transect samples for which there were both spring species composition samples and fall RDM measurements showed the same basic relationships as the full dataset NMDS. This suggests that grazing use, as measured by RDM, was not a major driver of change over time on the transects.

Two native shrubs, coyote brush and bush lupine (*Lupinus arboreus*), are known from the scientific literature to change in abundance, the former increasing with grazing and fire removal, the latter cycling in a climatic link to the abundance of a stem-boring insect (Ford and Hayes 2007). On six transects, coyote brush had increased dramatically by 2010. Three of those transects had very high RDM levels and light grazing in the 1990s, but the other three did not. None of those six transects

was resampled for RDM after the 1990s, making interpretation of grazing effect difficult. Only two transects contained significant bush lupine; on both, this short-lived shrub increased in the 1990s, then declined.

Synthesis

Upon detailed analysis, transects differed little by year or by degree of grazing use and may represent phase shifts in vegetation within one or more ecological states characterized by varying degrees of shrubs abundance in a coastal prairie-coastal scrub mosaic. However, because transects were located in what are called "Key Areas" to focus on the response of grasslands to livestock grazing, they did not capture the full range of sites and vegetation. The location of transects only in key grazed areas within grasslands, the lack of good soils information at the transect scale, and the irregular sampling limits the conclusions that may be drawn about the number and structure of ecological sites and states on Point Reyes.

Stressors

As described above, exotic annual plants have extensively invaded and occupied the grassland. The most common was ryegrass, and several other exotic grasses and forbs were abundant. The exotic annual grass false brome significantly increased over the time period evaluated, as did the exotic perennial grass common velvet grass. The prospects for significantly reducing common exotic annuals are poor (DiTomaso et al. 2007).

In contrast, the most common native species, California oatgrass, was only the 6th most frequent species on the transects and has declined over the sampling period.

An additional primary threat to coastal grasslands is encroachment of shrubs and trees, often native species, especially in the absence of grazing and fire (Ford and Hayes 2007). On six transects, coyote brush increased significantly by 2010.

Livestock grazing use, as measured by RDM, was not a major driver of change over time on the transects.

Level of confidence in assessment

Can the existing data from pastoral zone monitoring be used to develop good Ecological Site Descriptions (ESD) and associated state-and-transition models?

The answer is a very limited yes. The dataset analyzed included 344 transect-years spanning 1988 through 2013, but was a snapshot of only one small part of Point Reyes, and consequently, the diversity of types, environmental relationships, and the number of definable ecological sites cannot be accurately determined. Robust conclusions about conservation and management actions are similarly limited.

Elevation, slope, geologic substrate, and marine influence were significant factors in the spatial arrangement of plant species on the landscape. An ecological site approach would likely be useful for describing, understanding, and making predictions for management in the coastal grassland;

however, an ecological site characterization is insufficient without explicit incorporation of soils data at the appropriate spatial scale into the model.

The sampled vegetation fits squarely within the coastal prairie descriptions in the *Manual of California Vegetation* (Sawyer and Keeler-Wolf 1995). However, most of the diversity described for that type is missing at Point Reyes. For example, only one transect contained significant *Lupinus arboreus*. Likewise, transects with coyote brush have only contained significant amounts of that species in more recent years, and those transects were not sampled for residual dry matter during those years. The PORE range dataset provides information about only one small part of the overall Point Reyes landscape (the Key Areas). For this reason, the diversity of types, environmental relationships, catalog of states and transitions, and the number of definable ESDs cannot be accurately determined. This also means that the landscape-level consequences of conservation and management, including the influence of RDM, on species composition will need transects placed outside currently defined key areas of the PORE coastal grassland. The patterns of California oatgrass' decline in abundance, as well as increases in false brome and common velvet grass did not show any obvious relationships to grazing as reflected by RDM, but this conclusion is not especially robust and needs improved monitoring if answers are to be fully developed.

Developing more detailed Ecological Site Descriptions with associated state-and-transition models will require more widely distributed transects and better small-scale soils information.

> *Are these models likely to offer good predictions for the effects of management and environmental change?*

The data-driven models from this study revealed limitations in the existing information that means predicting management impacts and the effects of climate change are not reliable. Further and different analyses should await better and new data.

Gaps in understanding

Critical knowledge gaps include links to small scale variations in soil properties, site potential, effects of specific grazing practices, the role of fossorial vertebrates, and potential for further exotic species spread.

For technical assistance in identifying ecological sites and states – with the full suite of topographic, geologic, and edaphic variables required for such an analysis – we suggest contacting the Natural Resources Conservation Service, the agency leader in Ecological Site Descriptions.

Coastal Grassland Condition Summary

Coastal grasslands form a major landscape component at Point Reyes, are the primary resource for sustaining Point Reyes' authorized pastoral activities, and are of high conservation interest and value. Exotic plants have extensively invaded and occupied Point Reyes' coastal grassland, especially ryegrass [*Festuca perennis* (*Lolium multiflorum*)] and common velvet grass (*Holcus lanatus*). The prospects for significantly reducing common exotic annuals are poor. In addition, the native shrub, coyote brush (*Baccharis pilularis*), has encroached into Point Reyes' coastal grasslands. An important coastal prairie native grass, California oatgrass (*Danthonia californica*), declined

significantly at Point Reyes between 1988 and 2011, decreasing on 24 of the 37 transects on which it occurred. The map of coastal grassland condition by management zone (Figure 4.5.8) shows the condition of coastal grassland in the pastoral zone, the location of the vast majority of the transects from which the data used in the condition assessment came (Table 4.5.6).

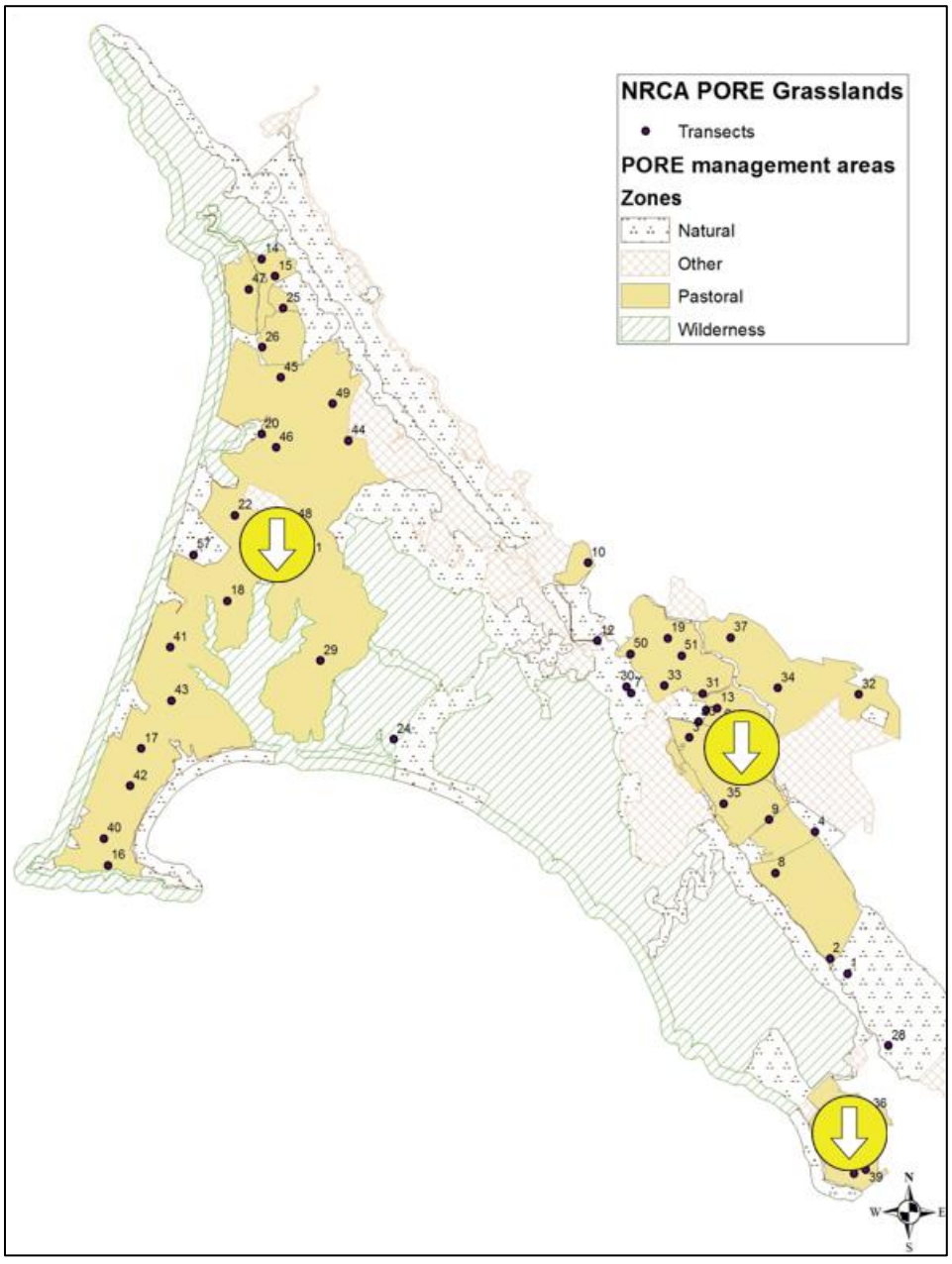
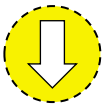
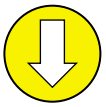
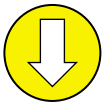


Figure 4.5.8. Point Reyes National Seashore coastal grassland condition assessment, 1988-2013, mapped by management zone.

Table 4.5.6. Resource condition summary for coastal grasslands at Point Reyes National Seashore.

Indicator of Condition	Specific Measure	Condition Status	Rationale
Invasion of exotic plant species into the coastal grasslands.	An increase in exotic plant species on 51 transect plots in grazed areas of Point Reyes.		See Table 4.5.3. The most common species observed on transect was an exotic, ryegrass (*Festuca perennis* (*Lolium multiflorum*)), although no trend in abundance observed. Exotic annual grass false brome (*Brachypodium distachyon*) significantly increased. Invasive perennial grass common velvet grass (*Holcus lanatus*) present on 23 transects and increased between 1988 and 2011 on 15 of those transects. Dataset limited: plots did not capture the full range of sites and vegetation.
Encroachment of shrub/tree species into coastal grasslands.	An increase in shrub frequency/abundance on 51 transect plots in grazed areas of Point Reyes.		On 6 transects, the native coyote brush (*Baccharis pilularis*) increased significantly by 2010, although these 6 transects were grazed during this period. Dataset limited: plots did not capture the full range of sites and vegetation.
Decrease in frequency/abundance of desired native plant species in coastal grasslands.	A decrease in frequency/abundance of desired native plant species on 51 transect plots in grazed areas of Point Reyes.		Native perennial bunchgrass California oatgrass (*Danthonia californica*) declined significantly between 1988 and 2011, decreasing on 24 of the 37 transects on which it occurred. Dataset limited: plots did not capture the full range of sites and vegetation.
Overall condition and trend of coastal grassland			–

4.5.4. Information Sources

Sources of Expertise

Point Reyes National Seashore Natural Resources staff, Dylan Voeller and Devii Rao, assisted us with data and their expertise.

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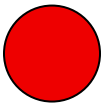
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4.6. Invasive Plants

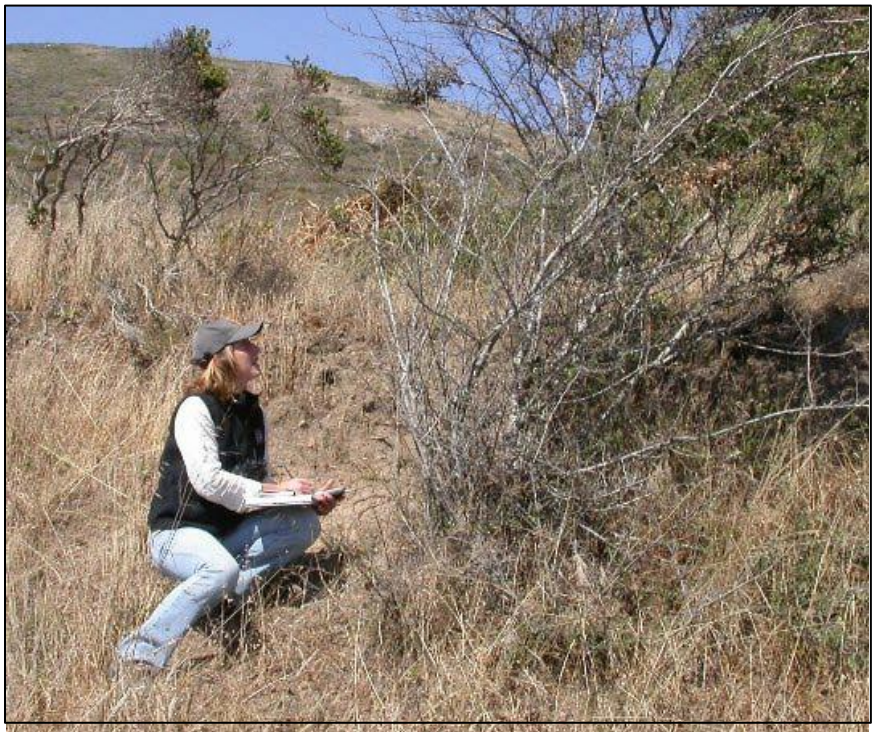


The total number of invasive plant species and the number of new introductions are high enough to warrant significant concern. Confidence in existing data varies by indicator and is limited by the relatively short time span.

4.6.1. 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.

PORE is an unusual unit in the NPS in that it incorporates livestock grazing and associated agriculture into management goals. Because of these and other potential human activity vectors for the spread of invasive plants, PORE 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 PORE, 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?
- How many new non-native species (i.e., formerly unknown in the park) are detected in PORE each year?
- What is the distribution of surveyed sites and treatment sites in PORE each year?
- How does survey effort impact the number of invasive species detected per subwatershed each year?

4.6.2. How Focal Resource Was Assessed

Measures

Two metrics were selected to assess the extent of exotic plant invasion and the potential for future introductions/spread of invasive plants: the total number of invasive species present and the number of new introductions per year. We used these metrics together to generate an assessment of invasive plant species by management zone and an overall assessment of invasive plant species in PORE.

Data Sources and Methods

PORE started an active management program in 1989 to map, monitor, and control invasive plants. In 1989, PORE produced an Exotic Plant Management Plan. One aspect of this plan was a ranked list identifying invasive species for early detection (Table 4.6.1). In 1994, PORE established the Habitat Restoration Program. This volunteer group focused on high-priority species removal and limited data

collection (location, species, hours worked, quantity accomplished). In 2002, PORE staff developed an SOP outlining data collection and management procedures.

Table 4.6.1. Tiered levels of data collection

Our Priorities	Example	Explanation	Data Collected
List 1 (Highest Priority Plants)	 Capeweed	List 1 plants are highly invasive and are typically not widespread. Control or even eradication is often feasible.	*Point occurrences* and *polygon assessments* are recorded for all patches, regardless of their size.
List 2 (High Priority Plants	 Cape Ivy	List 2 plants are highly invasive and usually more common than List 1 species. Small, outlier patches may be targeted for eradication or control.	*Point occurrences* are recorded for all patches regardless of their size, and *polygon assessments* are recorded for all patches smaller than 100m^2.
List 3 (Medium Priority Plants)	 Sweet fennel	List 3 plants are usually widespread and difficult to control at the scale of the park. Uncommon species of concern are also listed here to improve our understanding of their distribution in the park.	*Point occurrences* are recorded for all patches smaller than 100m^2.
List 4 (Lower Priority Plants)	 Rattlesnake grass	List 4 plants include all other exotic species that are not captured by Lists 1–3. Typically, these are very widespread invasive plants and are beyond control, or they are waifs.	These plants are not mapped. Observers record presence/absence.

The data used to assess the number of invasive species present and the number of new introductions per year was collected as part of the SFAN (San Francisco Bay Area Network) Early Detection of Invasive Species program. The following section briefly describes 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).

Exotic species were prioritized for monitoring and treatment based on current knowledge and rankings (see Williams et al. 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. PORE manages all or part of 7 watersheds and 124 subwatersheds. Twenty-five of these subwatersheds were deemed at high risk of invasion and harm to significant biological resources. These values include subwatersheds on adjacent GOGA lands that are managed by PORE (e.g. Bolinas Ridge). For the purposes of this report, data collected in those GOGA subwatersheds that are managed by PORE are included with PORE and not GOGA.

The list of priority areas where monitoring would take place was generated once for GOGA and PORE; in the year prior to full-protocol implementation (2008 and 2009 respectively). This was done by ranking subwatersheds using their number and degree of current infestations, risk of further infestations, and priority of natural resources present. For example, subwatersheds that scored highest were ones that exhibited low infestation levels, had a high risk of further infestation based on presence of infrastructure or invasible vegetation types, and included populations of rare plants or animals. Within PORE, 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 PORE 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 m 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 (Figure 4.6.1). 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. Information is stored in GeoWeed, Sonoma Ecology Center's improvement on The Nature Conservancy's Access-based vegetation management information system WIMS. GeoWeed (http://geoweed.org), like WIMS, is freely available and allows for digital data collection through a series of ArcPad forms. Negative data are tracked through the use of the "Survey Area" portion of the database.

For the initial survey of a route, point occurrences and polygon assessments were mapped for list 1 species; point occurrences and polygon assessments (if patch size is less than 100 m^2) for list 2 species; presence/absence or point occurrences (if patch size is less than 100 m^2) for list 3 species; and presence/absence recorded for list 4 species, along with the survey area.

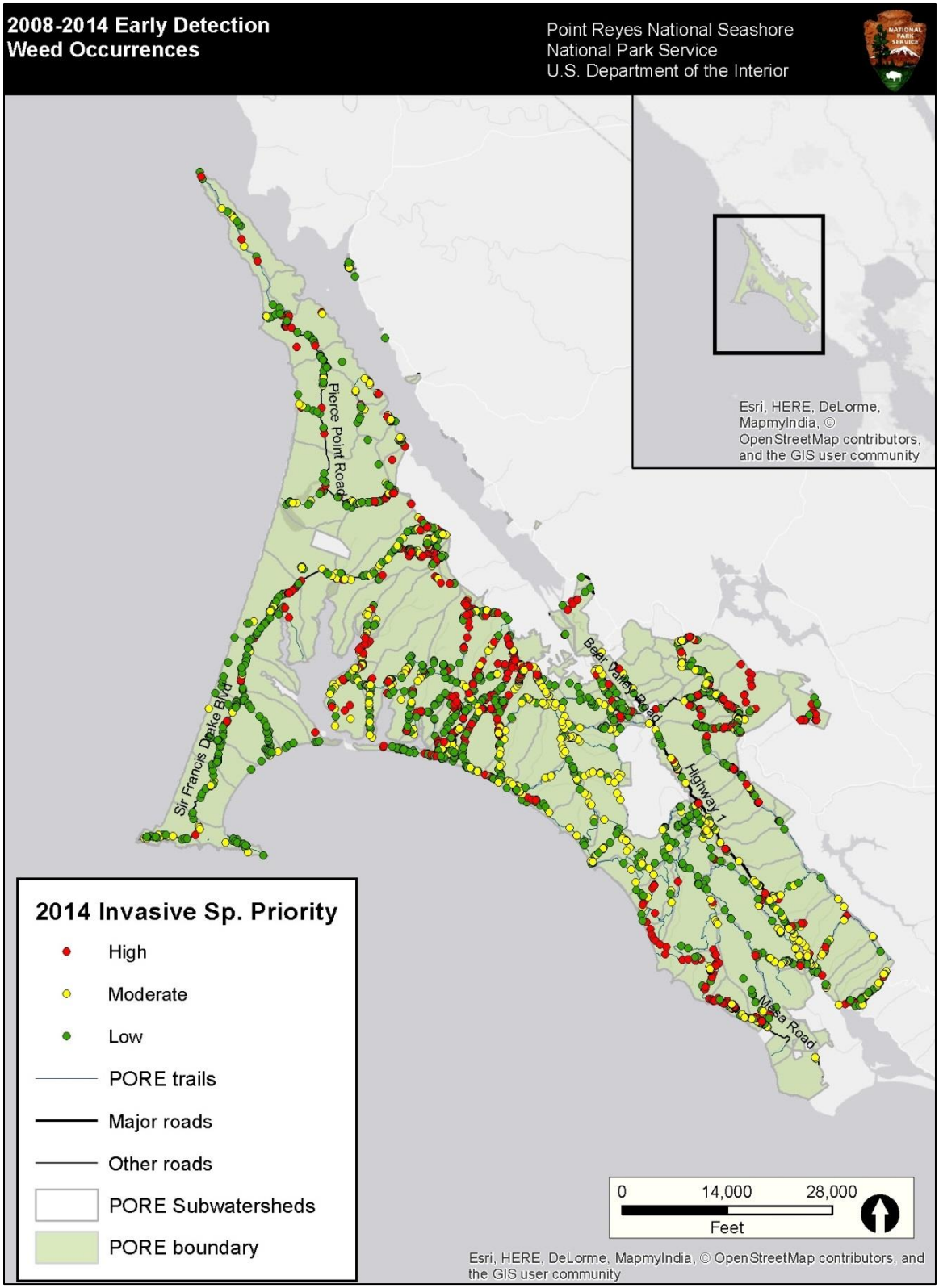


Figure 4.6.1. All invasive plant occurrences documented by Early Detection surveys in PORE between 2008 and 2014.

All of the reported field data to date have been collected during surveys for the full list of species by advanced observers. No data from unsupervised volunteers are in the GeoWeed database. A detailed description of field methodology can be found in the early detection of invasive plants protocol: SOP 2- Mapping; SOP 3- Field Data Collection (Williams et al. 2009).

To assess the status of invasive plants by management zone we ranked two metrics: the number of invasive species present 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 PORE. 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 0 to 10 invasive species, yellow for 11 to 40 invasive species, and red for more than 40 invasive species. The number of new introductions per year was ranked as green for no new invasive species, yellow for 1 to 4 new invasive species, and red for 5 or more 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 PORE was assessed by comparison to historic conditions. The selected reference condition was pre-European settlement or no invasive plants.

4.6.3. Condition Assessment

Condition and Trend

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

The SFAN invasive plant species list includes more than 300 invasive plant species. This list is updated annually in order to reflect early detection priorities. In 2014, the list of Early Detection priority invasive plant species in PORE included 167 species (Appendix 4.6.1). Figure 4.6.1 illustrates the distribution of invasive plants along roads and trails in PORE recorded by Early Detection surveys from 2008 to 2014. Of the 167 priority invasive plant species in PORE in 2014, 70 are categorized as high priority, 40 as moderate priority, and 57 as low priority. Invasive species in all three priority categories are widely distributed in PORE. The high priority invasive plant species have the lowest number of recorded occurrences (Figure 4.6.2, Figure 4.6.3, and Figure 4.6.4). Note that these maps do not show total area invaded. All surveys are conducted along roads and trails and, therefore, the areas not mapped as invaded may have no invasive plants present or may not have been surveyed.

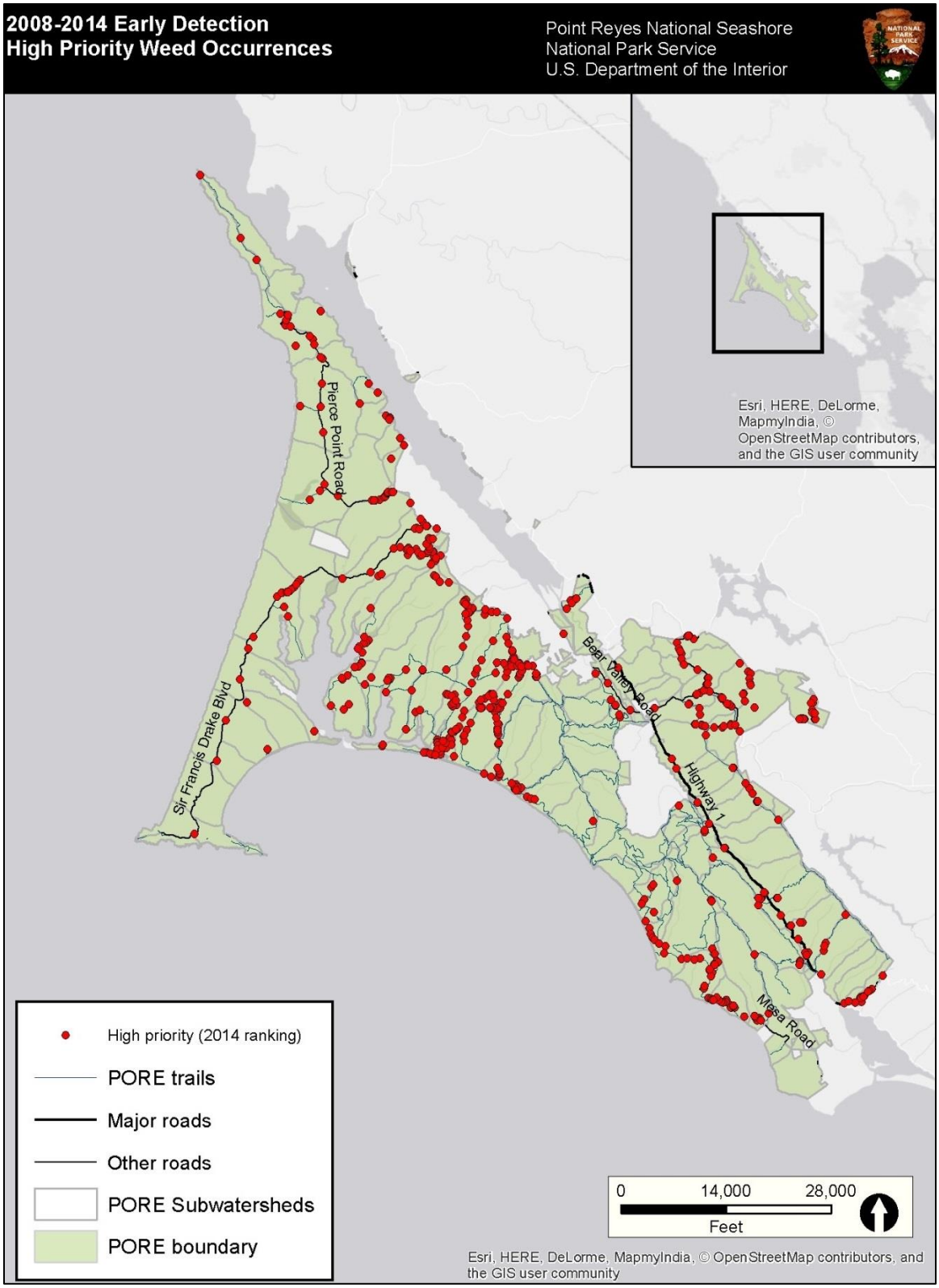


Figure 4.6.2. High priority invasive plant occurrences documented by Early Detection surveys in PORE between 2008 and 2014.

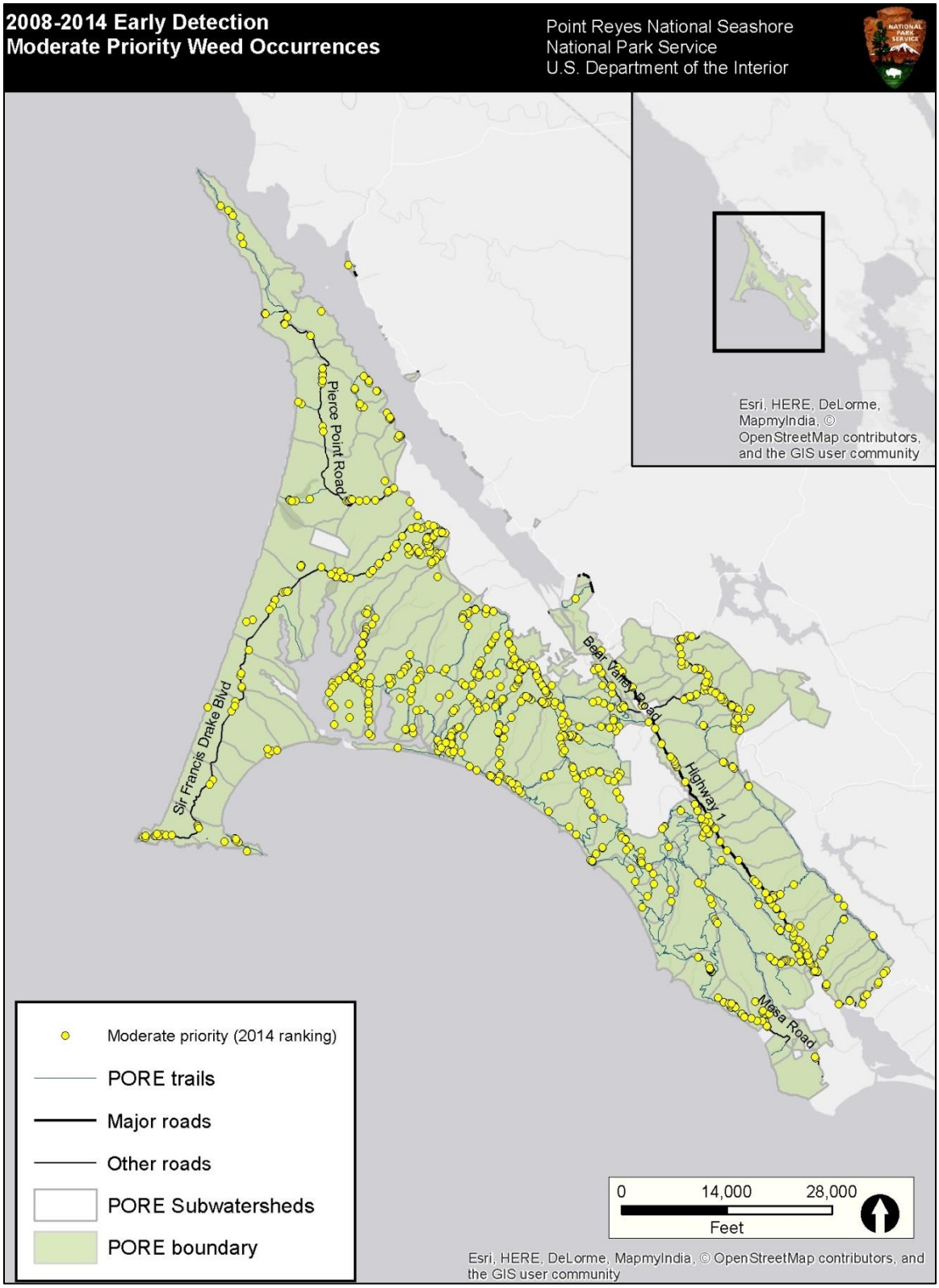


Figure 4.6.3. Moderate priority invasive plant occurrences documented by Early Detection surveys in PORE between 2008 and 2014.

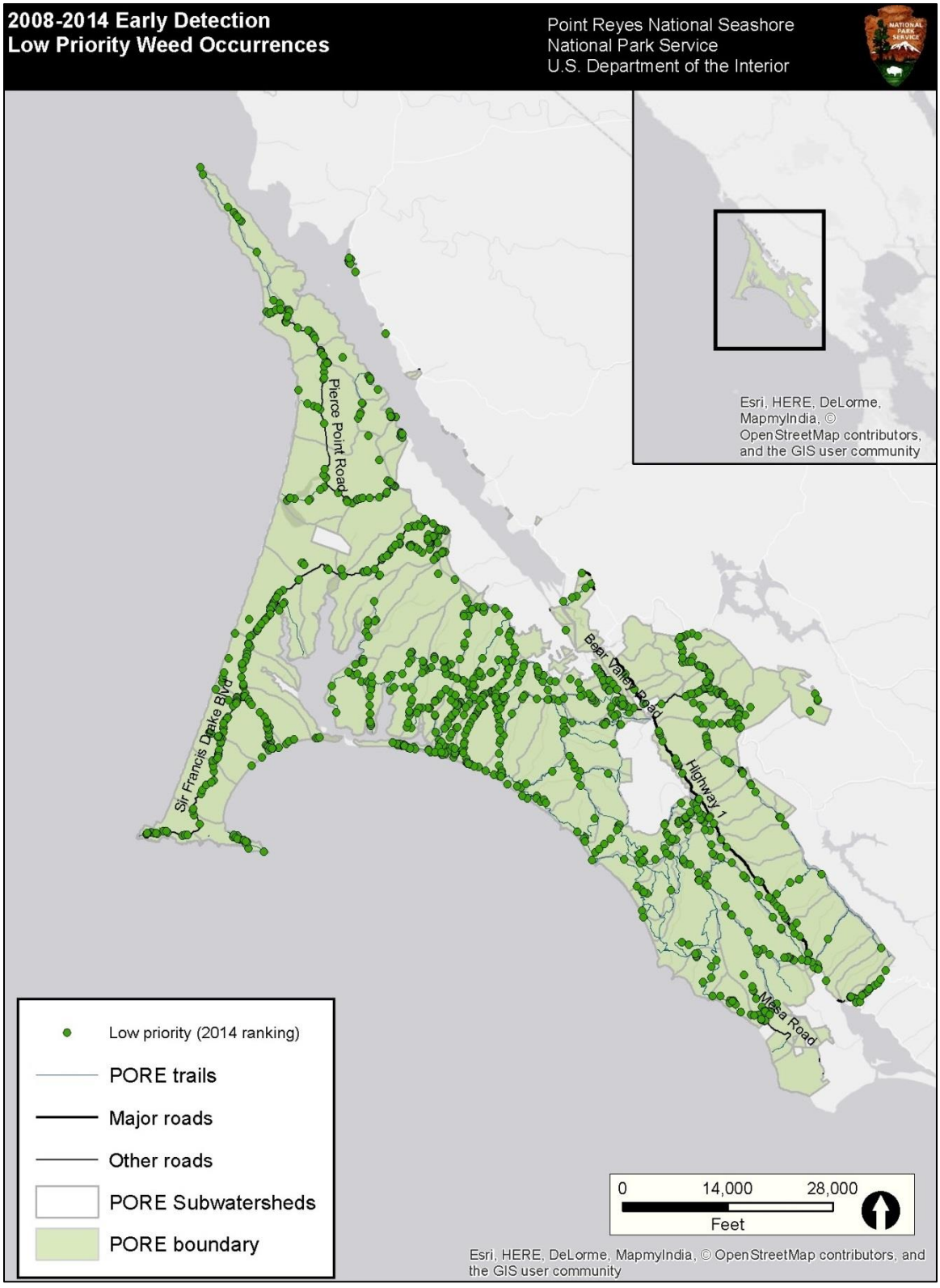


Figure 4.6.4. Low priority invasive plant occurrences documented by Early Detection surveys in PORE between 2008 and 2014.

This assessment focused on invasive plant species considered to be the highest priority for management in PORE. More data is available for many of these species, including spatial information. Figure 4.6.5 through Figure 4.6.28 show the distribution data for all the highest priority species that have been mapped. The majority of these species have widely dispersed, low numbers of recorded occurrences. *Rytidosperma penicillatum* is the most widely distributed of the mapped high priority species.

Of the 19 subwatersheds in PORE in which five or more consecutive annual surveys were conducted by Early Detection teams, nearly half (9 out of 19 subwatersheds) had three or fewer invasive species present in 2008. However, by 2014, only one subwatershed had three or fewer invasive plant species recorded. The subwatersheds with the greatest number of invasive species recorded by 2014 were PORE 5-5 (54 invasive plant species) and PORE 5-4 (39 invasive plant species). The median number of invasive plant species recorded per subwatershed by 2014 was 14. The number of invasive plant occurrences also varied significantly by subwatershed (Figure 4.6.29).

The Natural Zone had the largest number of invasive species of the three management zones both by absolute number, 107 invasive plant species, and when considered relative to the total area in each zone. The Wilderness Zone had the lowest number of invasive plant species with 64 recorded species. Again, the number of invasives in the Wilderness Zone was the lowest both in overall value and when considered relative to area in each zone. A total of 74 invasive plant species were recorded in the Pastoral Zone. These numbers represent minimum values for each zone 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 varied.

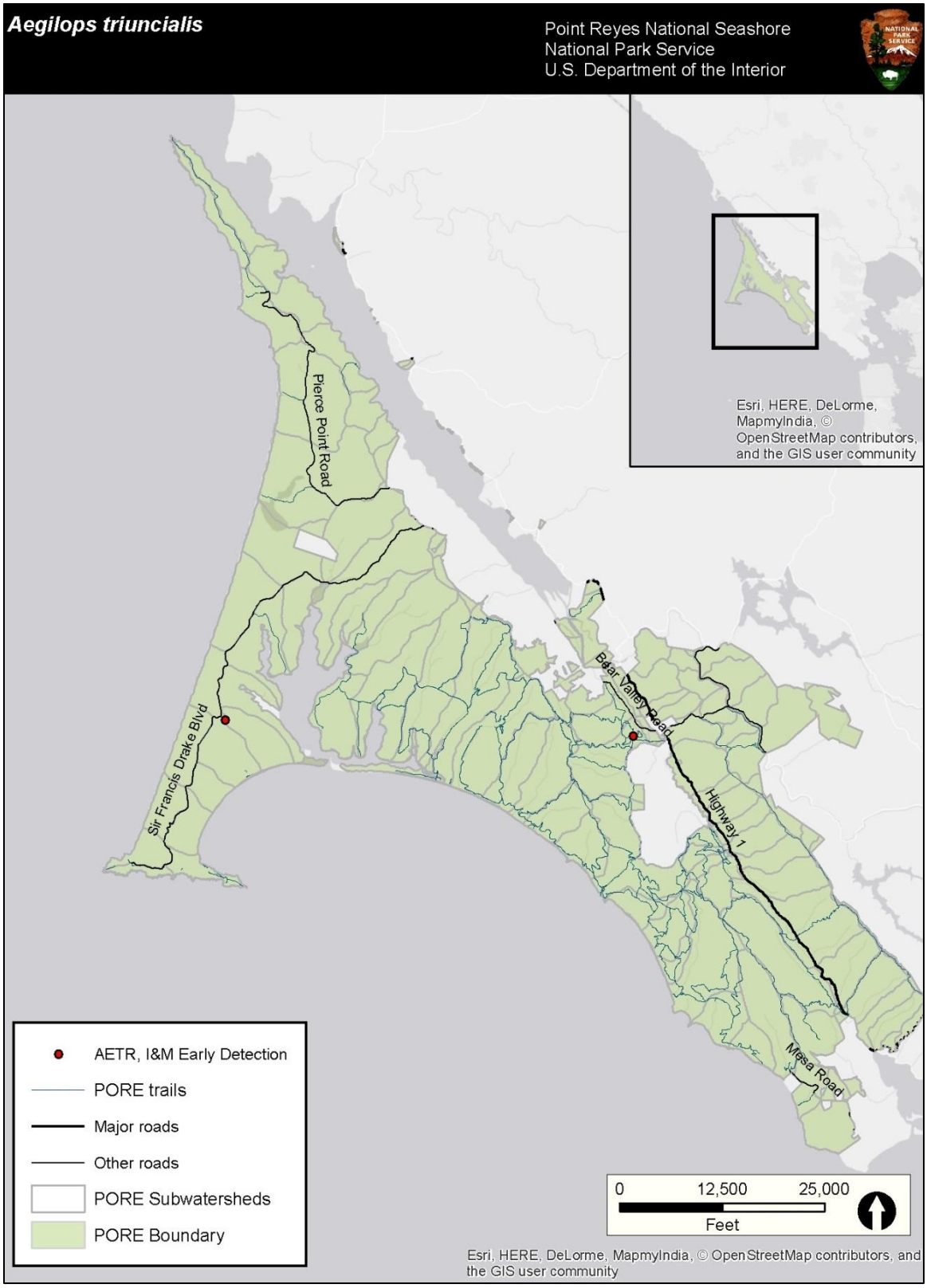


Figure 4.6.5. Recorded distribution of *Aegilops triuncialis* in PORE between 2008 and 2014.

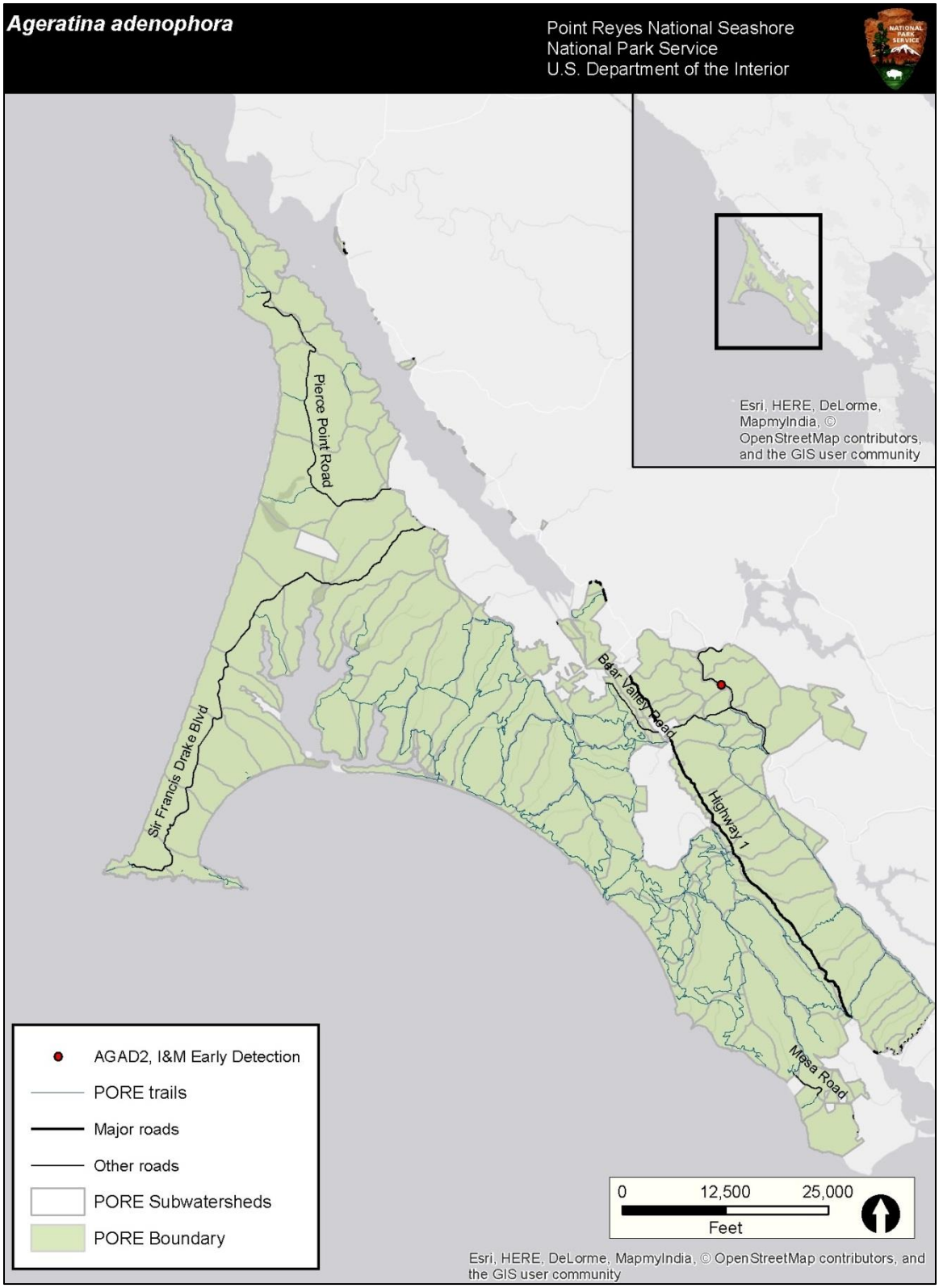


Figure 4.6.6. Recorded distribution of *Ageratina adenophora* in PORE between 2008 and 2014.

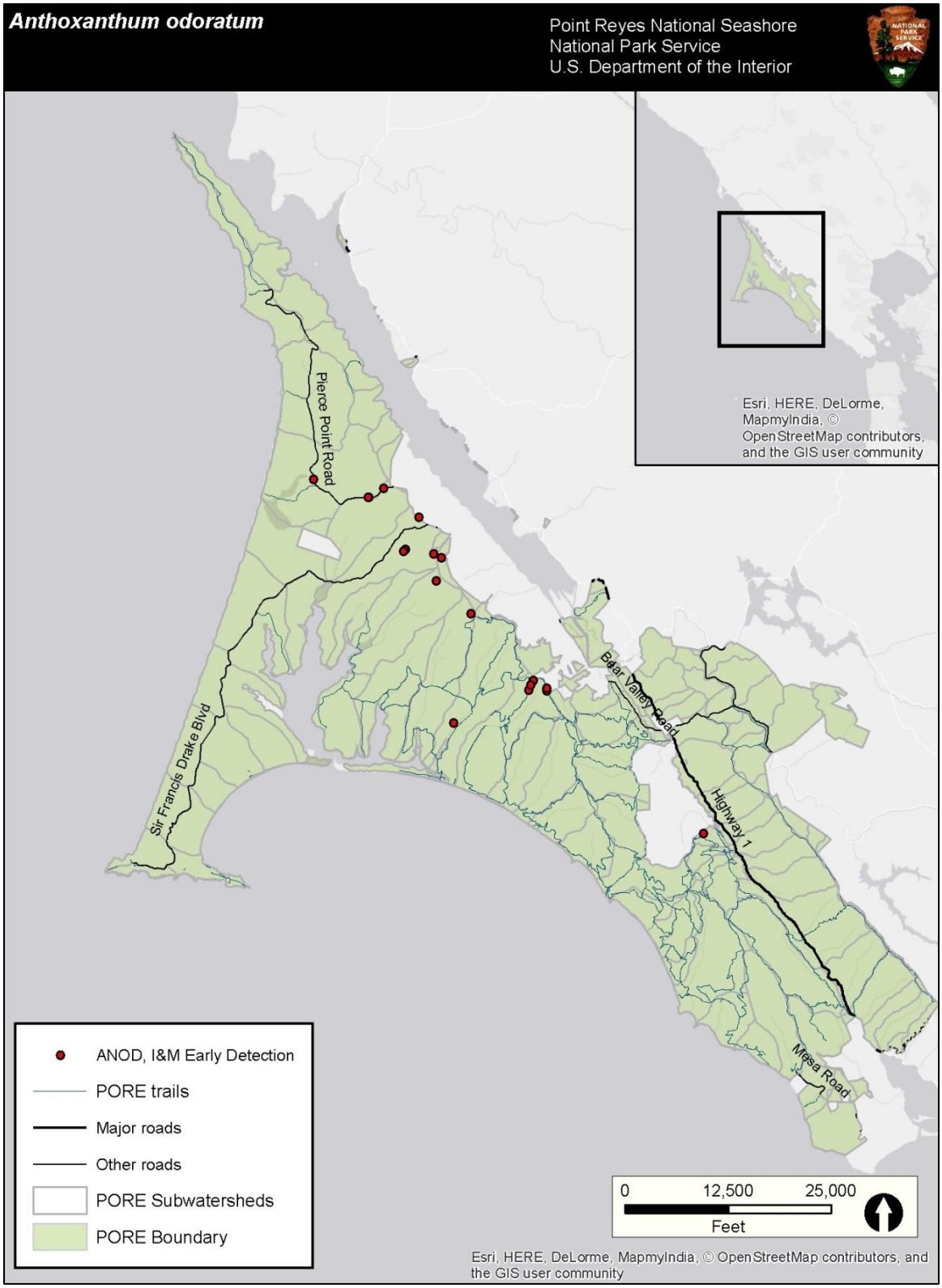


Figure 4.6.7. Recorded distribution of *Anthoxanthum odoratum* in PORE between 2008 and 2014.

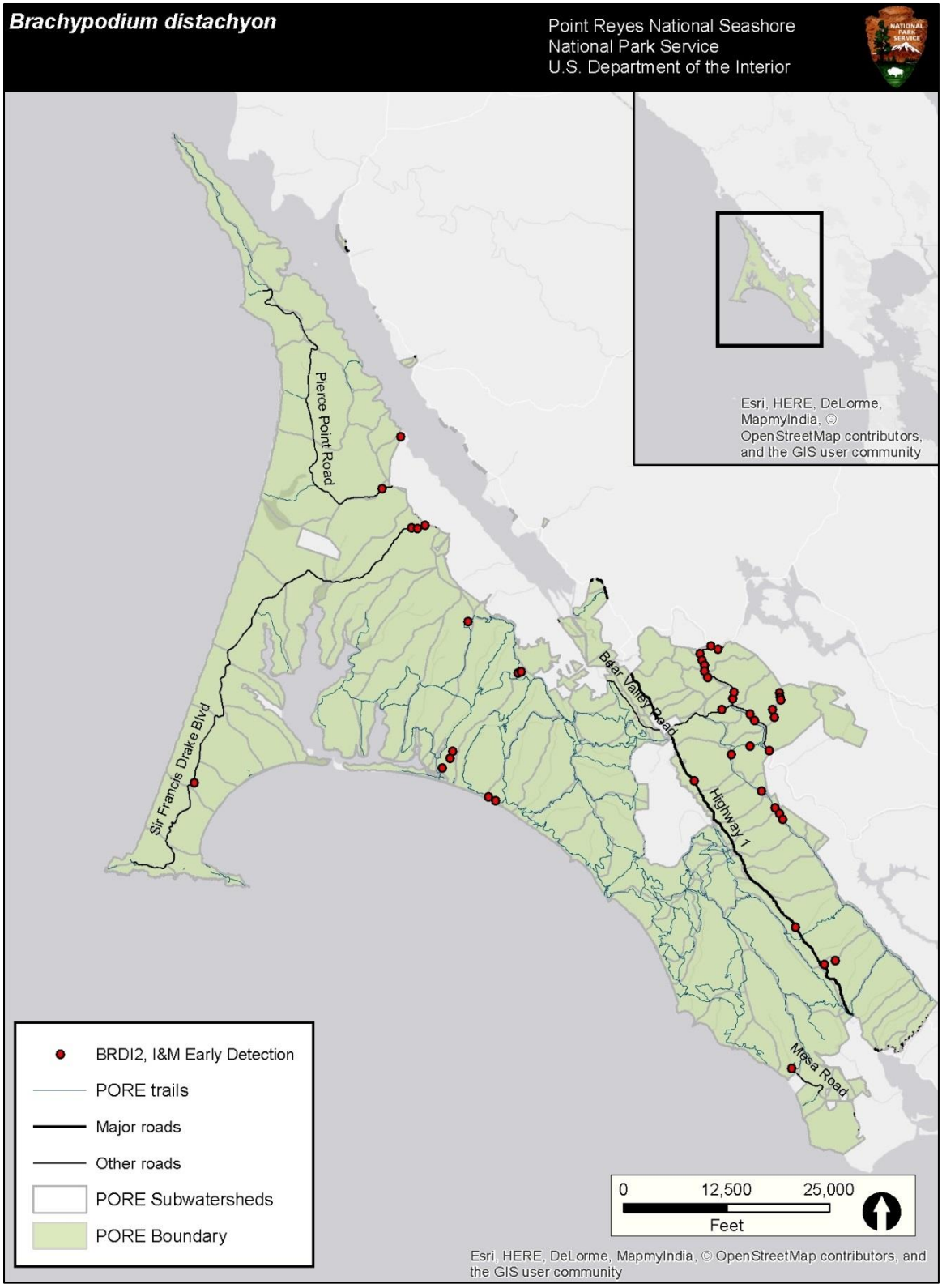


Figure 4.6.8. Recorded distribution of *Brachypodium distachyon* in PORE between 2008 and 2014.

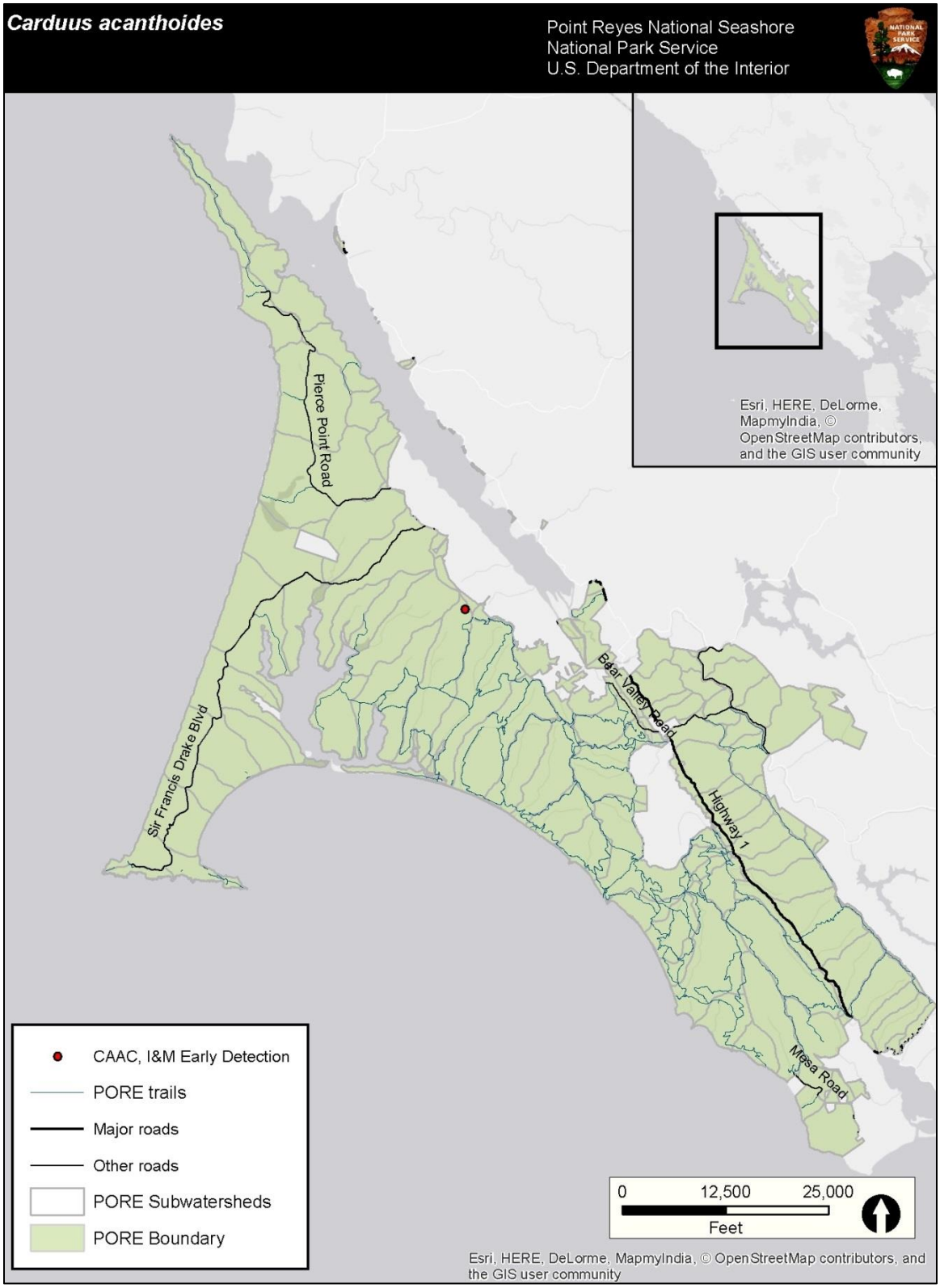


Figure 4.6.9. Recorded distribution of *Carduus acanthoides* in PORE between 2008 and 2014.

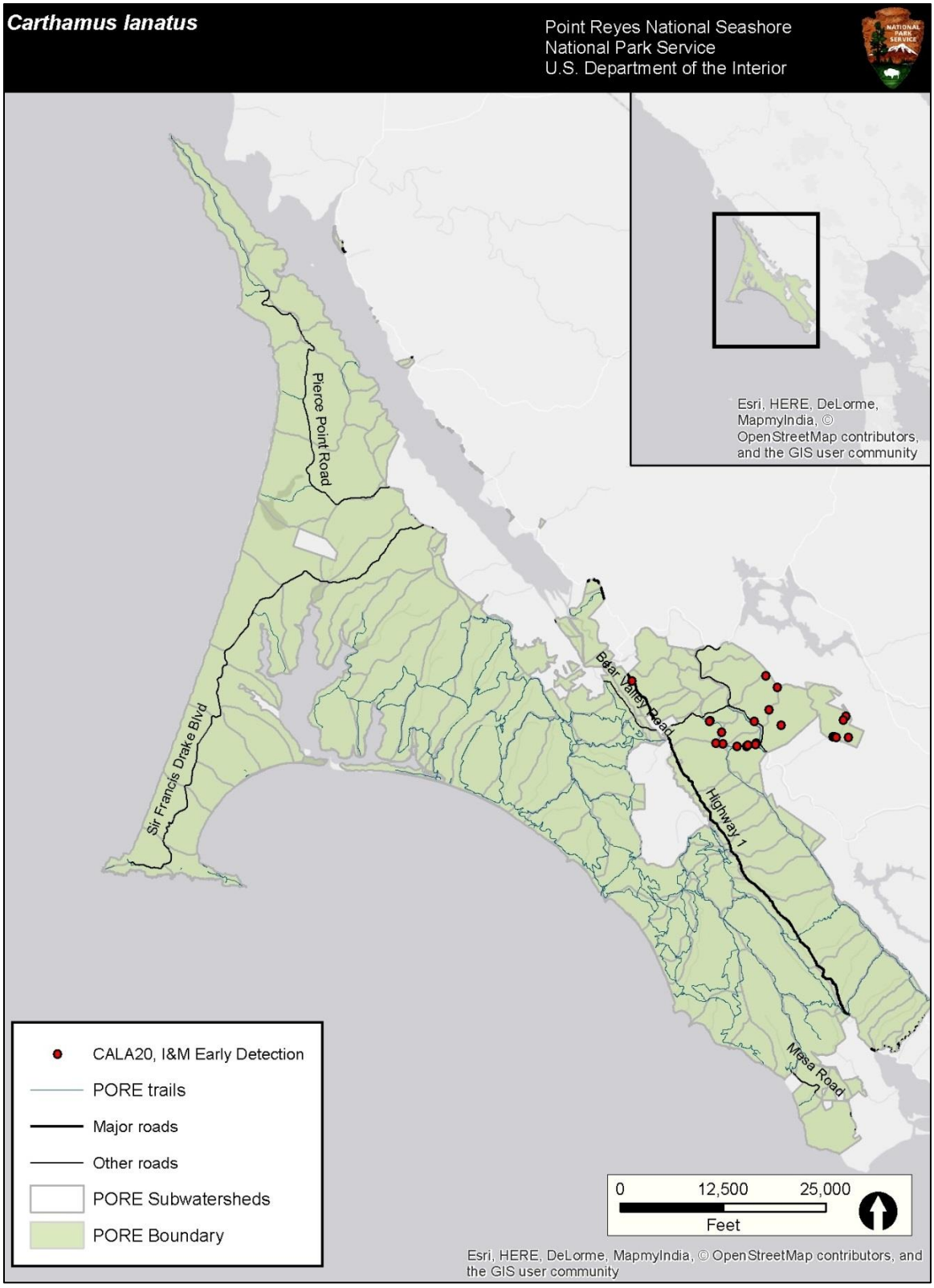


Figure 4.6.10. Recorded distribution of *Carthamus lanatus* in PORE between 2008 and 2014.

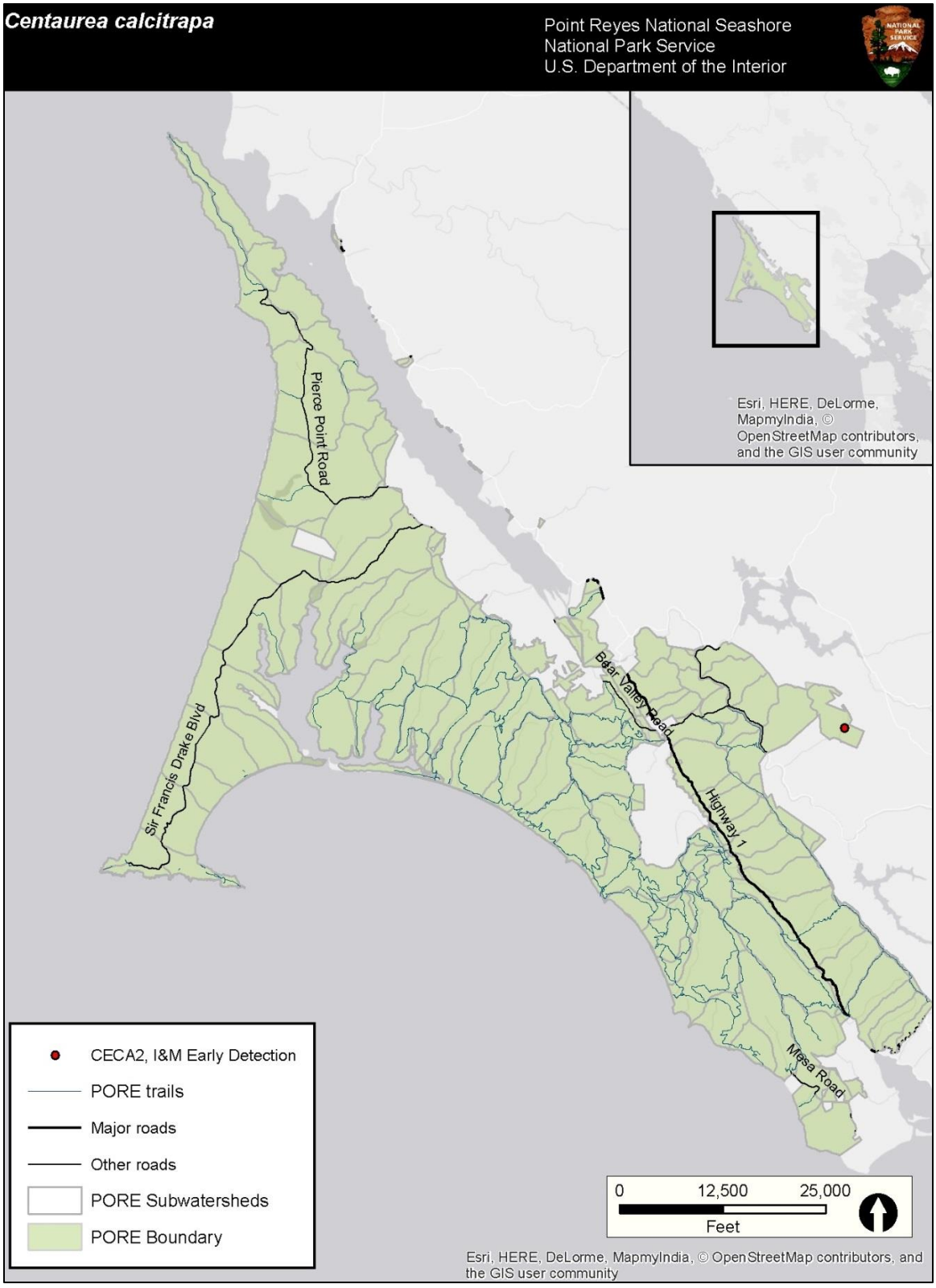


Figure 4.6.11. Recorded distribution of *Centaurea calcitrapa* in PORE between 2008 and 2014.

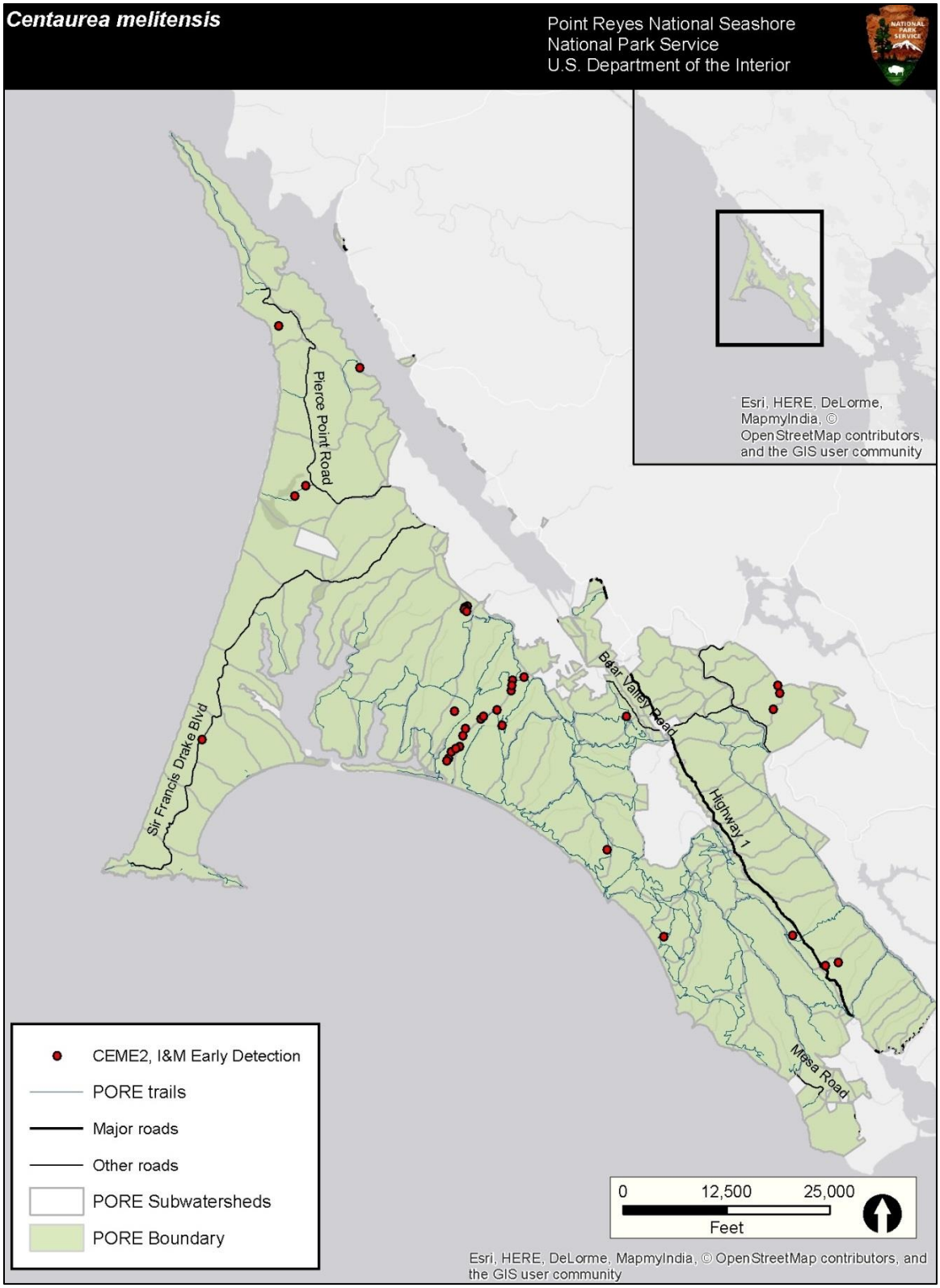


Figure 4.6.12. Recorded distribution of *Centaurea melitensis* in PORE between 2008 and 2014.

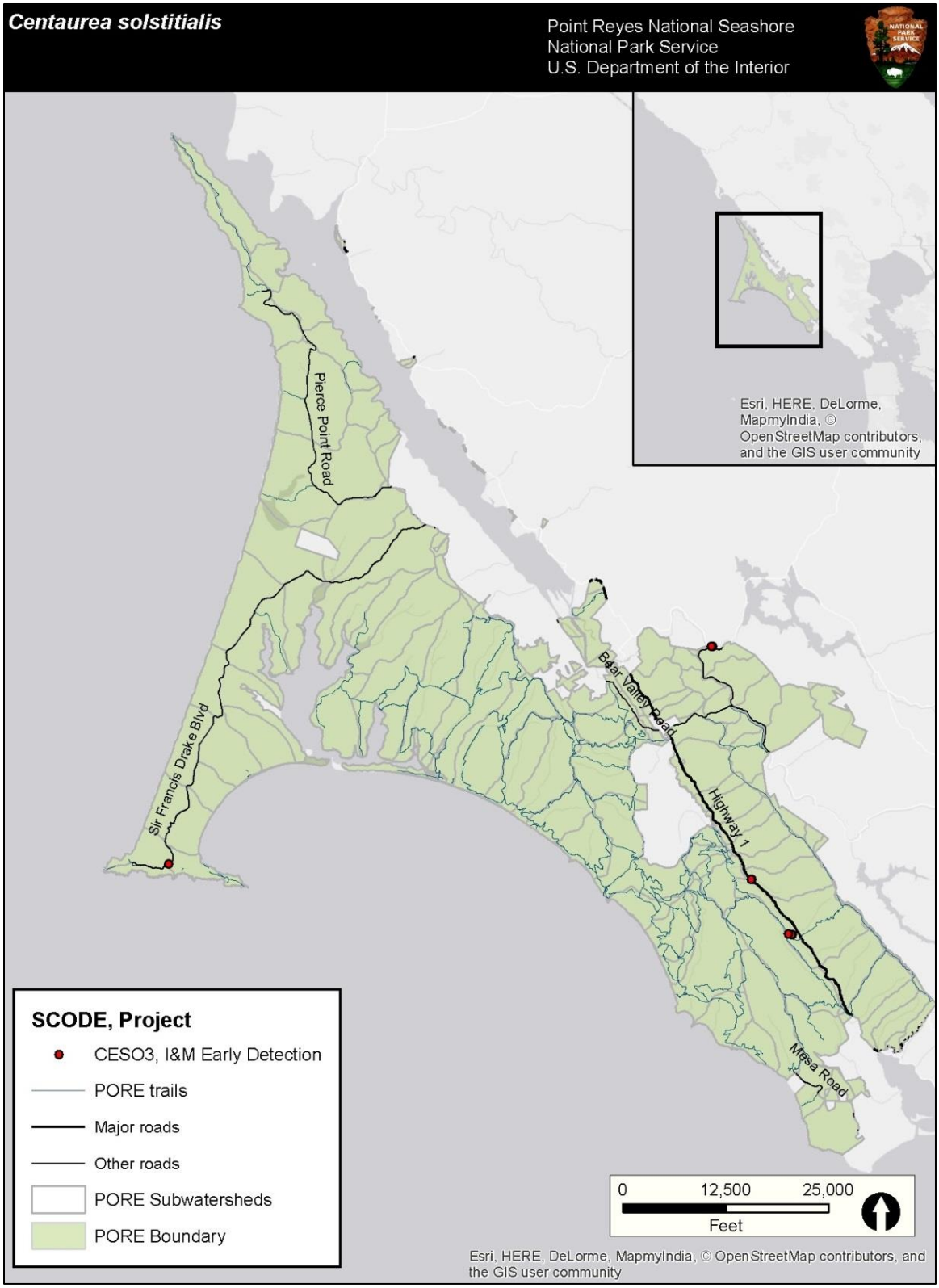


Figure 4.6.13. Recorded distribution of *Centaurea solstitialis* in PORE between 2008 and 2014.

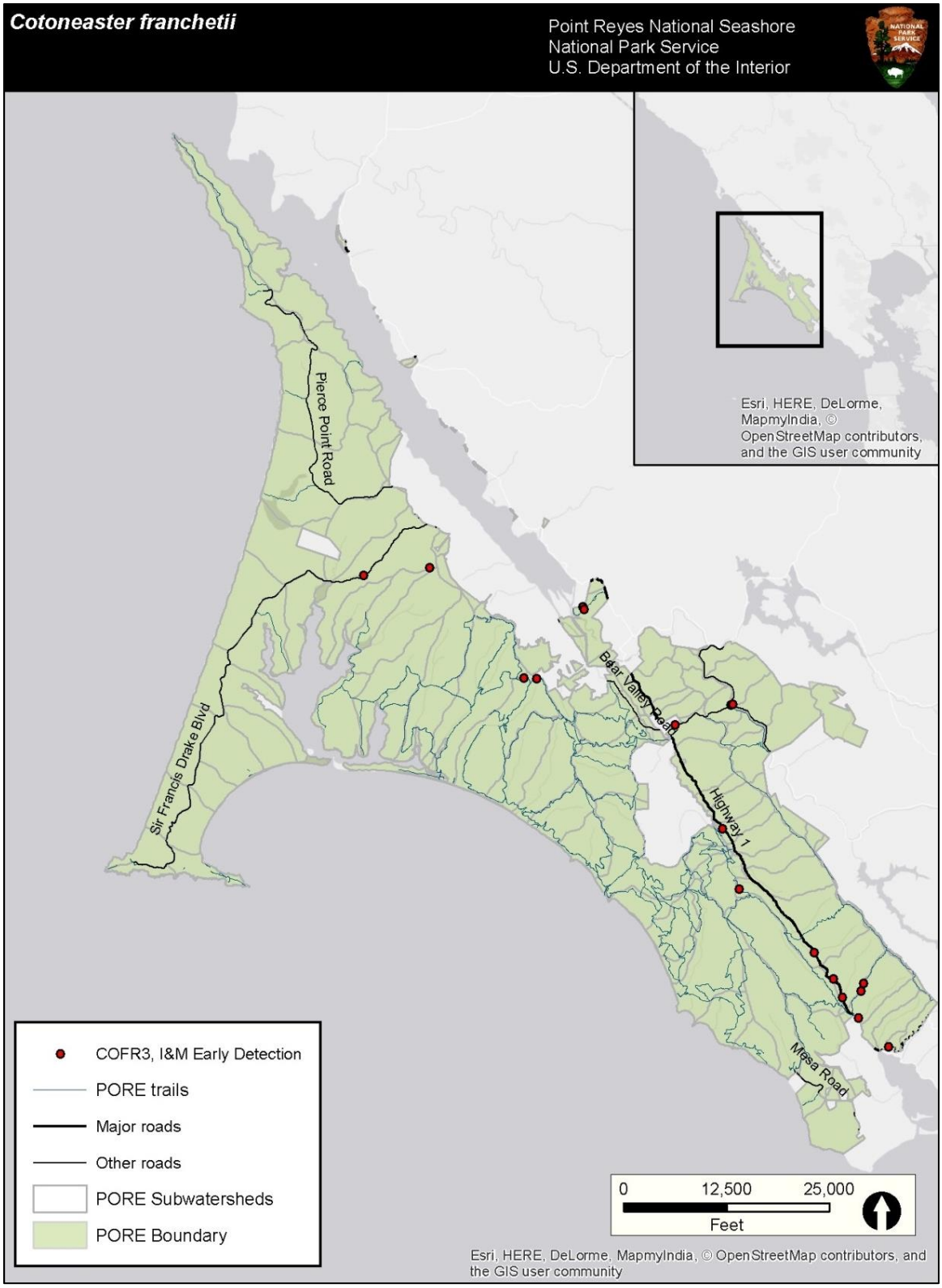


Figure 4.6.14. Recorded distribution of *Cotoneaster franchetii* in PORE between 2008 and 2014.

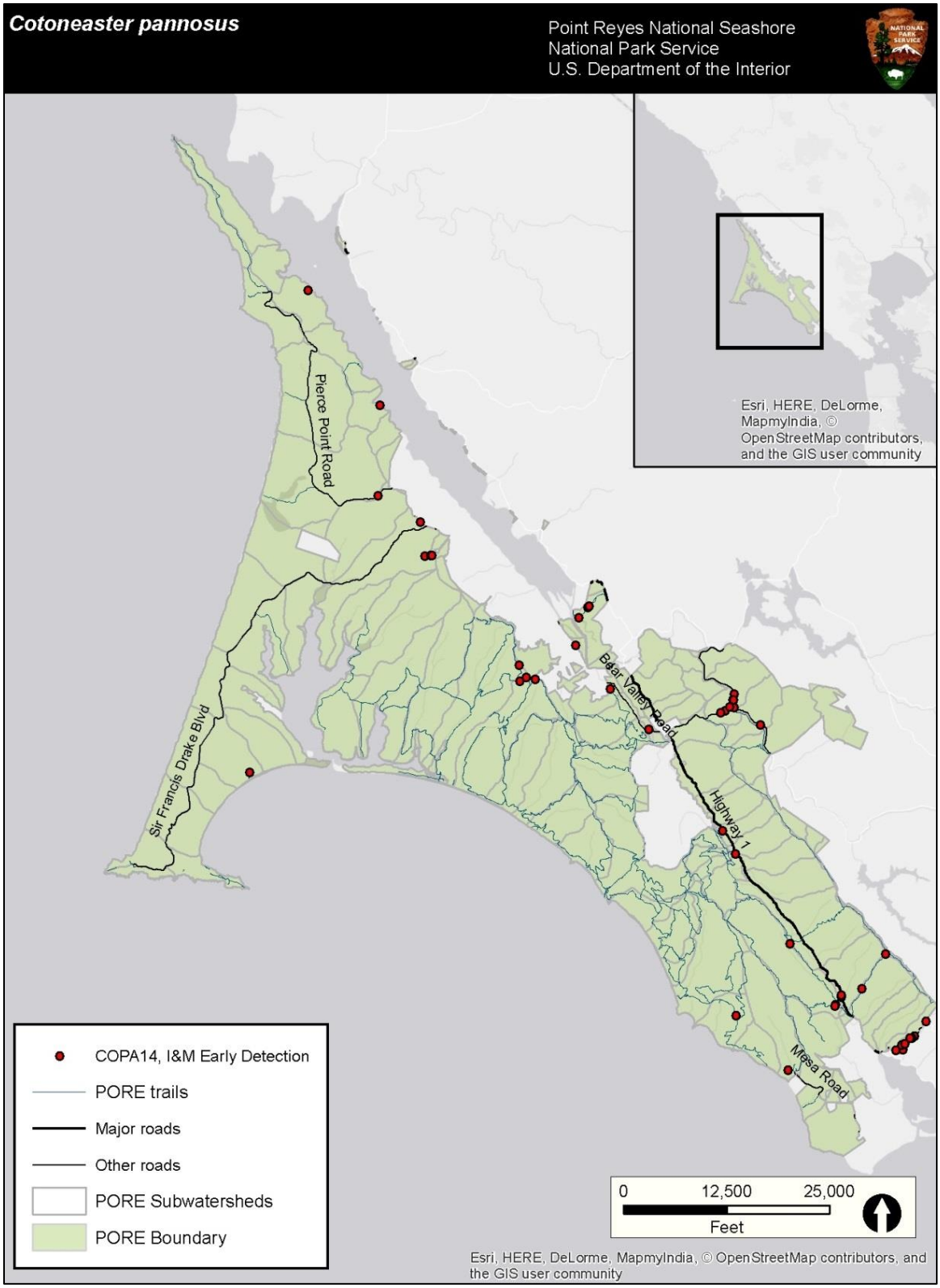


Figure 4.6.15. Recorded distribution of *Cotoneaster pannosus* in PORE between 2008 and 2014.

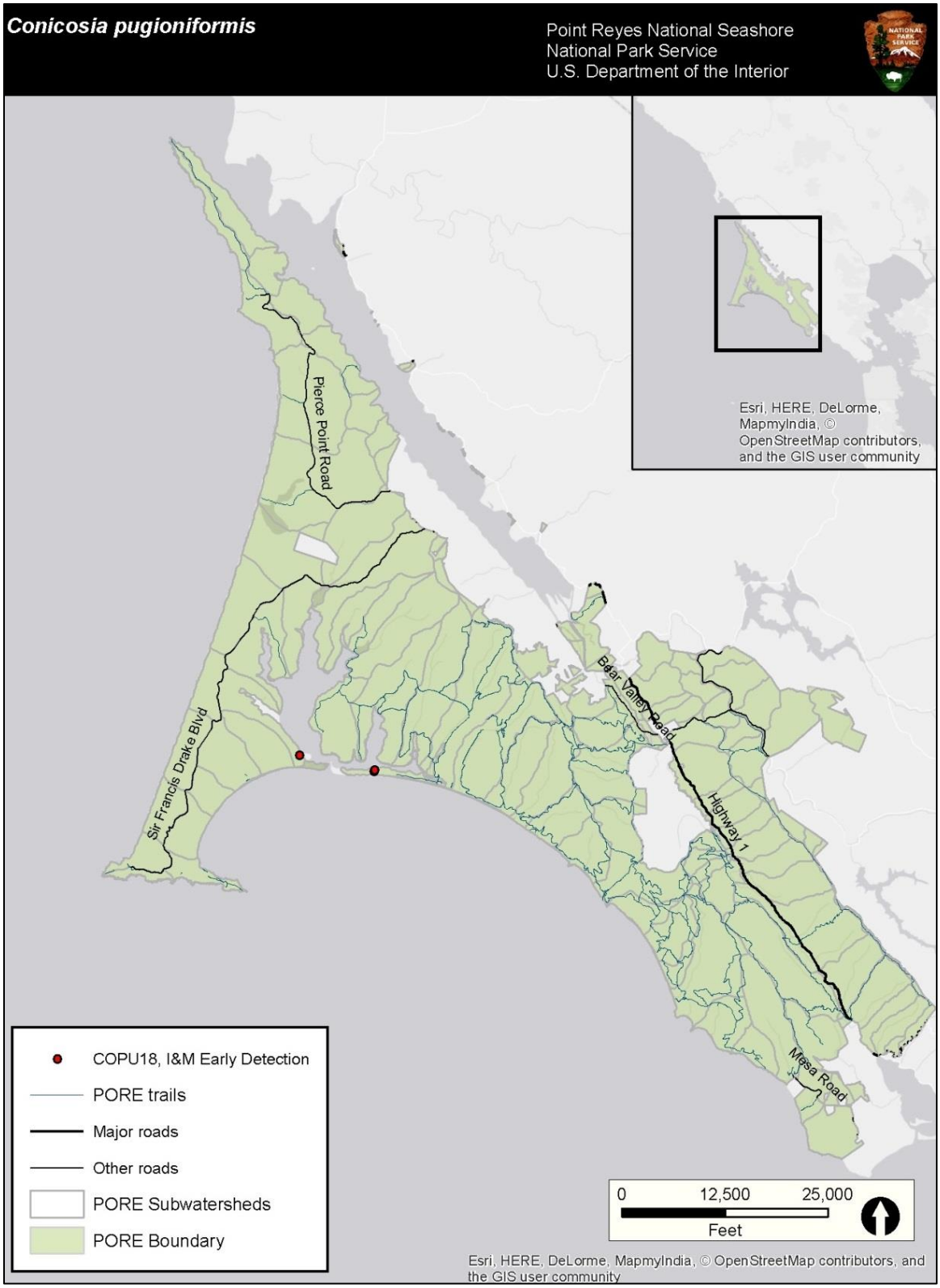


Figure 4.6.16. Recorded distribution of *Conicosia pugioniformis* in PORE between 2008 and 2014.

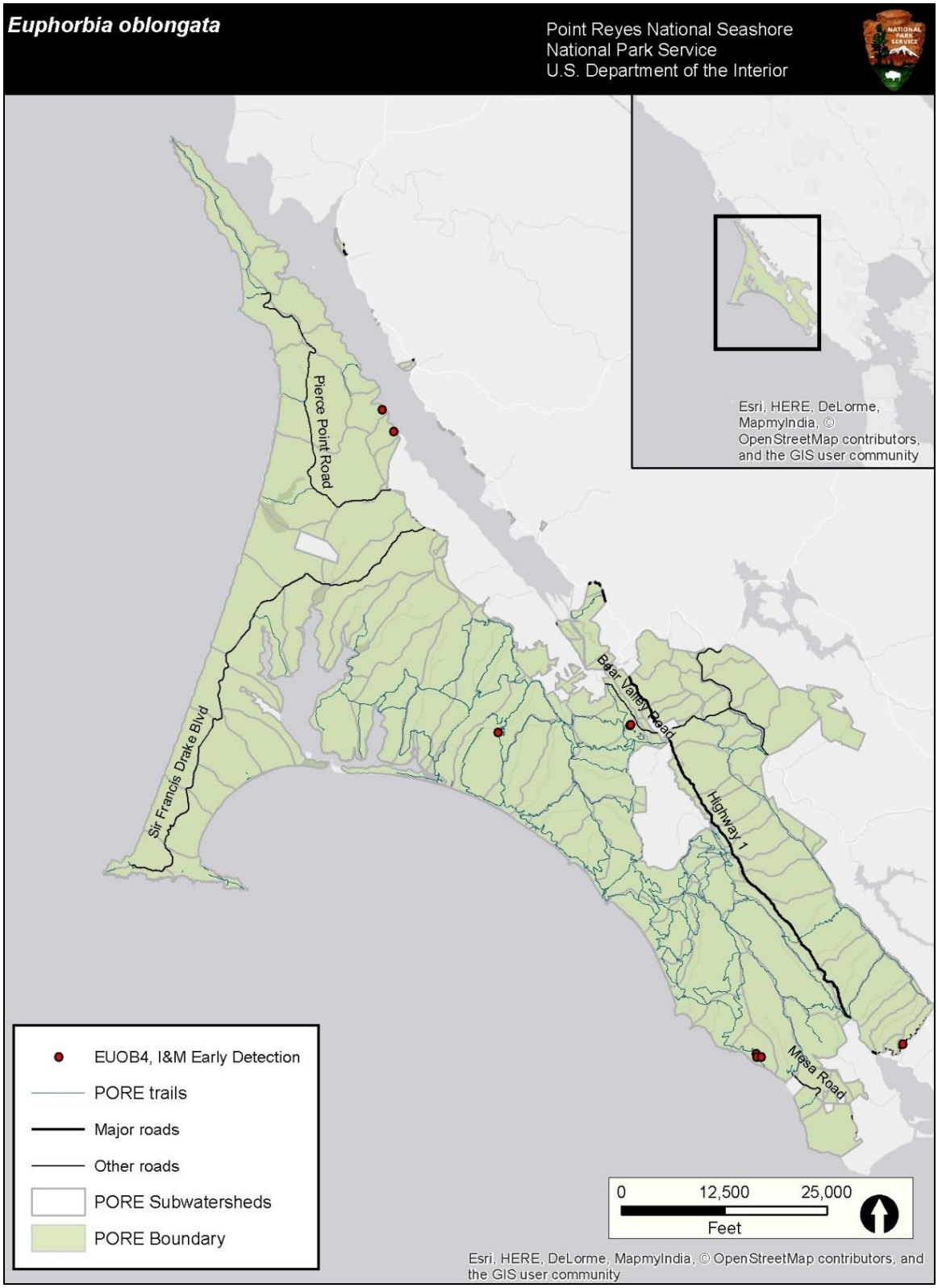


Figure 4.6.17. Recorded distribution of *Euphorbia oblongata* in PORE between 2008 and 2014.

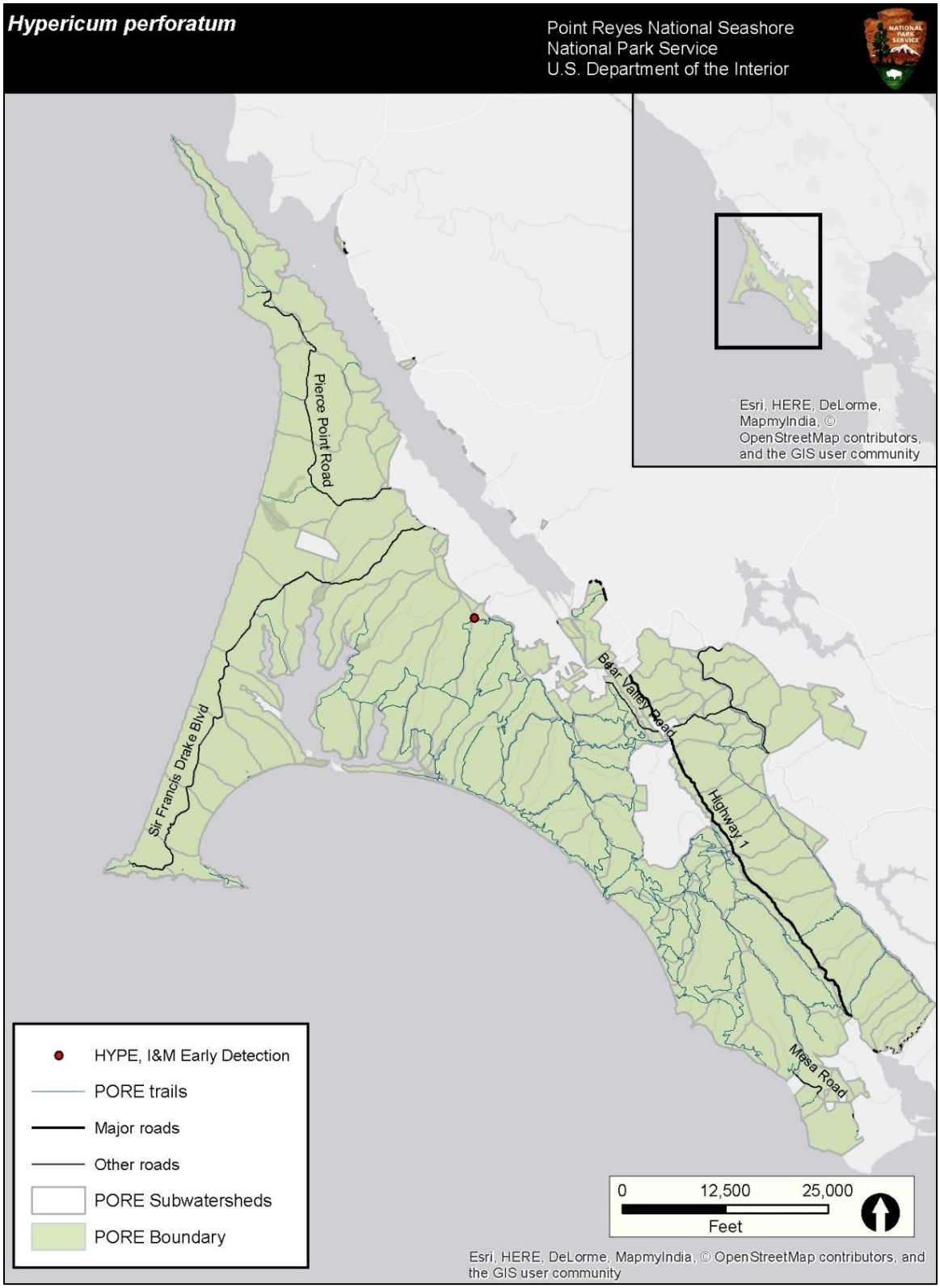


Figure 4.6.18. Recorded distribution of *Hypericum perforatum* in PORE between 2008 and 2014.

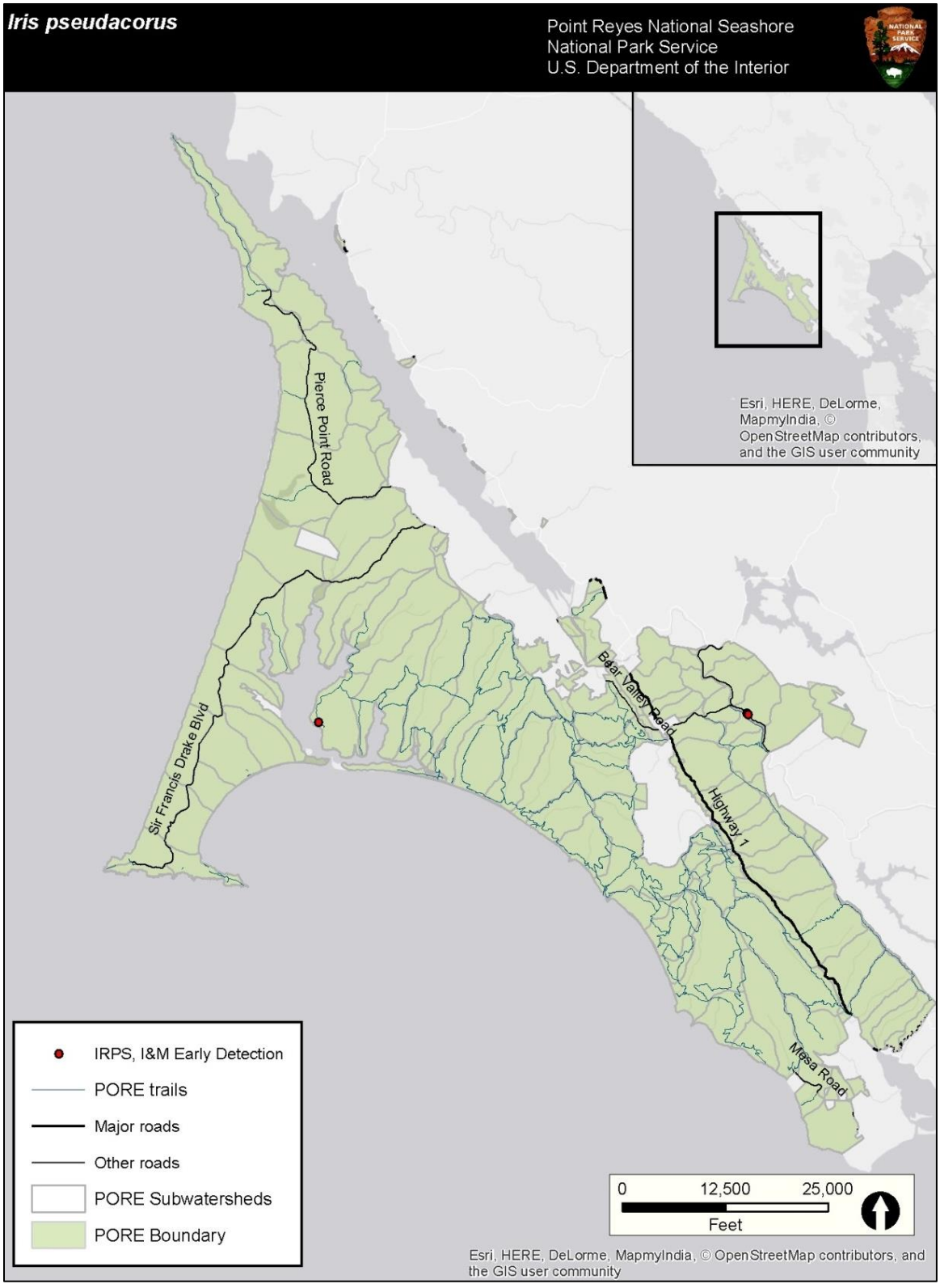


Figure 4.6.19. Recorded distribution of *Iris pseudacorus* in PORE between 2008 and 2014.

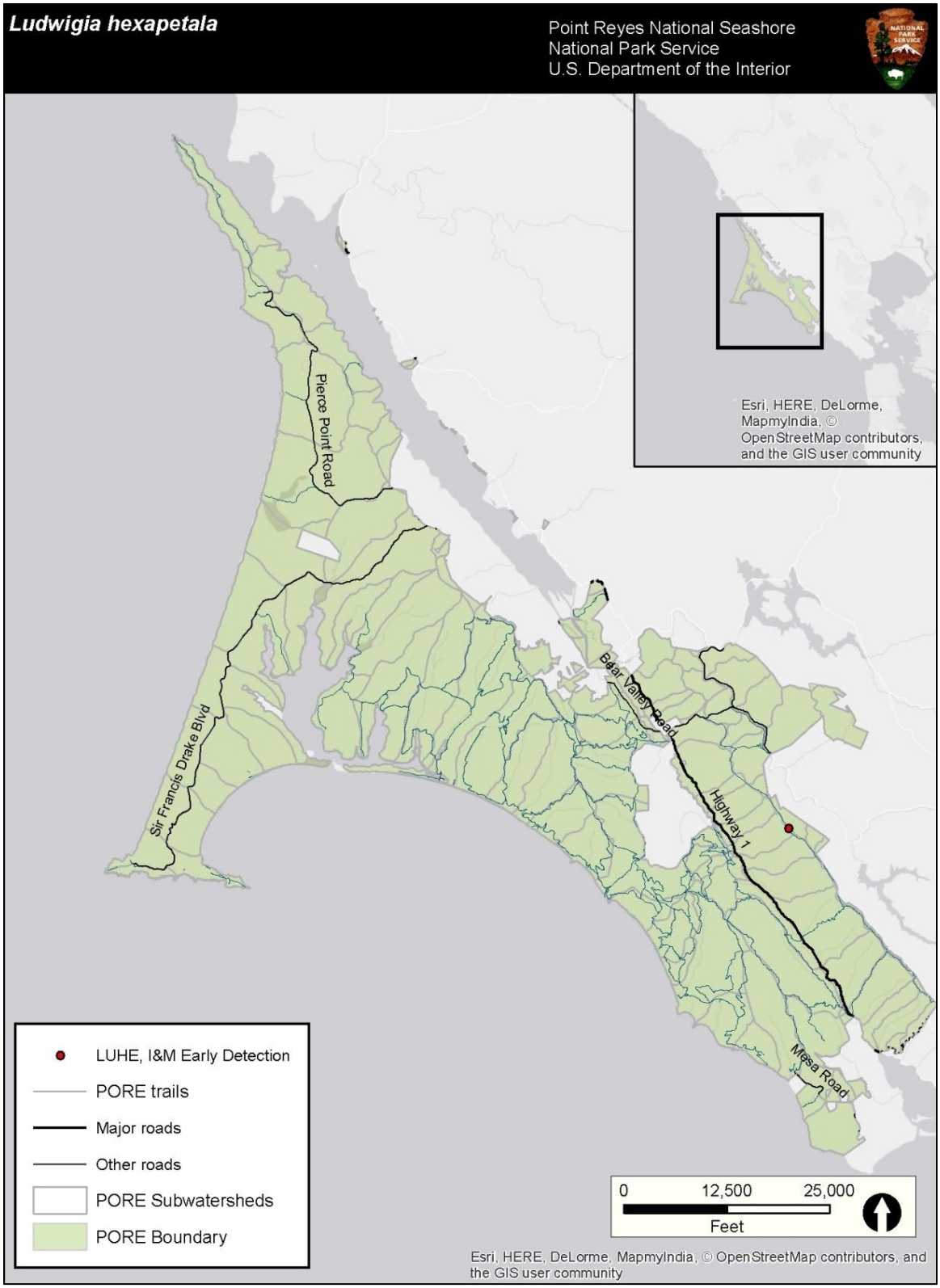


Figure 4.6.20. Recorded distribution of *Ludwigia hexapetala* in PORE between 2008 and 2014.

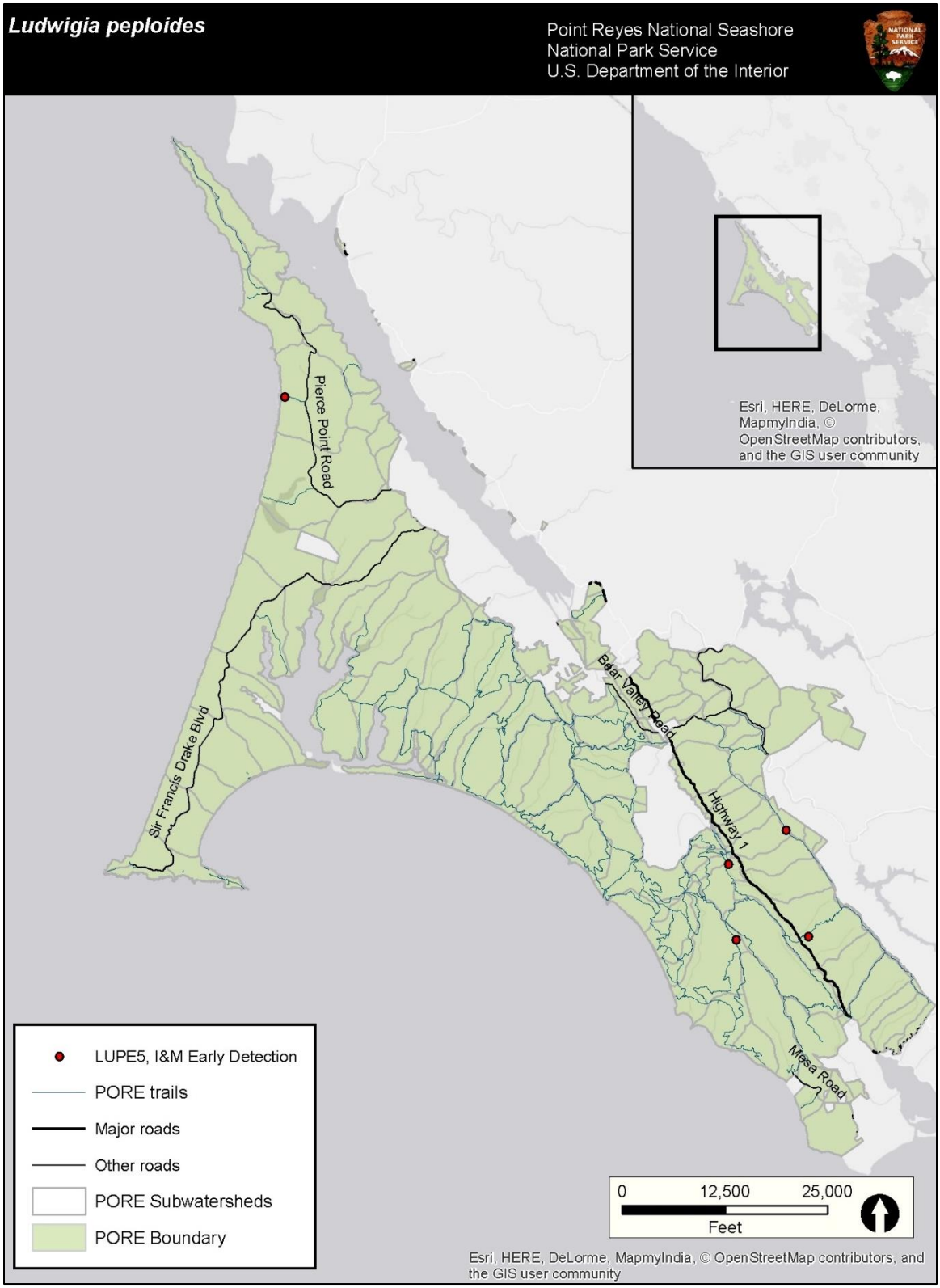


Figure 4.6.21. Recorded distribution of *Ludwigia peploides* in PORE between 2008 and 2014.

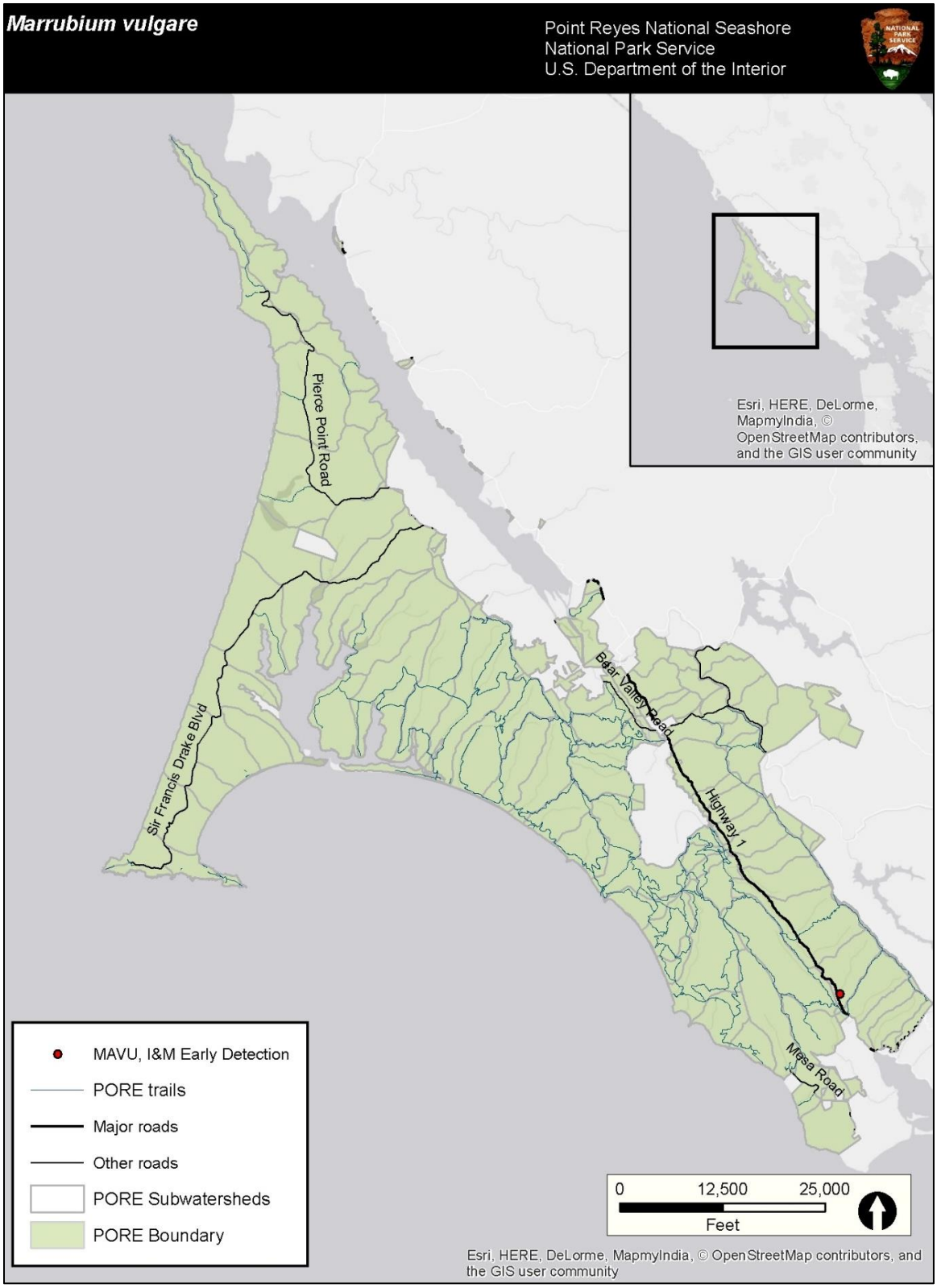


Figure 4.6.22. Recorded distribution of *Marrubium vulgare* in PORE between 2008 and 2014.

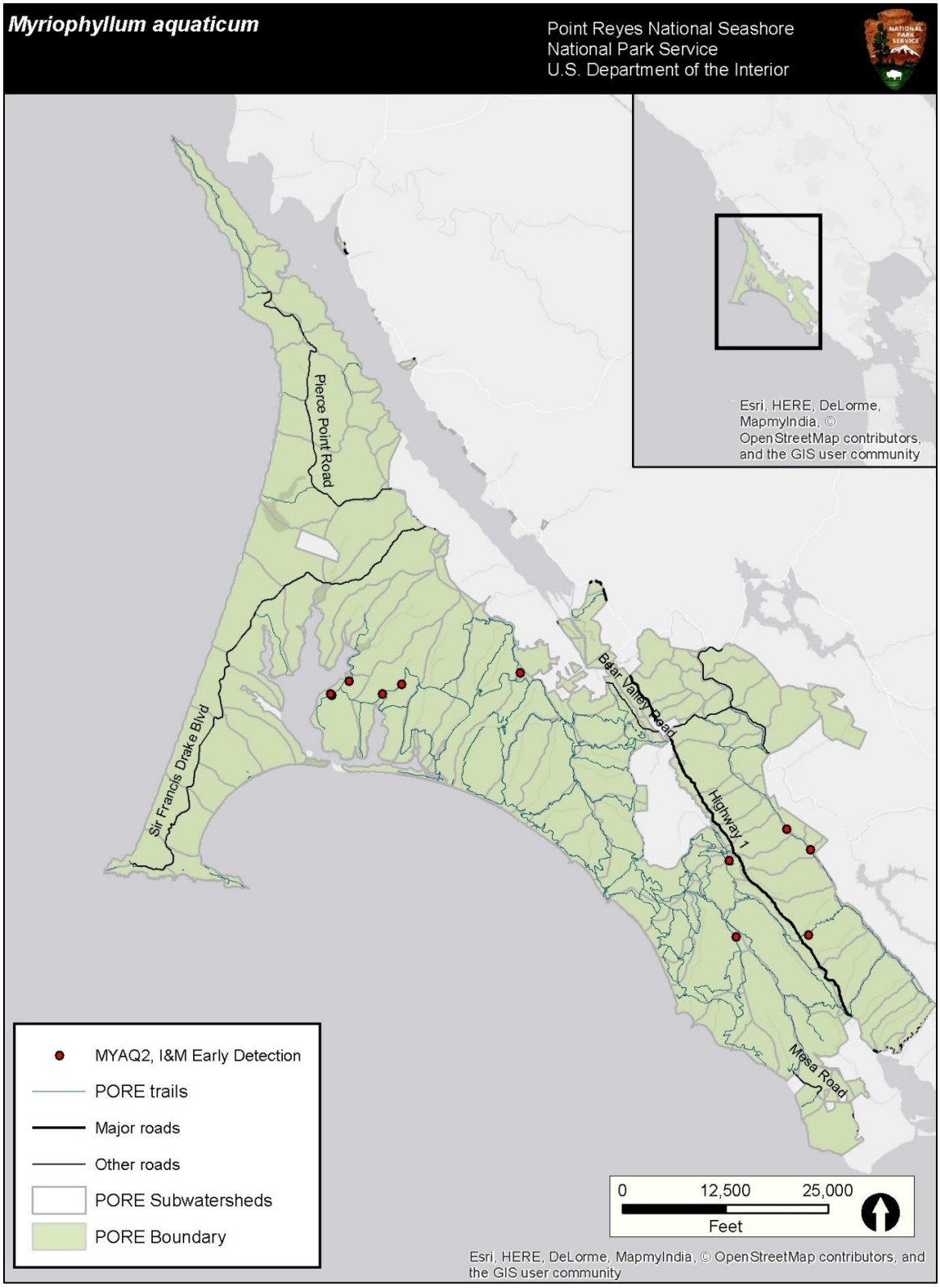


Figure 4.6.23. Recorded distribution of *Myriophyllum aquaticum* in PORE between 2008 and 2014.

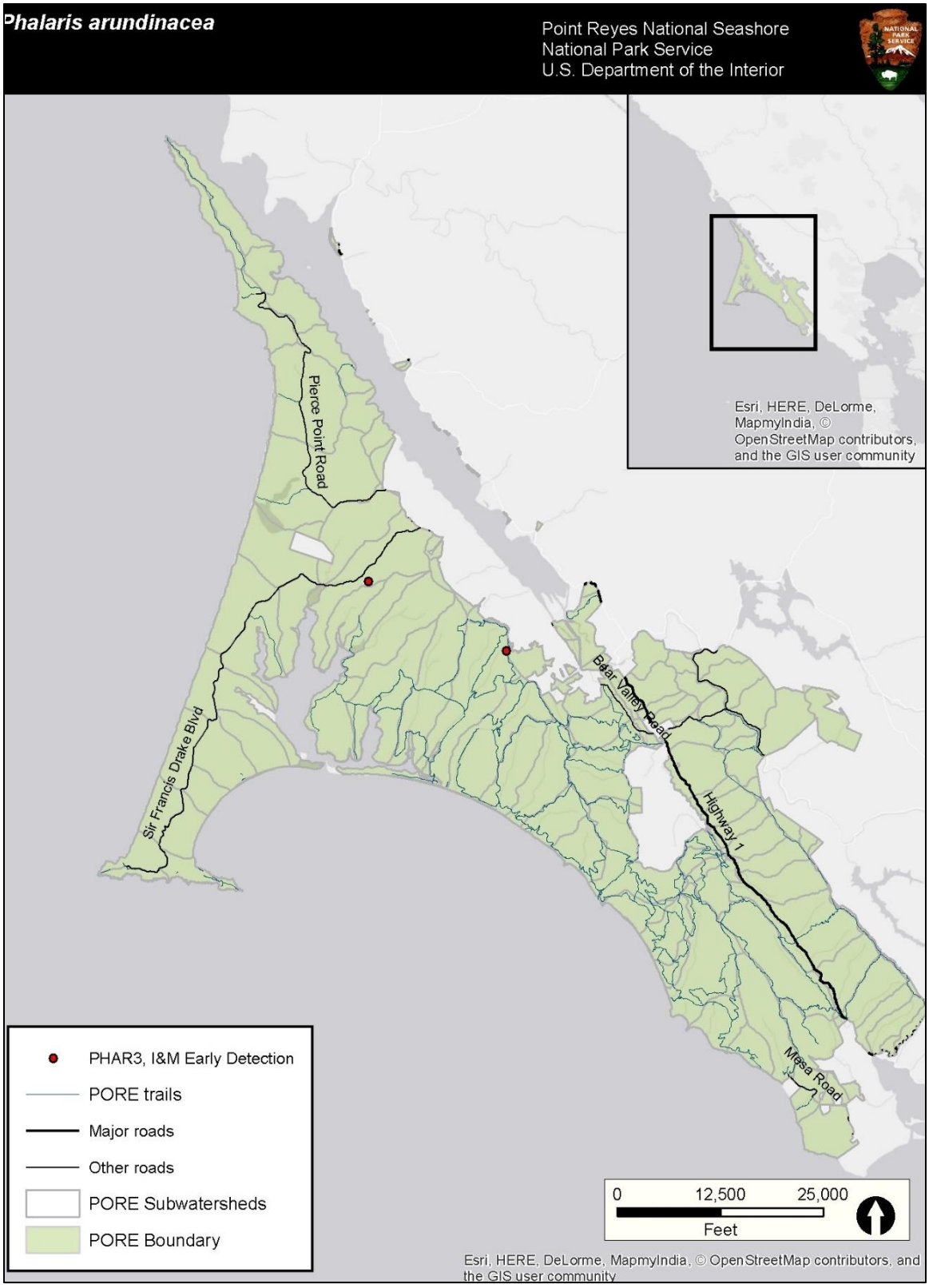


Figure 4.6.24. Recorded distribution of *Phalaris arundinacea* in PORE between 2008 and 2014.

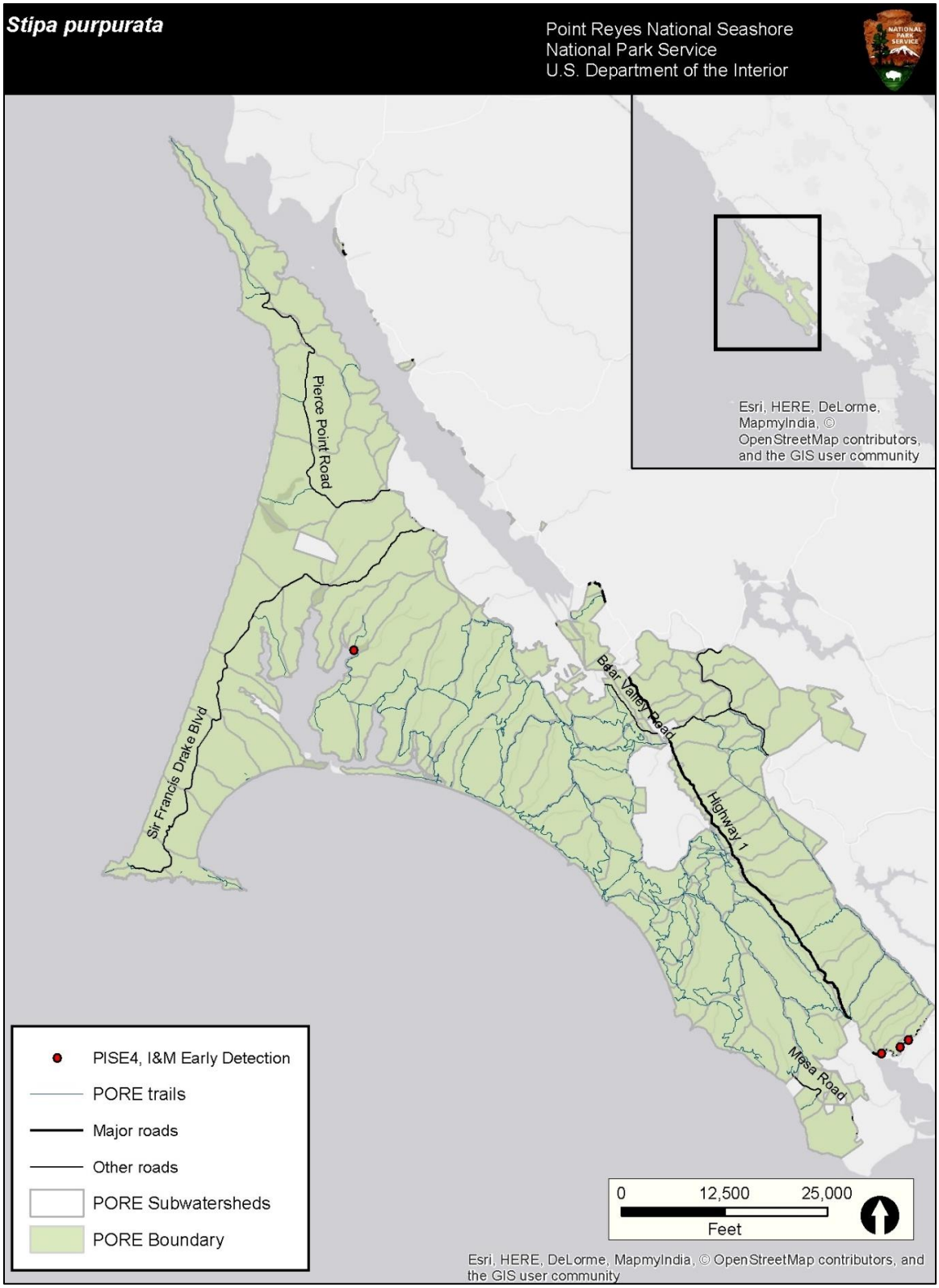


Figure 4.6.25. Recorded distribution of *Stipa purpurata* in PORE between 2008 and 2014.

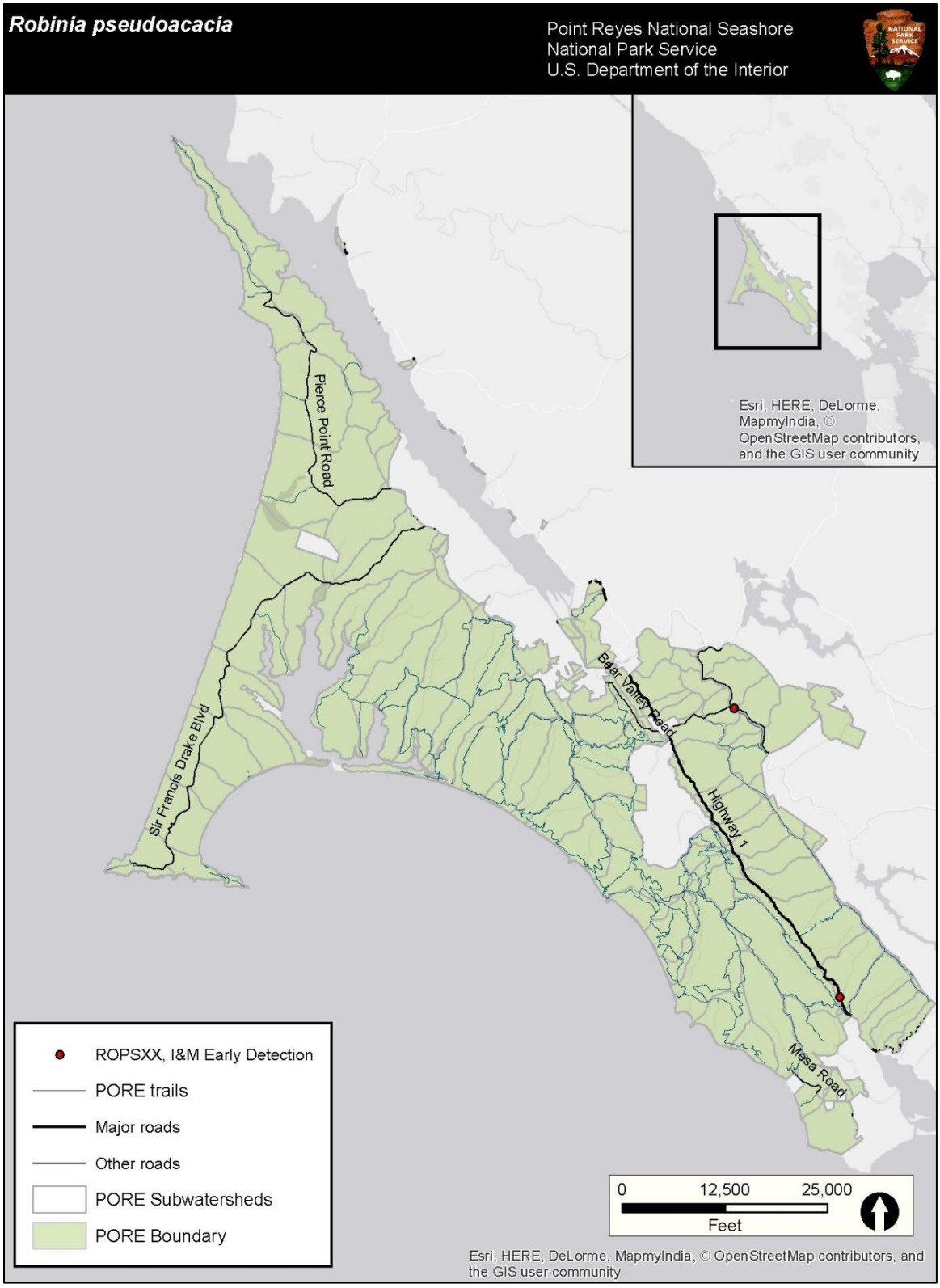


Figure 4.6.26. Recorded distribution of *Robinia pseudoacacia* in PORE between 2008 and 2014.

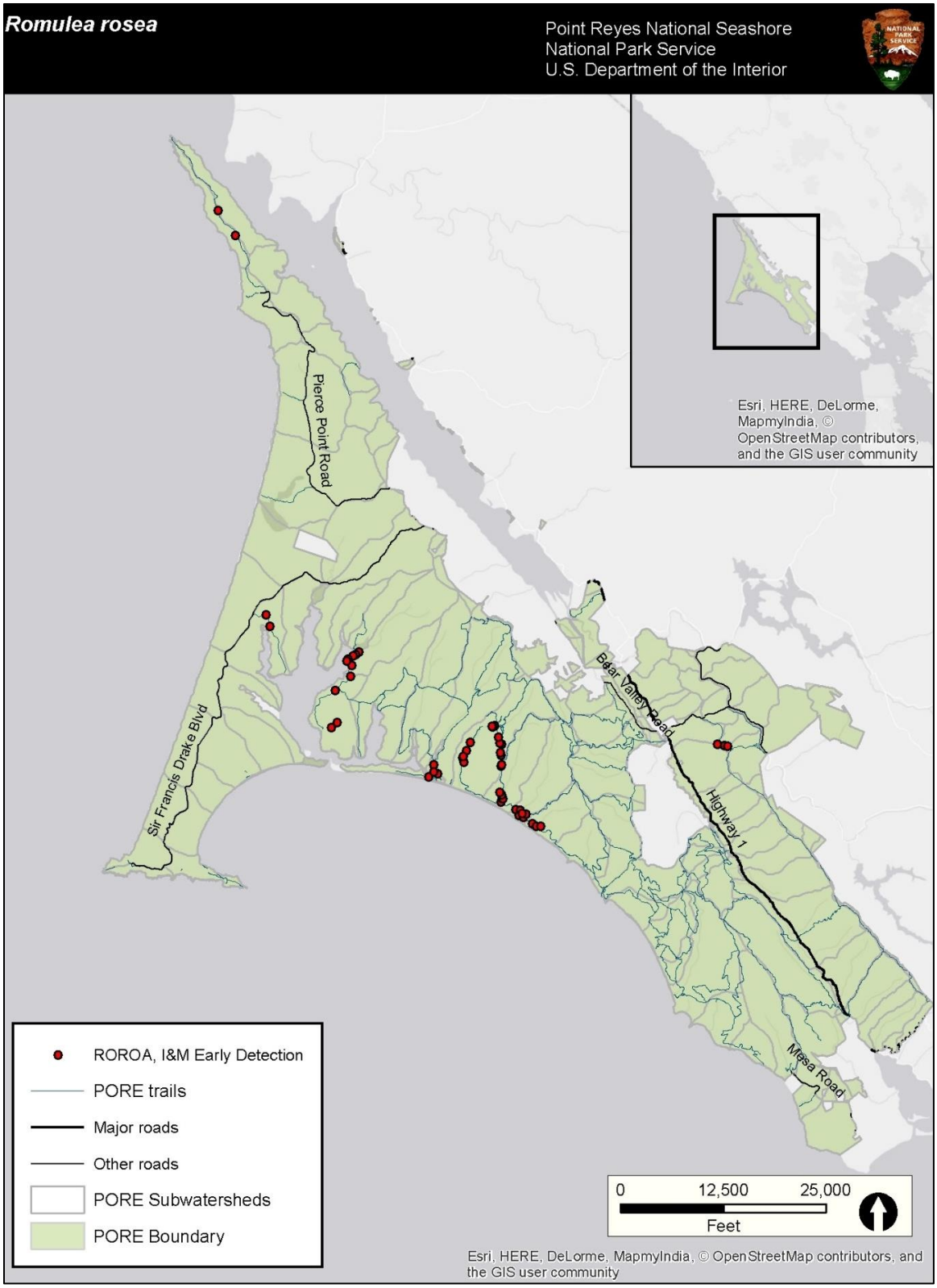


Figure 4.6.27. Recorded distribution of *Romulea rosea* var*. australis* in PORE between 2008 and 2014.

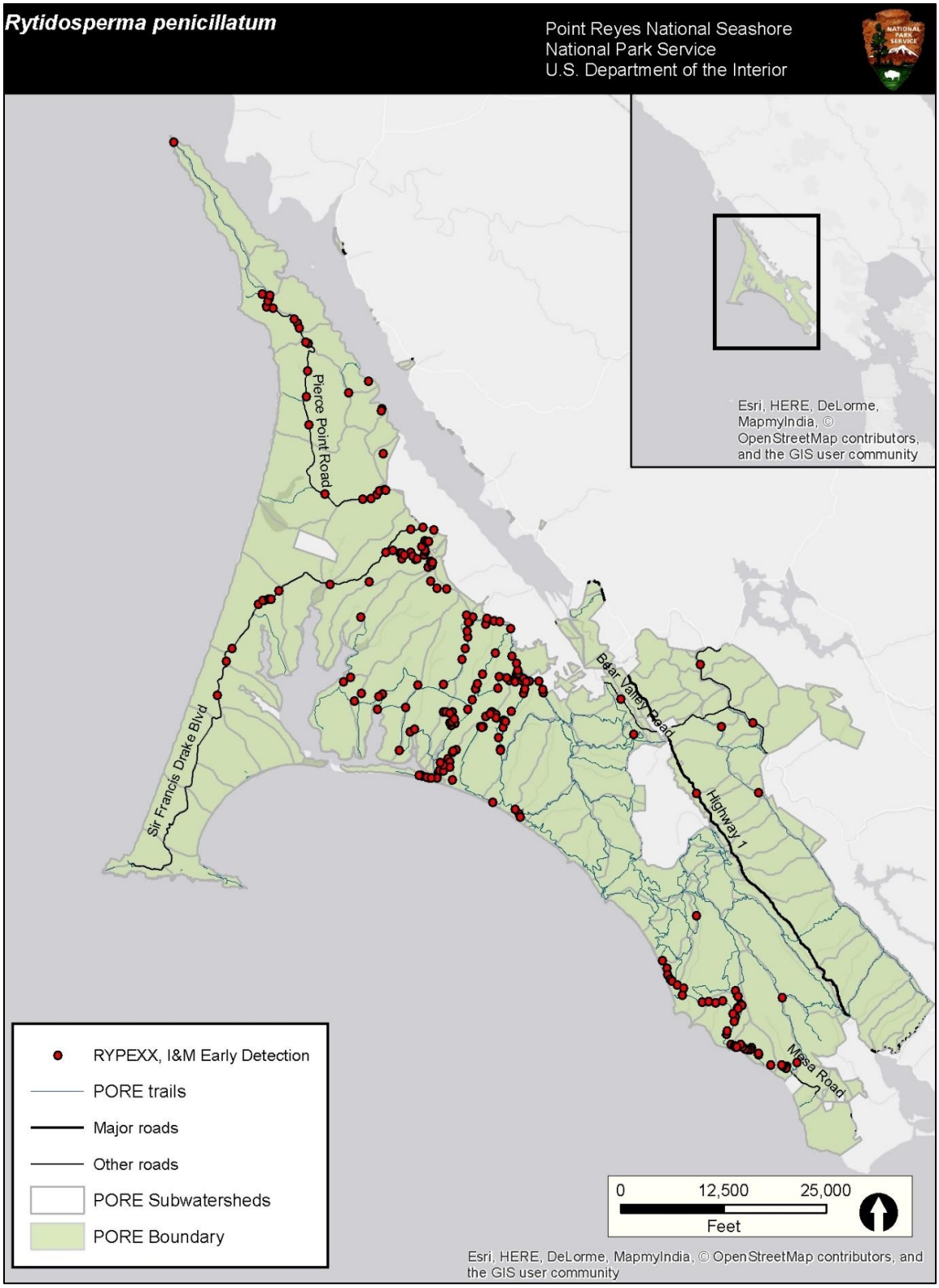


Figure 4.6.28. Recorded distribution of *Rytidosperma penicillatum* in PORE between 2008 and 2014.

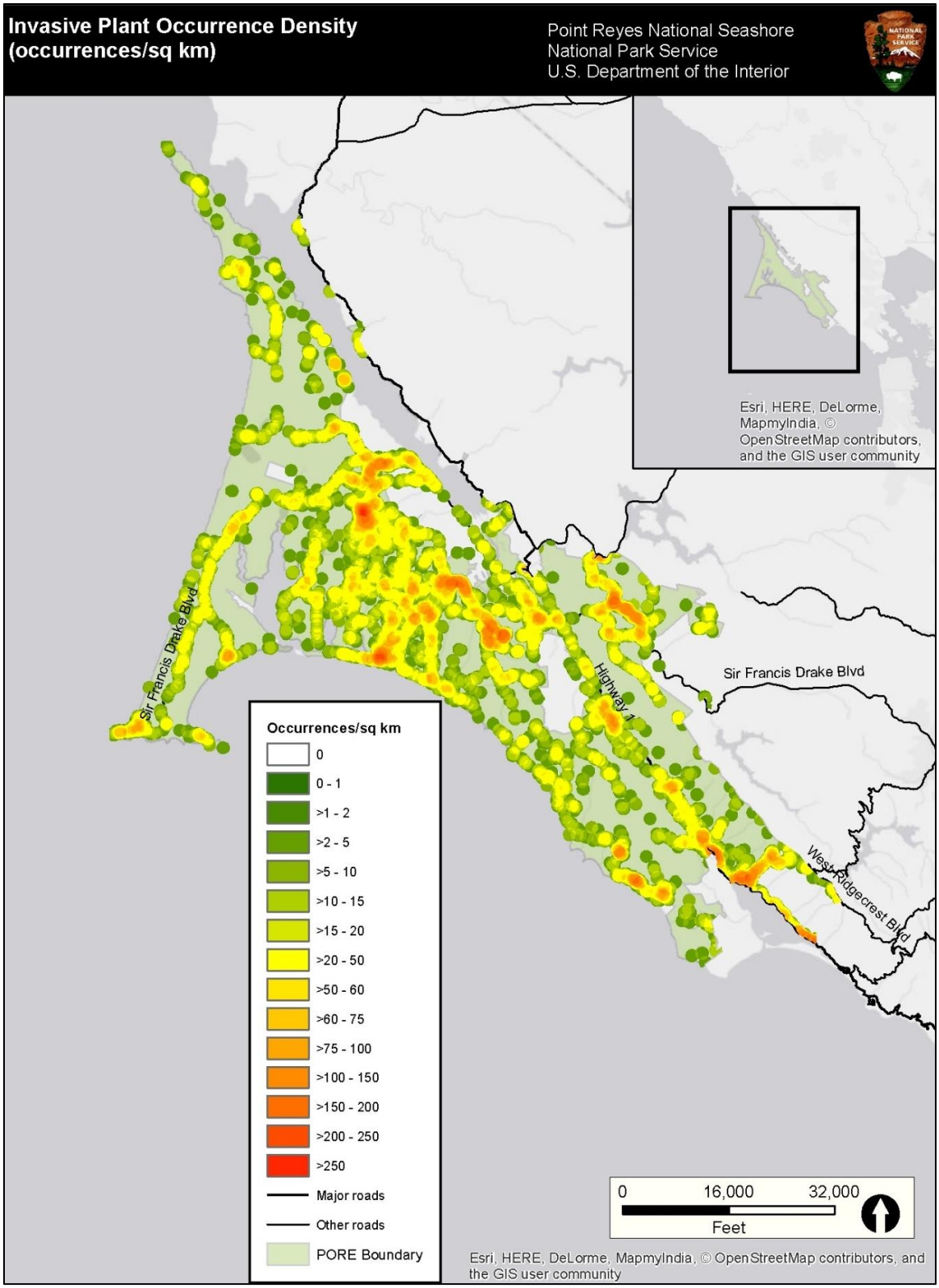


Figure 4.6.29. Number of invasive plant occurrences per km^2 recorded in PORE between 2008 and 2014.

How many new non-native species (i.e., formerly unknown in the park) are detected in PORE each year?
From 2011 to 2014, the Invasive Species Early Detection Team (ISED) observed 46 non-native plant species in PORE and GOGA that were not previously on the NPSpecies working lists (Table 4.6.2). Eleven of these species were located in PORE managed lands: *Dittrichia graveolens, Fallopia japonica, Glyceria declinata, Ligustrum vulgare, Lychnis coronaria, Phalaris elongata, Rhamnus alaternus, Sorghum halepense, Stipa miliacea, Symphytum officinale,* and *Trifolium angustifolium*. Appendix C provides a complete list of these newly documented non-native plant species. All of the newly recorded species in PORE were detected in the Natural Zone.

Table 4.6.2. Number of new non-native species (i.e., formerly unknown in the park) detected in lands managed by Point Reyes National Seashore and Golden Gate National Recreation Area from 2011-2014. Note that the total unique species number is less than the combined PORE and GOGA numbers because some of the same non-native plant species were detected in both parks.

Year	PORE	GOGA	Total unique species
2011	1	18	19
2012	2	12	13
2013	1	7	11
2014	7	3	7
Total	**11**	**40**	**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.

What is the distribution of surveyed sites and treatment sites in PORE?
The current survey schedule includes annual surveys for roads and trails within high-priority subwatersheds, biennial surveys for significant-priority subwatersheds, surveys within three years for moderate-priority subwatersheds, and within five years for low priority subwatersheds. Under this schedule approximately 55% of subwatersheds would be visited each year. Figure 4.6.30 to Figure 4.6.36 show the subwatersheds surveyed by Early Detection teams each year from 2008 to 2014.

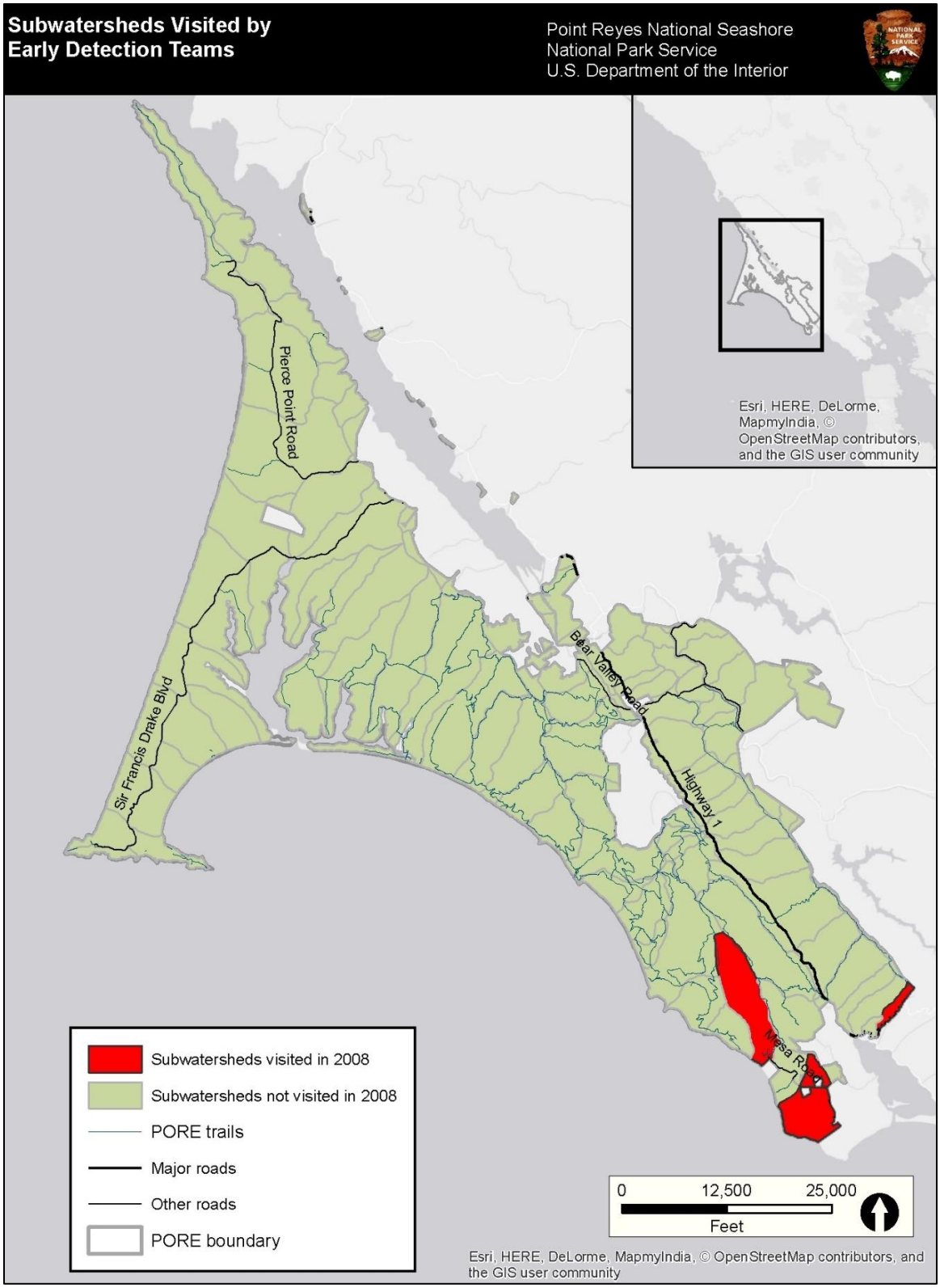


Figure 4.6.30. Subwatersheds surveyed by Early Detection teams in 2008.

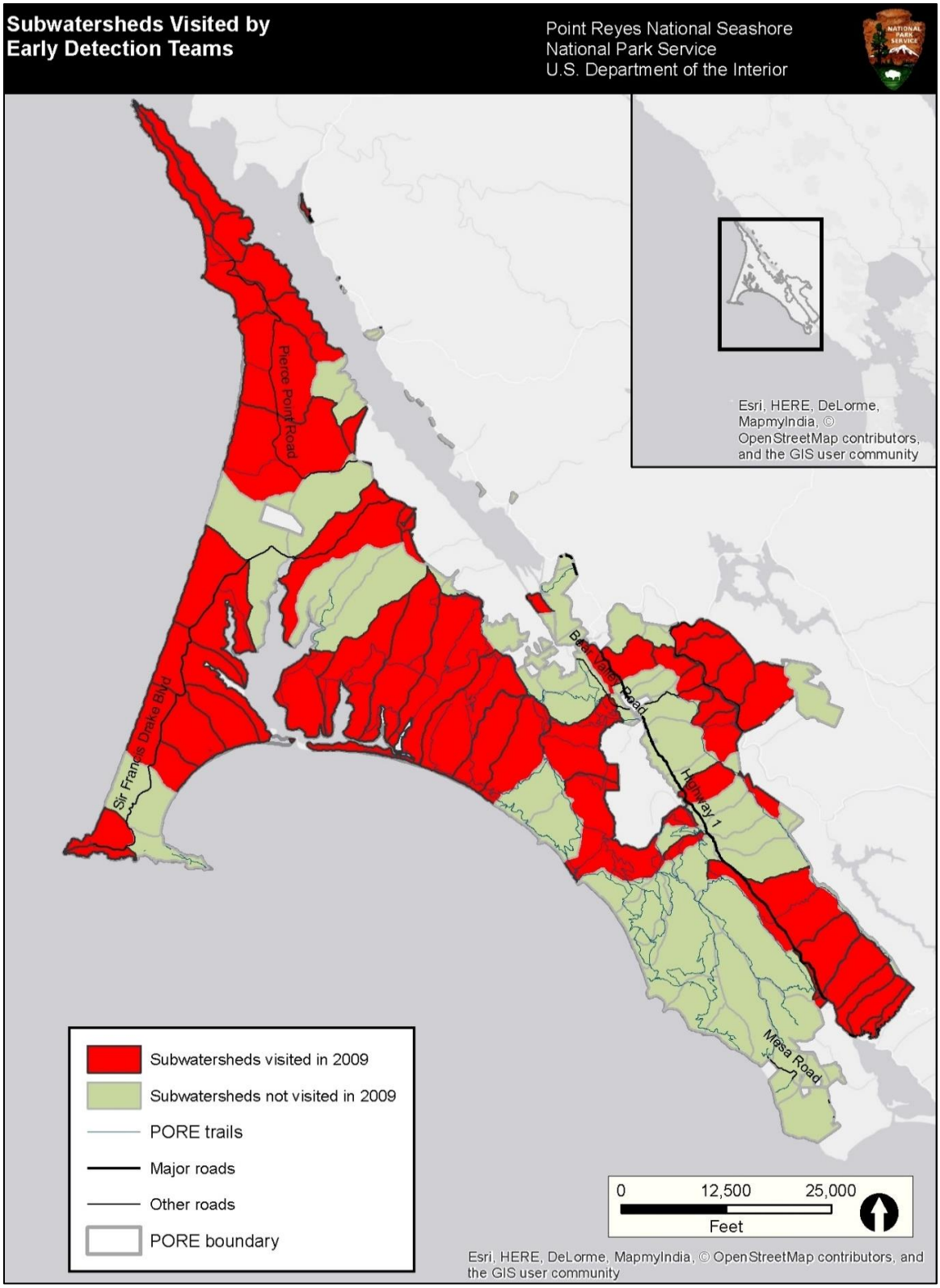


Figure 4.6.31. Subwatersheds surveyed by Early Detection teams in 2009.

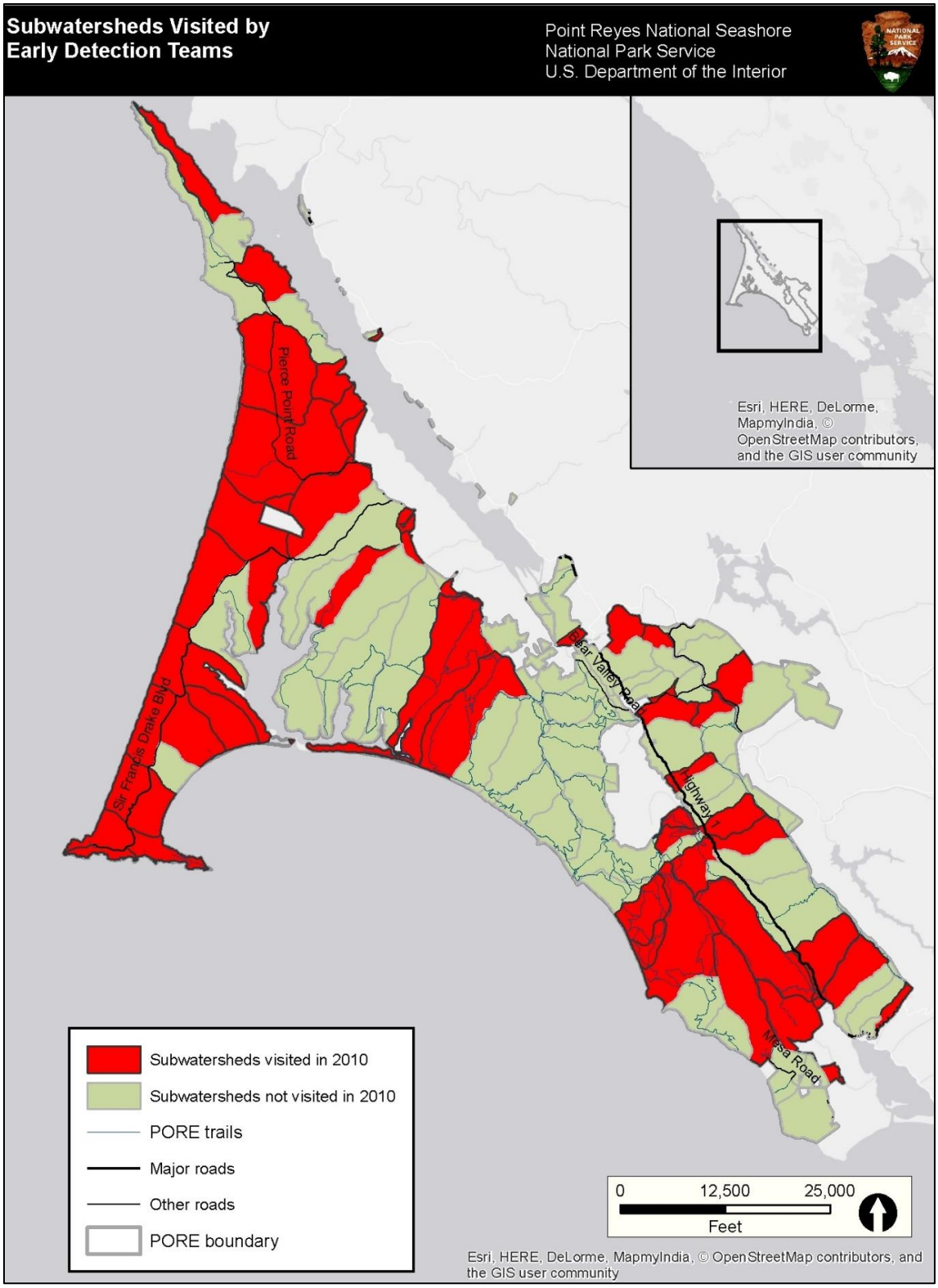


Figure 4.6.32. Subwatersheds surveyed by Early Detection teams in 2010.

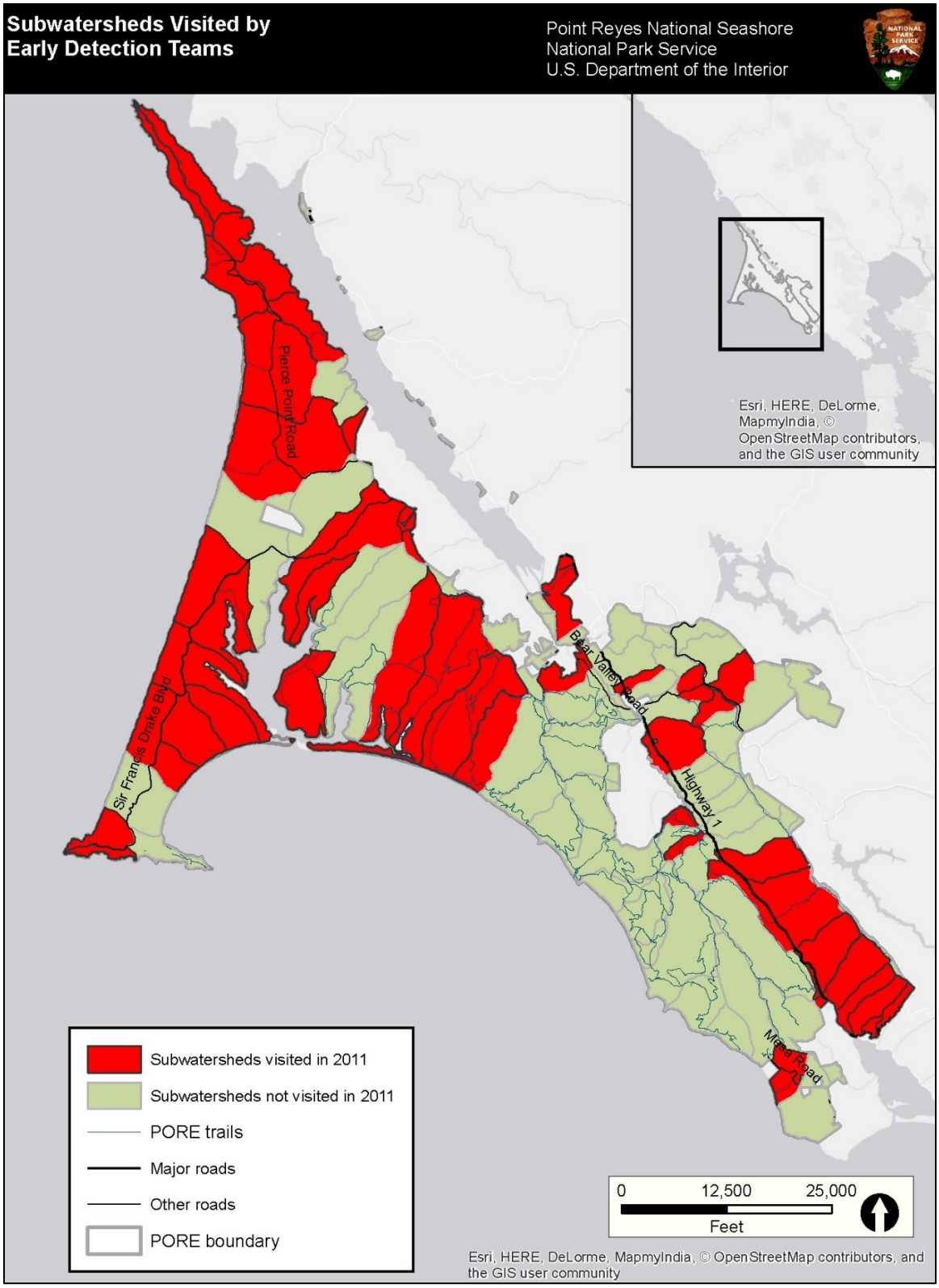


Figure 4.6.33. Subwatersheds surveyed by Early Detection teams in 2011.

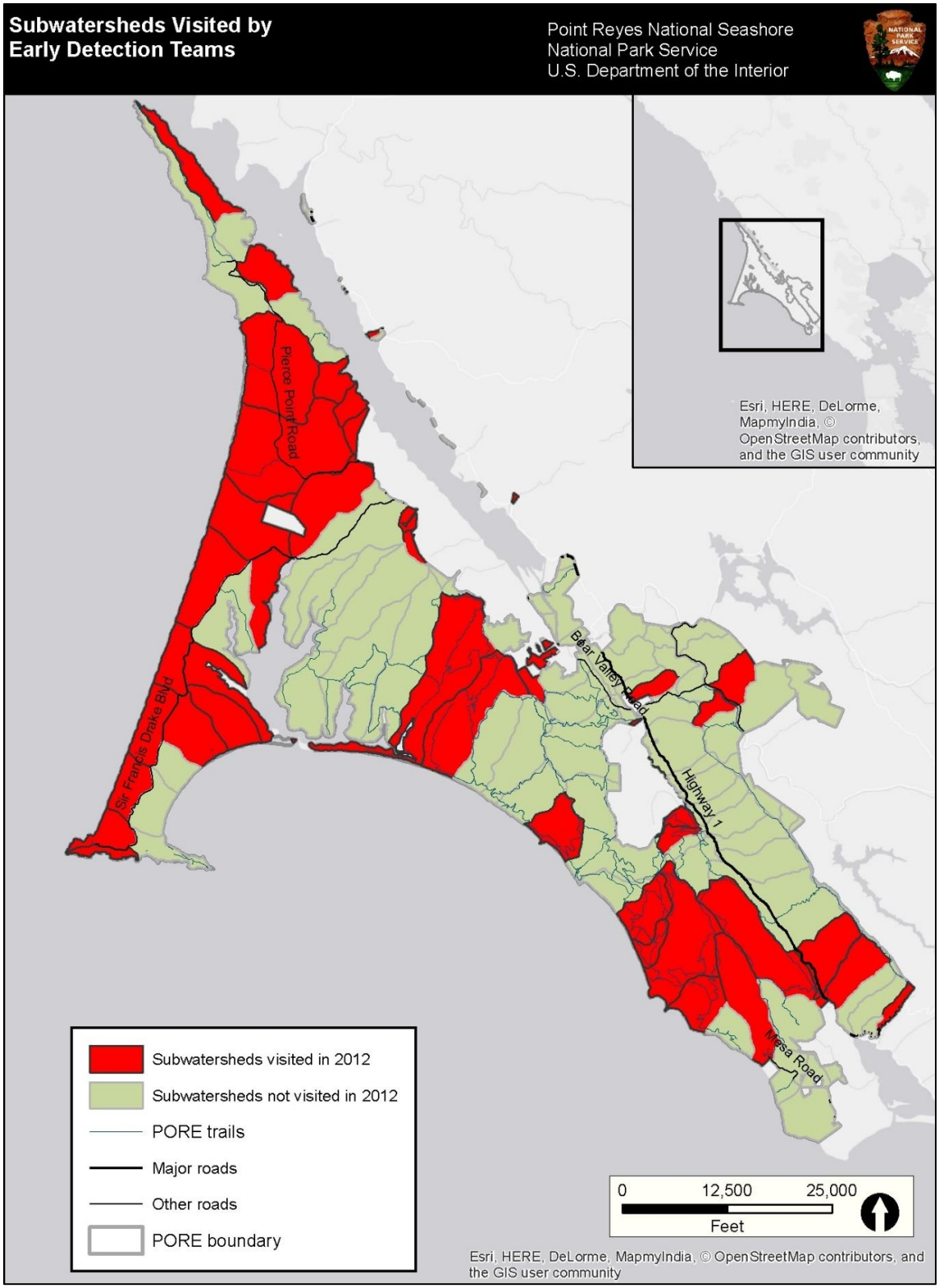


Figure 4.6.34. Subwatersheds surveyed by Early Detection teams in 2012.

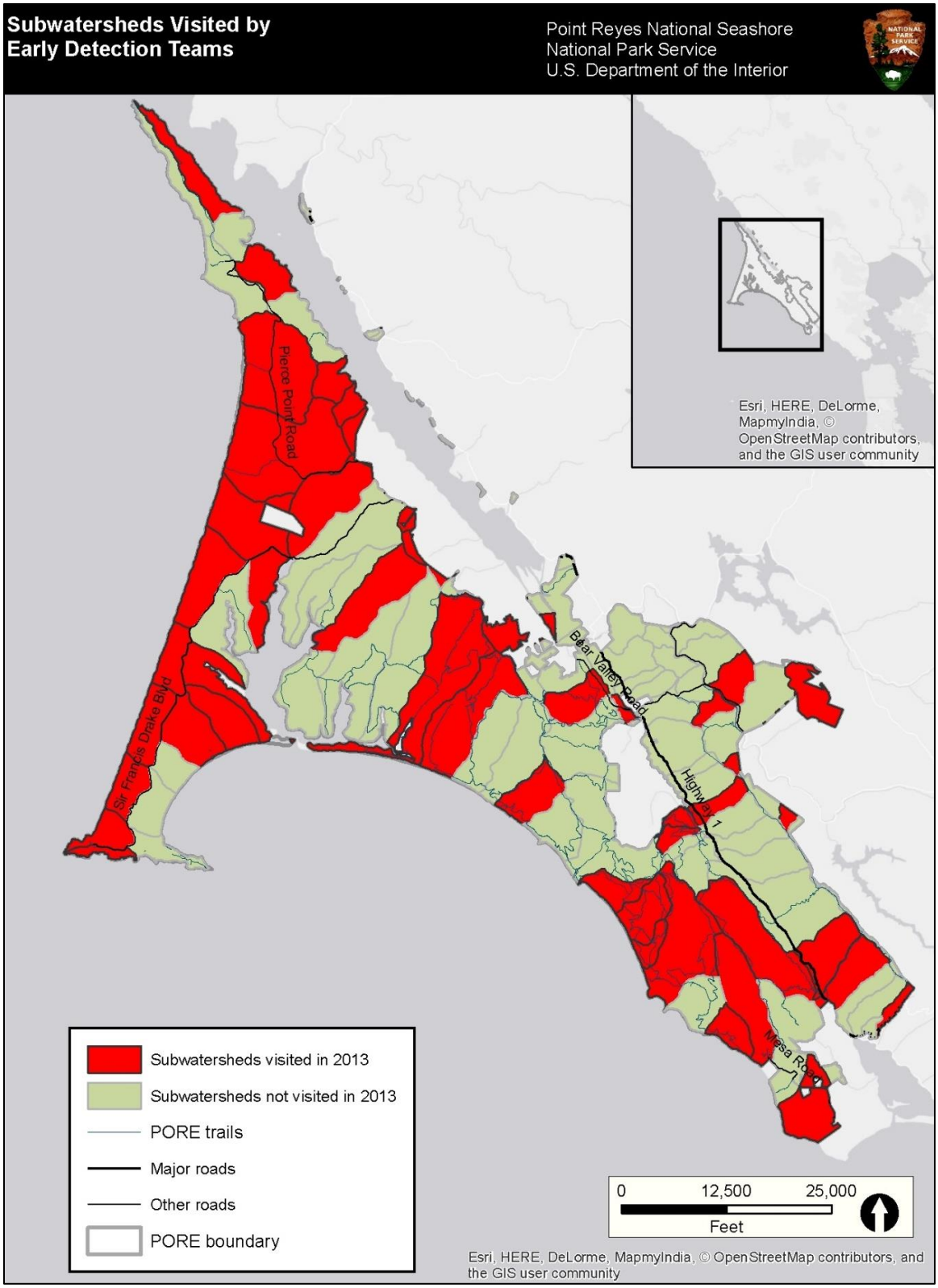


Figure 4.6.35. Subwatersheds surveyed by Early Detection teams in 2013.

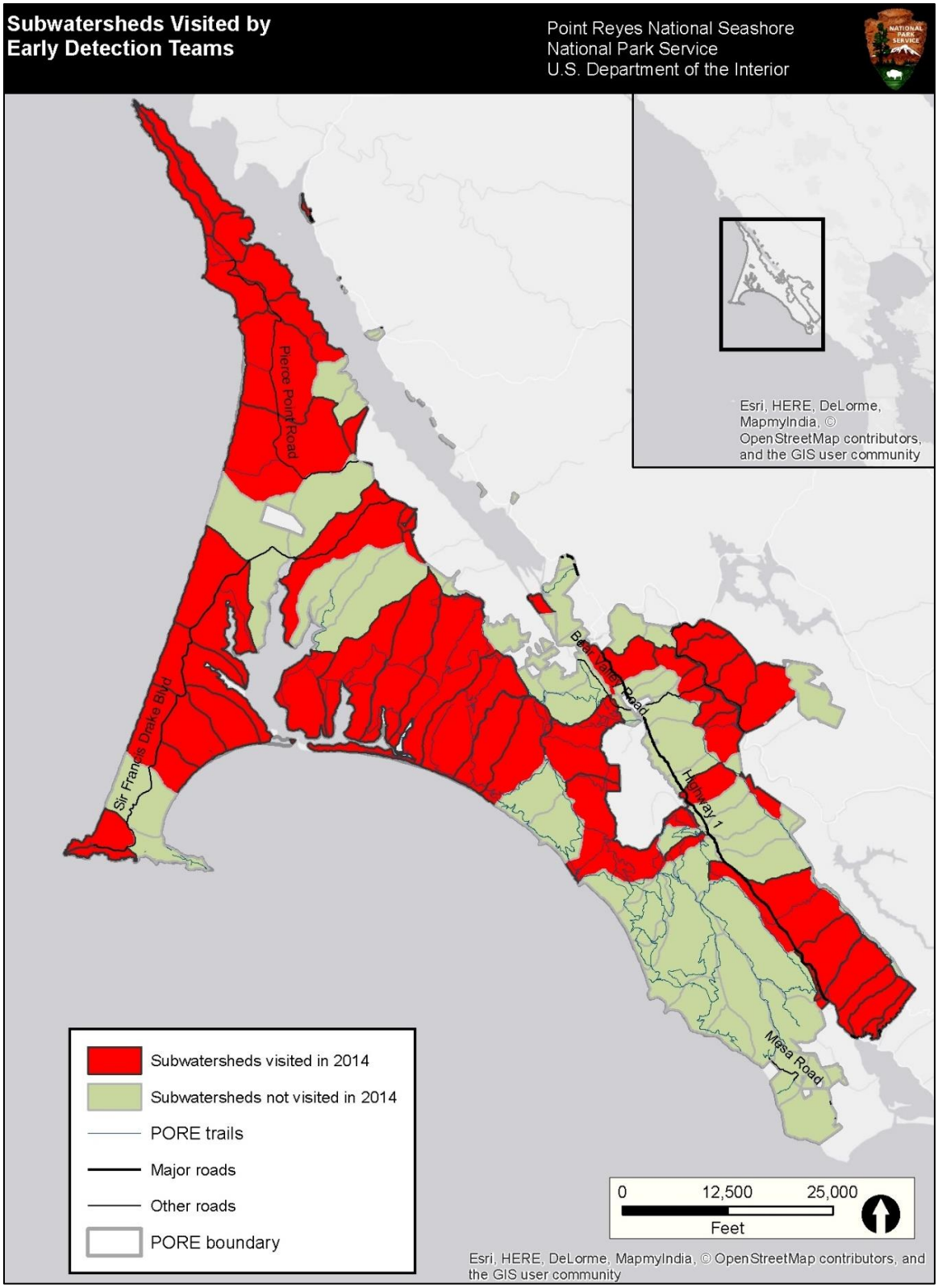


Figure 4.6.36. Subwatersheds surveyed by Early Detection teams in 2014.

Invasive plant surveys have the greatest utility to park management when coupled with a rapid response to new plant invasions. Invasive plant management teams in each of the SFAN parks remove high priority invasive plant species and record the area treated, type of control method, and how much staff and/or volunteer time was spent controlling weeds. Note that this report includes only treatments conducted by the SFAN Early Detection program. PORE also has a dedicated weed control program, the Habitat Restoration Program. However, additional treatment data was not available for inclusion in this report. Figure 4.6.37 shows all the recorded SFAN Early Detection program treatment areas for the high priority invasive plant species from 2008 to 2014. These treatments vary in size and are widely distributed throughout PORE. From 2008 to 2014, 195 treatments were documented in the Wilderness Zone, 182 in the Natural Zone, and only 53 in the Pastoral Zone. Although the Wilderness Zone had the highest number of invasive plant population treatments during this time period, the Natural Zone had the largest total area treated. Nearly all of the area treated for invasive plant species (>99%) was located within the Natural Zone. The total area treated by management zone ranged from 34.1 acres in the Natural Zone to 0.03 acres in the Pastoral Zone.

The number of invasive plant populations treated by Early Detection teams increased greatly from 2008 to 2014 (Table 4.6.3). Throughout this study period a total of 350 invasive plant treatments were documented. The highest number of treatments, 195, were performed in 2014. Figure 4.6.38 to Figure 4.6.43 show the locations of invasive plant treatments by watershed from 2008 to 2014. More than 70% of the treatments conducted from 2008 to 2014 were located within watershed PORE5.

Table 4.6.3. Number of invasive plant treatments performed by Early Detection teams in Point Reyes National Seashore watersheds from 2008 to 2014.

Watershed	2008	2009	2010	2011	2012	2013	2014	Watershed Total
PORE1	0	0	0	6	0	2	27	35
PORE3	3	2	9	0	0	5	9	28
PORE4	1	1	0	2	5	4	14	27
PORE5	2	2	2	17	6	59	137	225
PORE6	0	1	2	7	2	8	7	27
PORE7	0	0	1	2	3	1	1	8
Annual Total	6	6	14	34	16	79	195	350

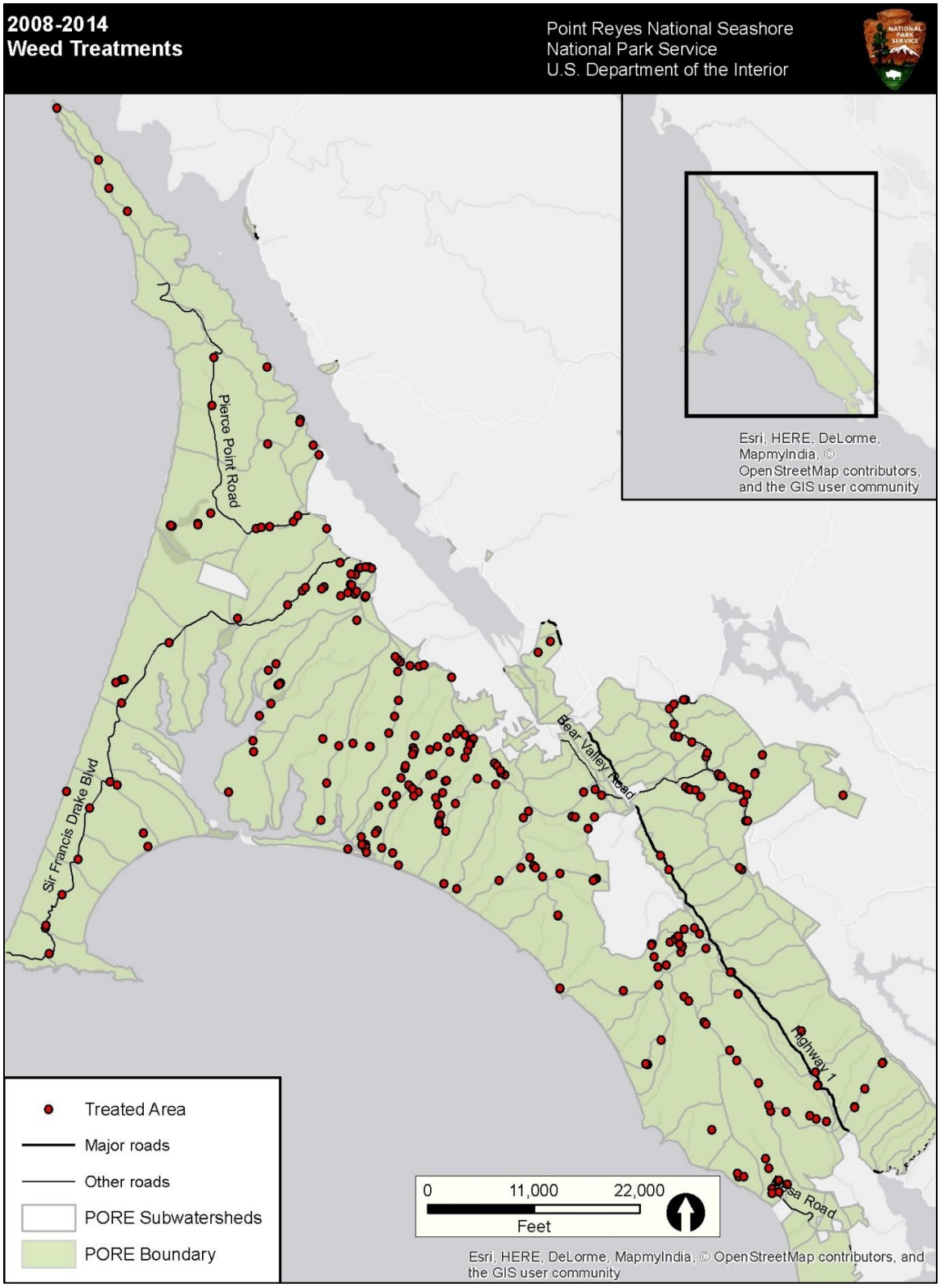


Figure 4.6.37. Early Detection team invasive plant treatment locations in PORE from 2008 to 2014.

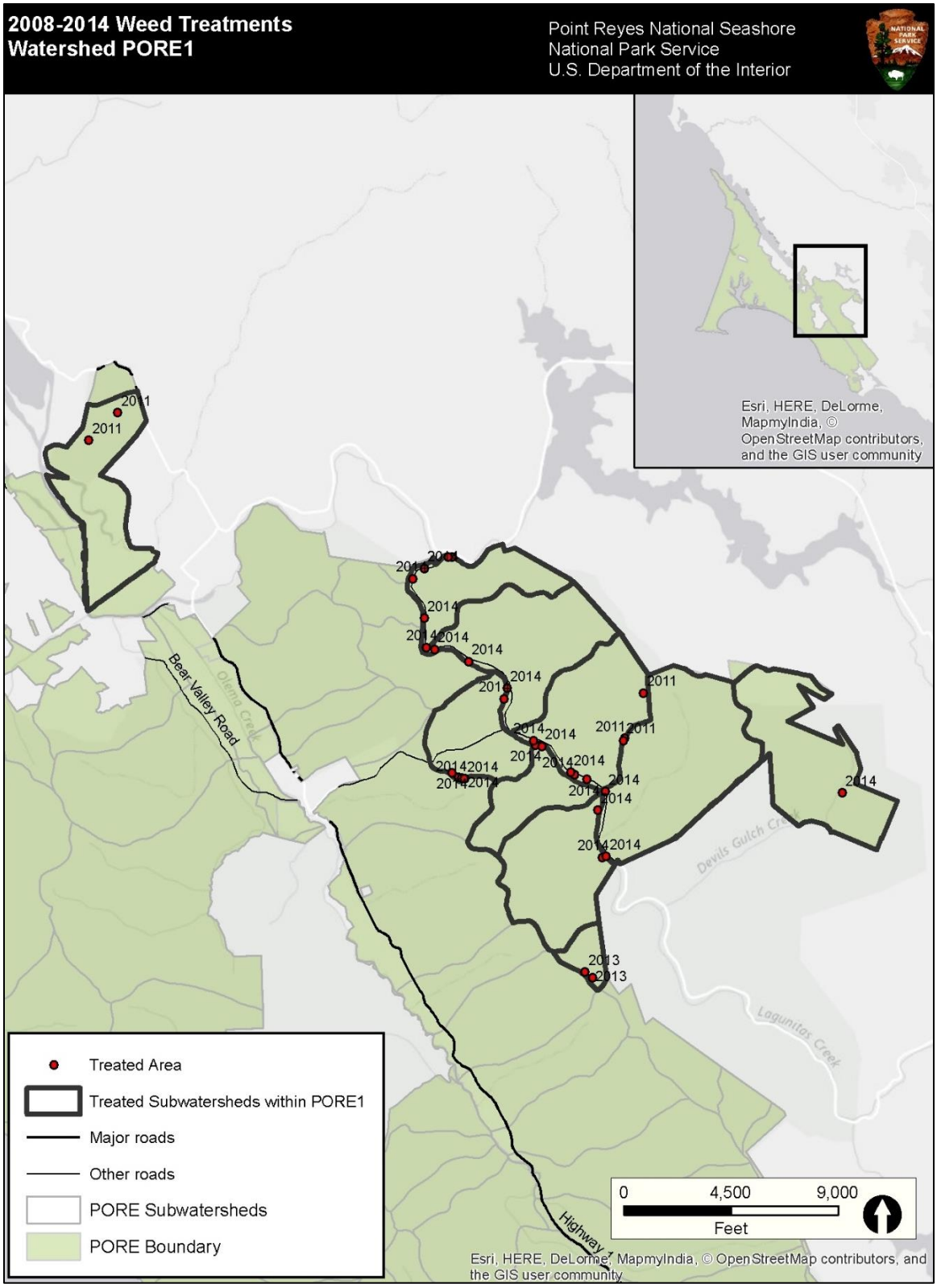


Figure 4.6.38. Early Detection team invasive plant treatment locations in watershed PORE1 from 2008 to 2014. Labels identify the treatment year.

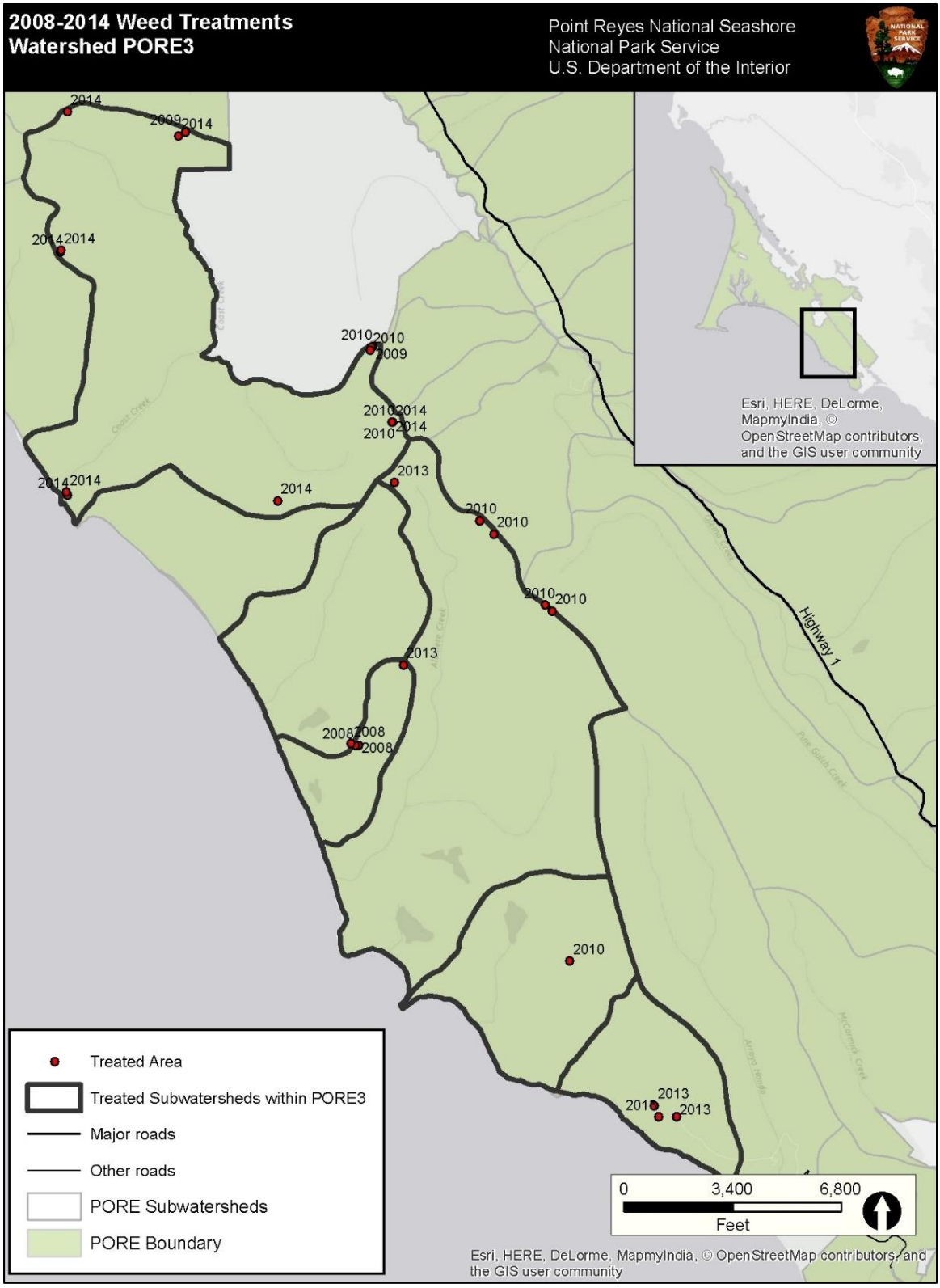


Figure 4.6.39. Early Detection team invasive plant treatment locations in watershed PORE3 from 2008 to 2014. Labels identify the treatment year.

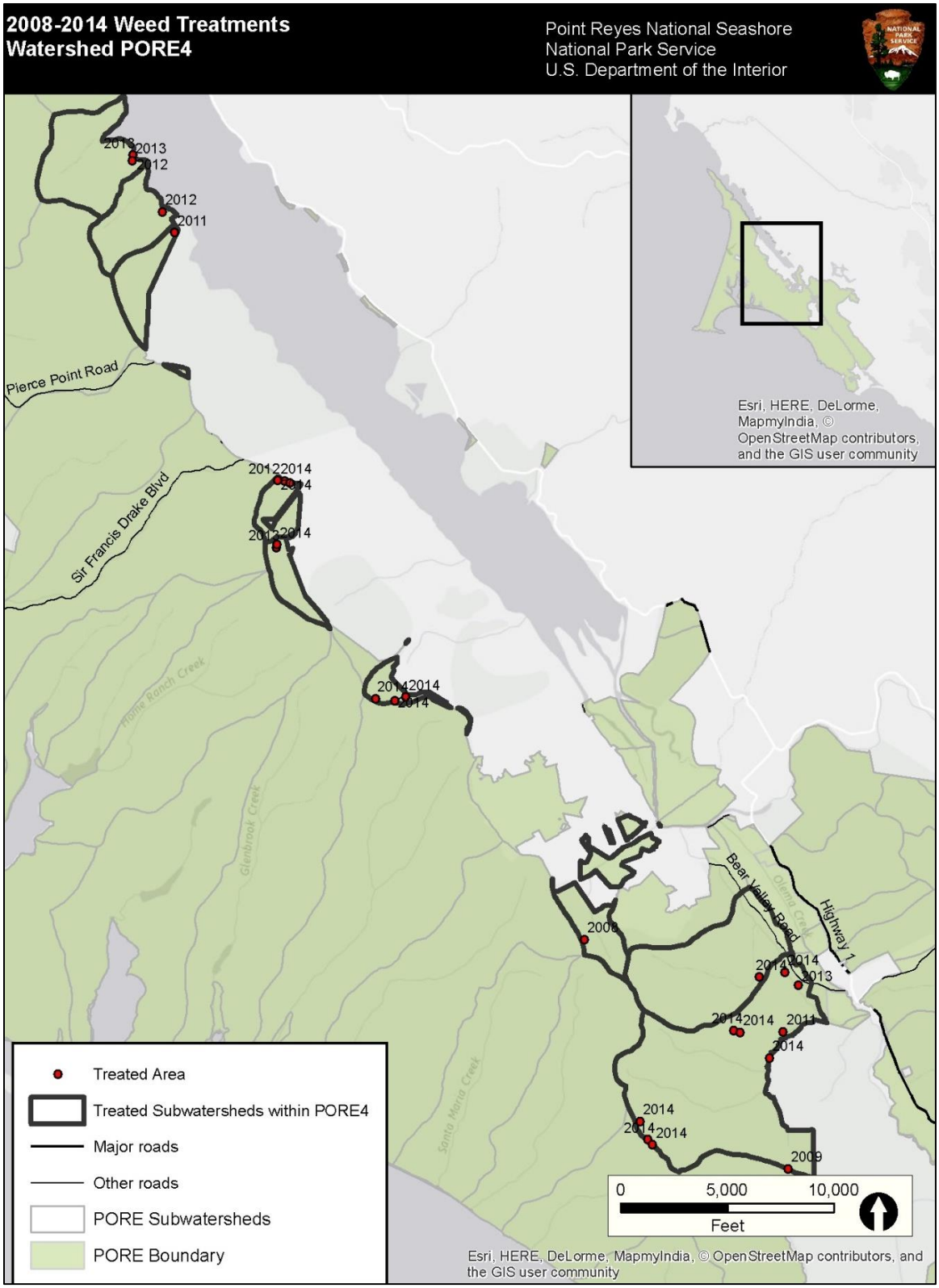


Figure 4.6.40. Early Detection team invasive plant treatment locations in watershed PORE4 from 2008 to 2014. Labels identify the treatment year.

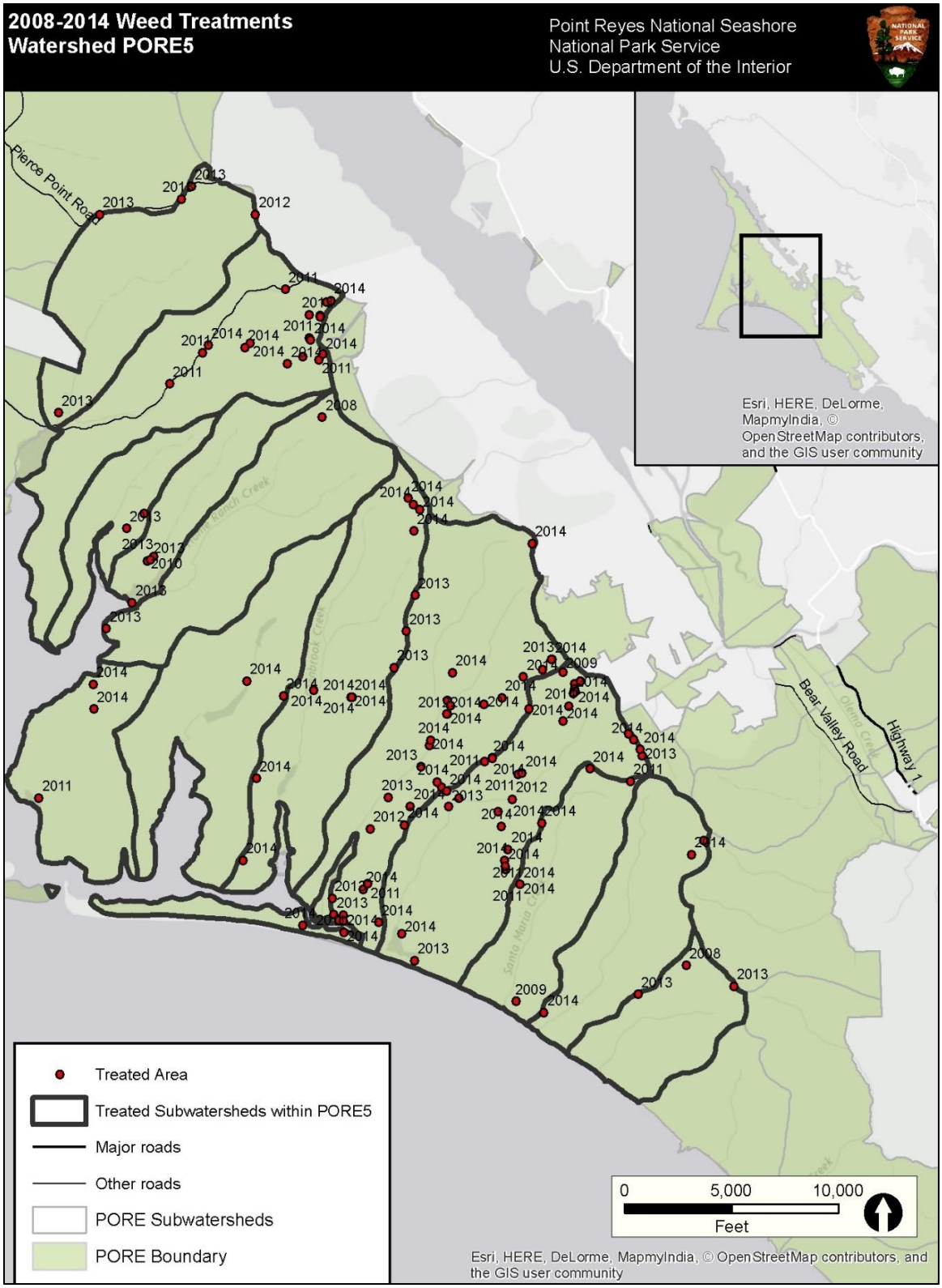


Figure 4.6.41. Early Detection team invasive plant treatment locations in watershed PORE5 from 2008 to 2014. Labels identify the treatment year.

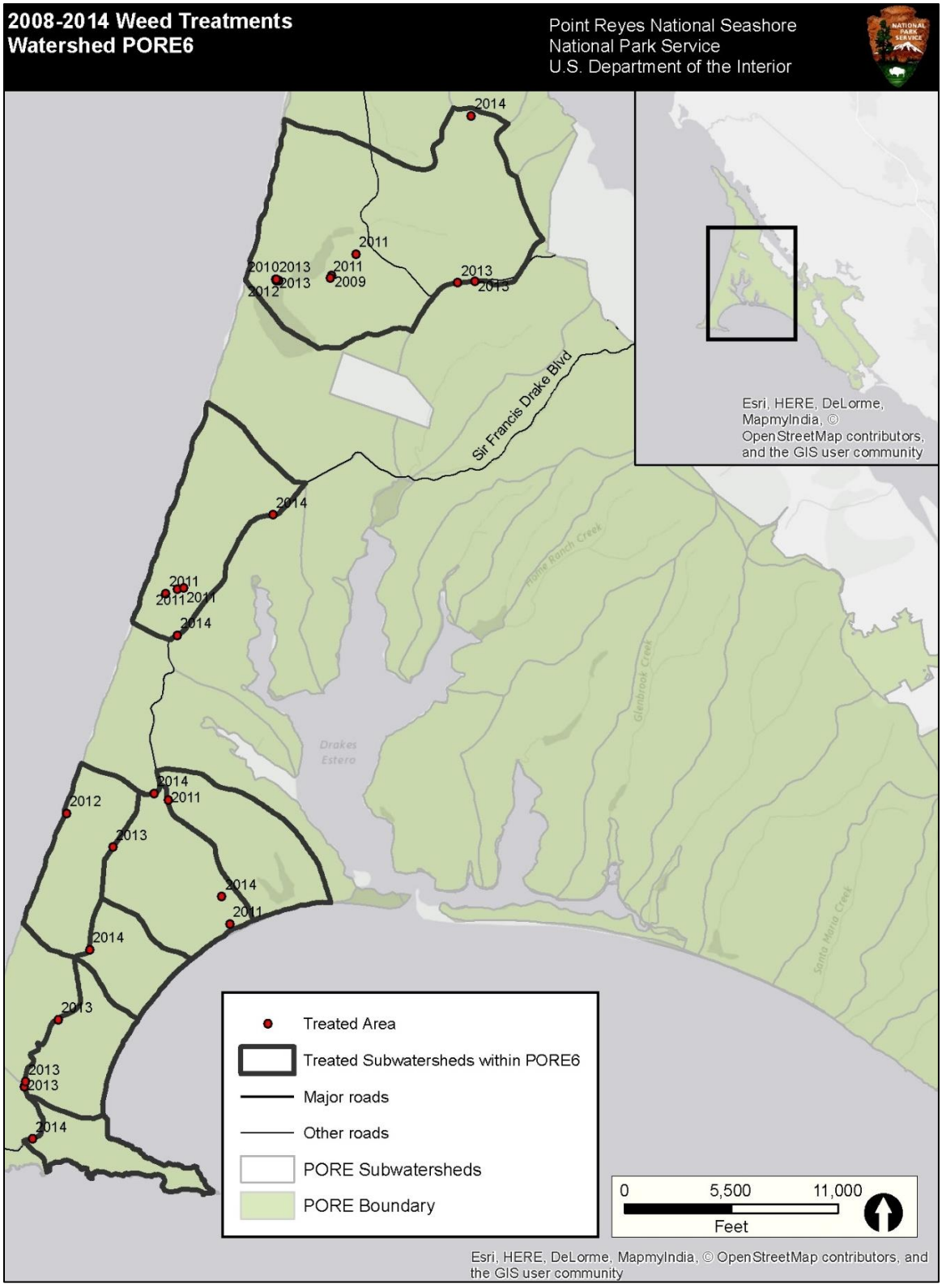


Figure 4.6.42. Early Detection team invasive plant treatment locations in watershed PORE6 from 2008 to 2014. Labels identify the treatment year.

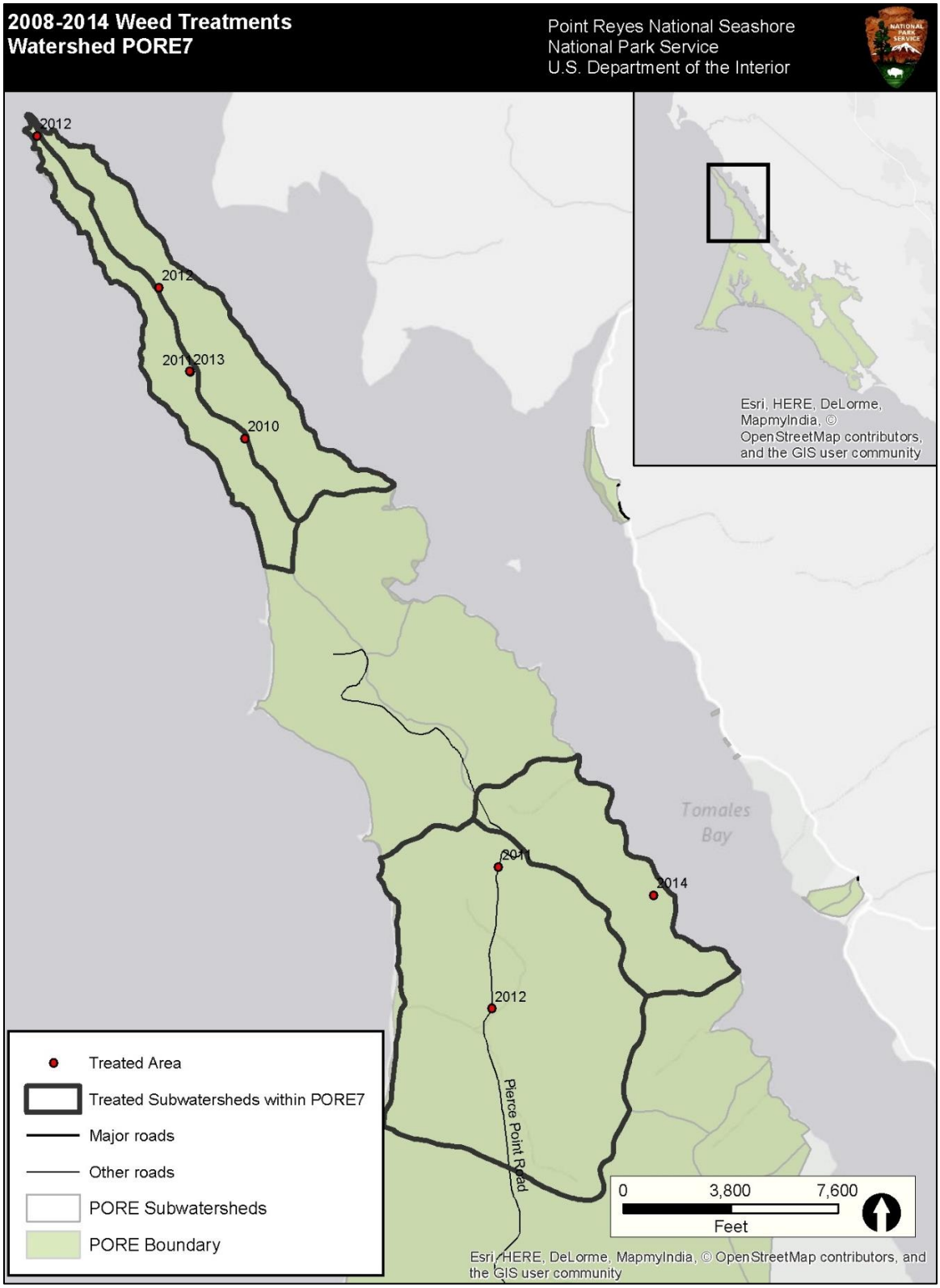


Figure 4.6.43. Early Detection team invasive plant treatment locations in watershed PORE7 from 2008 to 2014. Labels identify the treatment year.

How does survey effort impact the number of invasive species detected per subwatershed each year?
To investigate the impact of survey effort on the number of species detected each year, we generated species discovery curves for each of the 19 subwatersheds in PORE that received at least five consecutive annual surveys by Early Detection teams (Figure 4.6.44a, Figure 4.6.44b, Figure 4.6.44c). 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 4.6.45). The number of new invasive species occurrences within these subwatersheds was similar in all studied years. These species discovery curves suggest the importance of frequent surveys and relatively rapid changes in the invasive species populations by subwatershed. For instance, in these 19 subwatersheds, an average of approximately 36 new occurrences of an invasive plant species were recorded annually from 2008 to 2014 (Figure 4.6.45). In some subwatersheds, new species detections are approaching an asymptote which suggests that new species are not arriving in these subwatersheds. However, for the majority of subwatersheds and the entire dataset combined by year, the annual increase in invasive species has not leveled off.

In 2008, 13 of the 19 subwatersheds in GOGA that received at least five consecutive annual surveys by Early Detection teams had fewer than five documented invasive species present. By 2014, only one of these subwatersheds had fewer than five recorded invasive plant species. In addition, nine of these subwatersheds contained 15 or more invasive plant species by 2014. Subwatershed PORE1-45 had the greatest increase in the number of invasive species over the study period with an additional 29 invasive species recorded in 2014. The PORE subwatershed with the highest recorded number of invasive plants recorded by 2014 was PORE5-5 which had more than 50 invasive plant species documented between 2008 and 2014.

The species discovery curves suggest that the number of invasive species increased in all studied subwatersheds from 2008 to 2014. However, these numbers may be inflated by annual additions to the list of target species. On average, 2.8 species were added to the PORE target species list each year (14 species total). In addition, observer skill has increased over the course of program implementation due to improvements in institutional knowledge and plant identification tools. Increased observer skill may also have contributed to the increase in species identified over time.

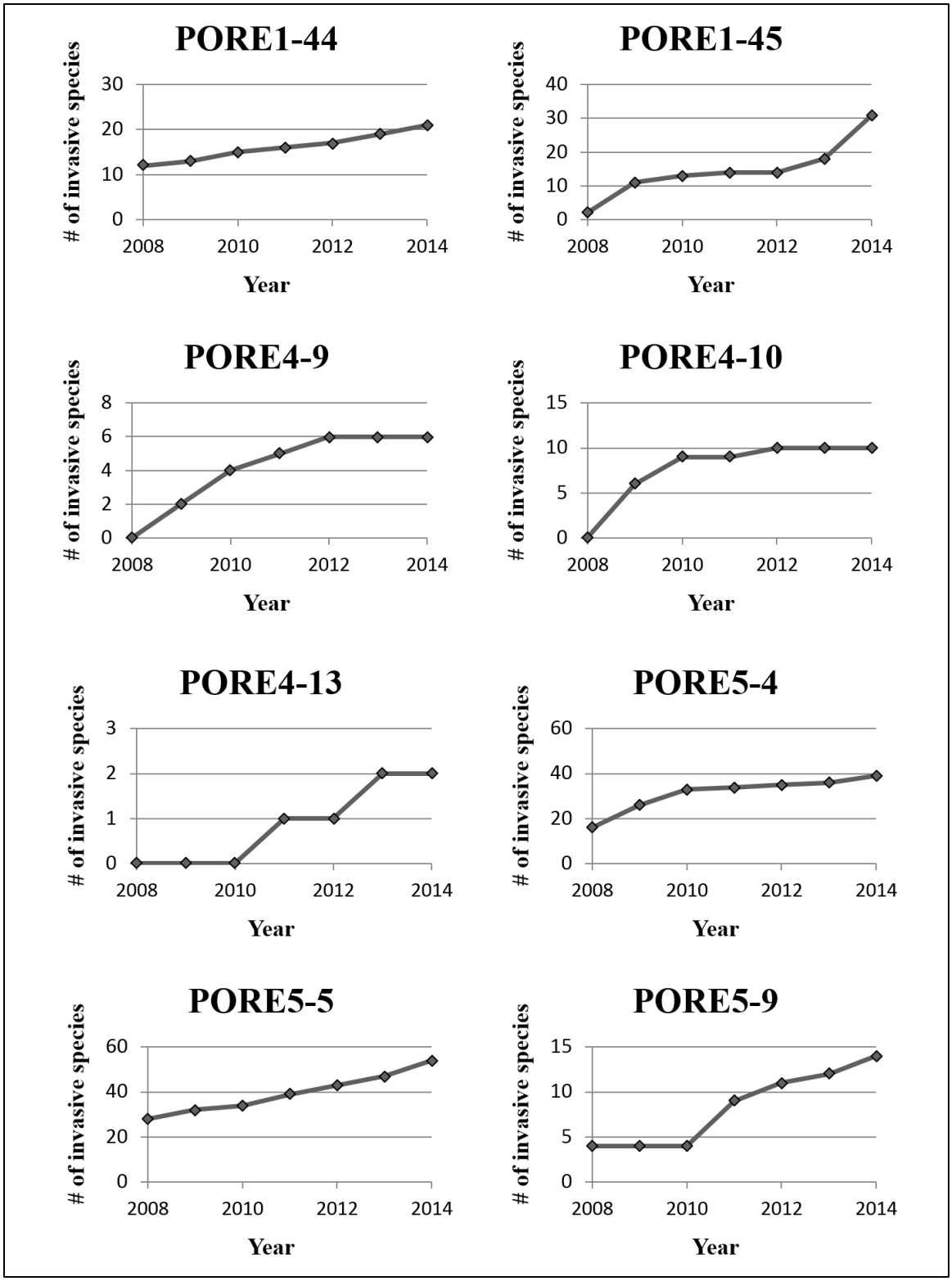


Figure 4.6.44a. Species discovery curves for each subwatershed with at least five consecutive years of annual surveys by Early Detection teams (2008 to 2014). Data presented for each year represents the cumulative number of invasive species documented in each subwatershed.

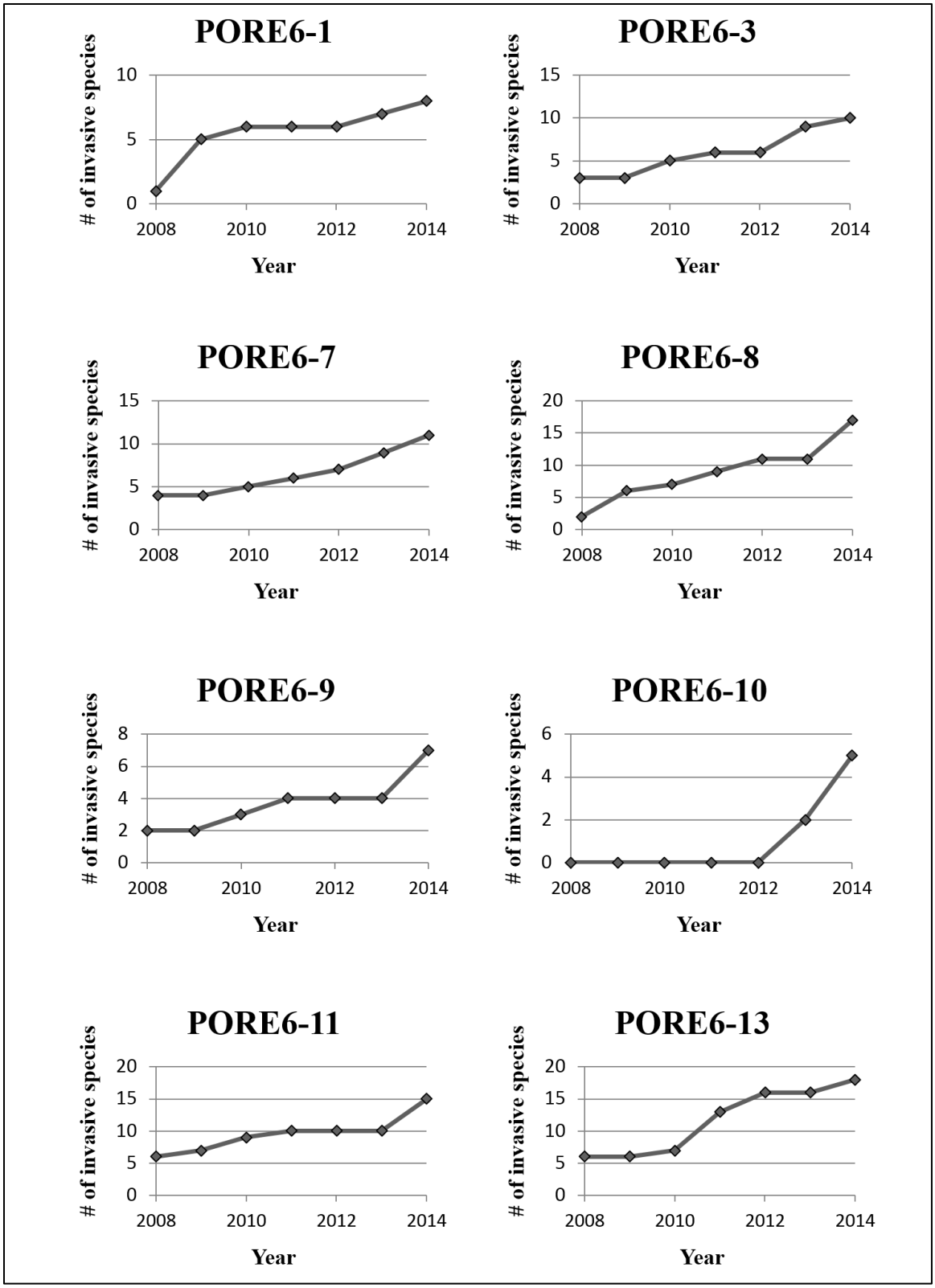


Figure 4.6.44b. Species discovery curves for each subwatershed with at least five consecutive years of annual surveys by Early Detection teams (2008 to 2014). Data presented for each year represents the cumulative number of invasive species documented in each subwatershed.

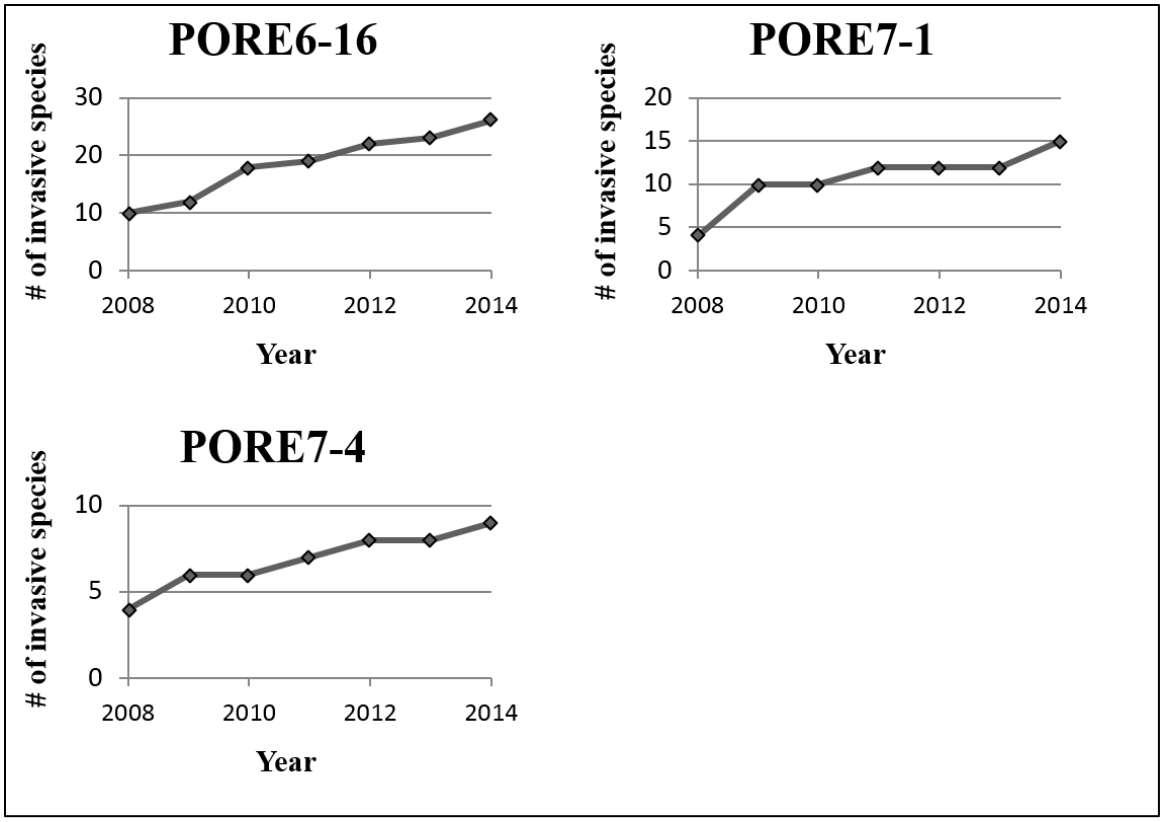


Figure 4.6.44c. Species discovery curves for each subwatershed with at least five consecutive years of annual surveys by Early Detection teams (2008 to 2014). Data presented for each year represents the cumulative number of invasive species documented in each subwatershed.

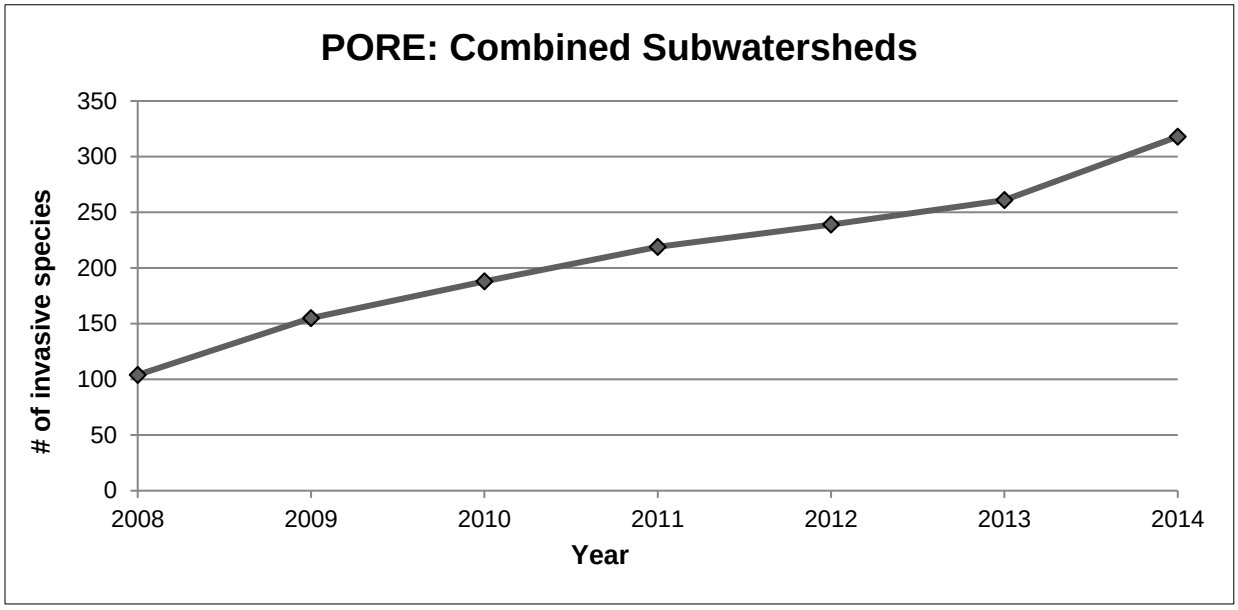


Figure 4.6.45. Sum of the total number of species detected in all 19 PORE subwatersheds with at least five consecutive years of annual surveys from 2008 to 2014.

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). 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 PORE, disturbances commonly associated with non-native plant invasions into nearby natural areas include land-uses such as settlement, grazing, pasturing, and the presence of roads and trails.



A pasture in Point Reyes invaded by *Carthamus lanatus*. NPS photo.

Fragmentation of natural habitats has also been associated with enhanced invasibility in ecological communities (Theoharides and Dukes 2007, Malavasi et al. 2014). Many areas in PORE 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. Non-native plants are not known to have directly influenced pest and pathogen issues in PORE.

Level of confidence in assessment

Medium While the Early Detection protocol provides a relatively comprehensive sampling program, the data are too temporally limited for many indicators of invasive plant condition. Only six years of full protocol-level surveys have been completed in PORE. Due to the survey cycle (five years) only one comprehensive survey of all roads and trails has been completed. Only 19 high priority subwatersheds have been surveyed five or more times. The data provide sufficient information for general assessment of some indicators, such as the number of invasive species present. However, not enough data has been gathered for a sufficient time period to determine any trends in condition. In addition, indicators such as the number of new introductions per year may be impacted by seasonal changes in species' detectability and by differences in observer skill levels.

Gaps in understanding

The Early Detection protocol for invasive plant monitoring in PORE appears to provide a consistent and efficient means of tracking the invasive plant species present in PORE, the number of invasive plant occurrences, and most new invasive species introductions. With additional years of monitoring, this data should provide information on some trends in these indicators. However, the data are limited for other important management objectives such as assessing the rate of spatial spread for high priority invasive species. For instance, we did not have absence data available beyond road and trail corridors to definitively indicate the areas with no invasive plant species present. Further, although occurrence data is useful for assessing some indicators of invasive plant populations, the total area or patch size of invasive species is a better means of assessing spatial spread and tracking temporal changes in the area invaded.

The ability to assess the efficacy of invasive plant treatments could be improved with more in-depth data on treatments, including the species treated, population size treated, and person hours involved.

Although monitoring along roads and trails may be an efficient method of detecting new invasive species, it does limit the data’s span of inference with regard to park-wide assessments of invasive plant species. For instance, because some invasive species are more likely than others to occur along roads and trails it is difficult to infer from this data alone whether the most commonly recorded species are actually the most abundant park-wide or simply the most abundant along roads and trails. Further, because surveys are limited to roads and trails, this data cannot address the important question: are invasive species spreading from roads and trails into sensitive or critical park habitat? Integrating data collected from more remote areas could help build on the knowledge gained from the existing survey protocol and enhance the overall assessment of invasive plants in PORE.

Condition Summary

Point Reyes National Seashore has a high total number of invasive plant species and new introductions recorded from 2011 to 2014. Based on these indicators, our assessment suggests that invasive plants in GOGA should be considered a significant concern (red). The condition of each individual indicator was ranked as either moderate or significant concern for each management zone

(Figure 4.6.46). 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. Confidence in existing data varies by indicator and is limited by the relatively short time span of Early Detection surveys (Table 4.6.4).

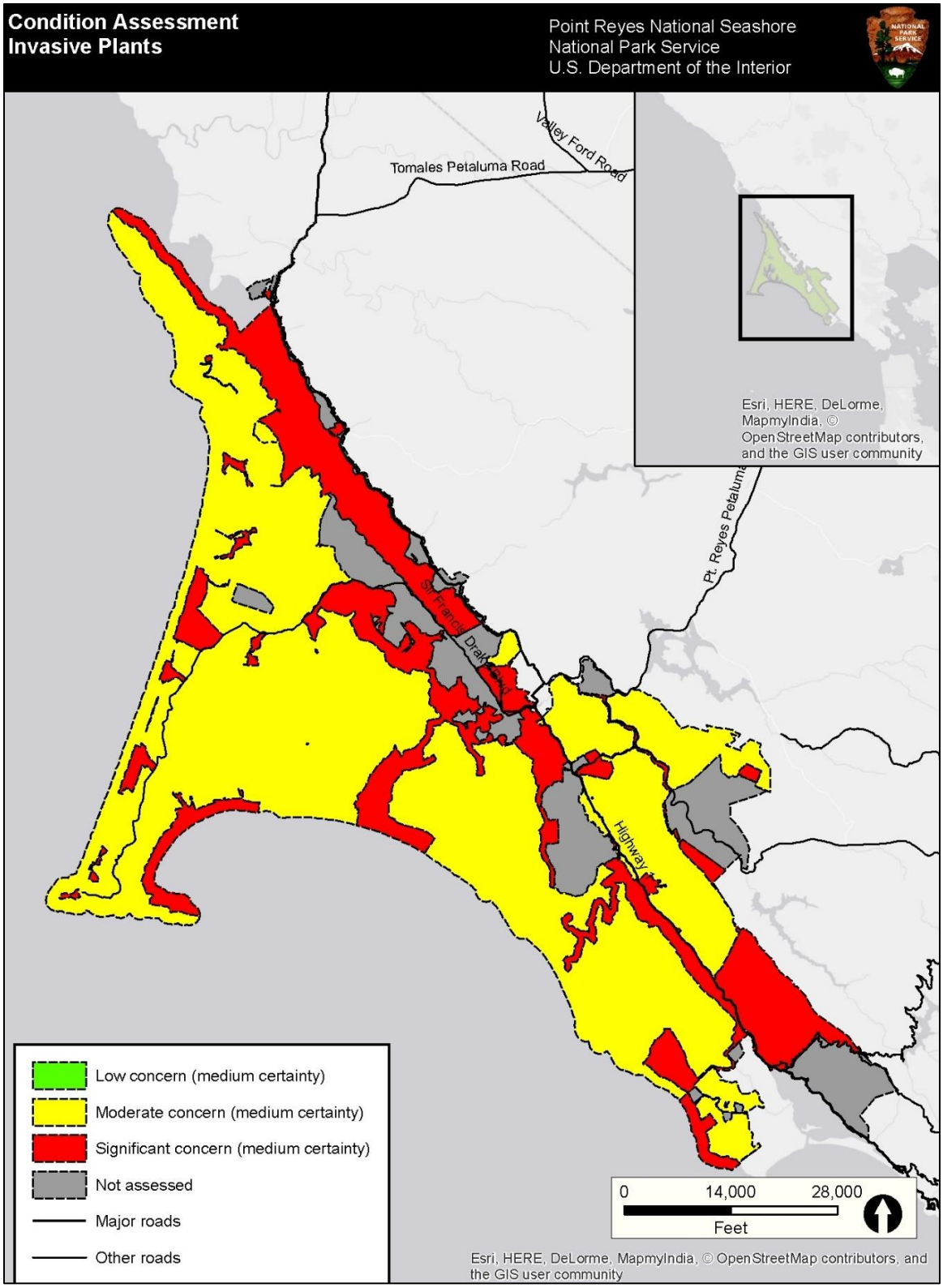
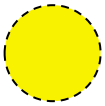
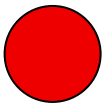
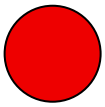


Figure 4.6.46. Assessment of threat posed by invasive plants by management zone. Color indicates condition: red = significant concern; yellow = moderate concern; green = low concern. The confidence level for this assessment was *medium*.

Table 4.6.4. Resource condition summary for invasive plants at Point Reyes National Seashore.

Indicators of Condition	Specific Measures	Condition Status	Rationale
Propagule pressure/invasibility	Number of new introductions		5 additional invasive species documented since 2011
Potential for spread	Number of invasive species		More than 100 invasive plant species documented
Overall condition and trend of invasive plants			–

4.6.4. Information Sources

Sources of Expertise

- Daniel George, Program Manager, San Francisco Bay Area Network Inventory and Monitoring Program
- Sarah Wakamiya, Data Manager/Ecologist, San Francisco Bay Area Network Inventory and Monitoring Program
- Eric Wrubel, Network Botanist, San Francisco Bay Area Network Inventory and Monitoring Program

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4.7. Rare Plants



Managed rare plant populations extant; introduction efforts generally not successful; USFWS Recovery Criteria generally in progress or completed. Data gaps warrant moderate confidence in findings and fail to support trend analysis.

4.7.1. 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, is 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 populations in California (Falk and Holsinger 1991). The conservation of public lands by the National Park Service, including the Point Reyes National Seashore (PORE), protects landscapes and their associated rare flora, while providing for management of those species.

Four rare plant taxa found within PORE-managed lands were selected for a review of status and distribution: Beach layia (*Layia carnosa*), Sonoma spineflower (*Chorizanthe valida*), Tidestrom's lupine (*Lupinus tidestromii*), and Sonoma alopecurus (*Alopecurus aequalis* var. *sonomensis*). Additional rare plant taxa were selected for a more general geospatial analysis of habitat and distribution. These four species are of interest due to the small size of their populations as well as the unknown effects that grazing, climate change, and invasive plant species may have on their abundance and distribution. The species of interest include small populations and restricted distributions, which makes them more vulnerable to extinction from the effects of inbreeding and reduced fecundity (Keller 2002, Kery 2000). Two of the four species, the Sonoma spineflower and Sonoma alopecurus, occur in cattle grazed landscapes where grazing seems to be beneficial. However, the effects of grazing management practices should be monitored to ensure that the grazing practices benefit or have no negative effect on the species. All four species are being outcompeted by native and/or non-native invasive plants. This is particularly serious in the case of Tidestrom's lupine, where the invasive species not only outcompete the lupine for resources, but also shelter small mammalian predators which consume the lupine's seeds both pre and post dispersal.

In the future, climate change will likely alter the distribution and quality of suitable habitat for all four species. Overall, California is likely to experience an increase of 1.5 to 4.5°C, on average

relatively stable precipitation amounts, loss of snow pack, increased flood potential, and increased warming in the summer as compared to winter (Cayan et al. 2008b, Dettinger 2011). Other studies indicate in significant increase in precipitation due to extension of the Pacific jet stream (Neelin et al. 2013).

It is not certain how climate change will specifically affect California's coastal landscapes. Fog cover has declined historically, increasing drought stress for plant species dependent on fog (Johnstone and Dawson 2010). Coastal areas have also been experiencing an average decrease in temperature attributed to increased cross-coastal winds, but an increase in extreme high daytime temperatures (Potter 2014). This decrease in average temperature may continue with climate change due to increases in inland temperature (Snyder 2008). One predictive study indicates that coastal upwelling will increase, and fog banks may increase (Bakun 1990). In contrast, another predictive study indicates that upwelling events will occur less frequently, but events will last longer and be more intense (Iles et al 2012). A study of Mediterranean systems showed high confidence that PORE would maintain a Mediterranean climate within a range of projected emission and climate scenarios (Klausmeyer and Shaw 2009). However, the overall temperature, precipitation, and solar radiation will likely change at least seasonally (Ryan and Parsons 2014a).

Another important aspect of climate change is the expected sea level rise due to loss of sea and continental ice sheets. 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. 2008a). These changes are particularly important for coastal species that occur within future impact zones.

The majority of taxa endemic to the California Floristic Province are expected to experience reductions in their current range in the next century. Projected climate change scenarios vary in terms of the anthropogenic carbon emissions, varying sensitivities of climate variable to emissions, and dispersal of plant taxa. In a variety of these scenarios, Loarie et al. found that endemic plant diversity remained relatively high along the California coast, particularly surrounding the San Francisco Bay Area (Loarie et al. 2008). While diversity may be high in the region of PORE. Ackerly et al. (2010) predicted that coastal Bay Area projected areas will experience increasing climate diversity by 2100. Tolerances of current species currently located within California protected areas may not overlap with the climate parameters present in the future. Bay Area coastal areas may become refuges for cool-temperature species due to increased migration of species along an east-west temperature gradient (Riordan and Rundel 2014, Ackerly et al. 2010). However, PORE is also expected to experience among the greatest temperature variation seen in the Bay Area (Ackerly et al. 2010).

Given the highly variable outcomes described here, it is important to consider that climate and species distribution models include many sources of error, such as algorithms of species distribution, quality of input data, scale of data and output, and model structure (Wiens 2009).

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 PORE.

1. What is the current status and distribution of rare species of interest within PORE?

2. What significant stressors are currently affecting these species?
3. What habitats or regions within PORE have a high incidence of endangered and threatened plants of interest? How are these areas distributed?
4. Are the areas of greatest known rare species occurrences within certain habitat types that may have a larger distribution within PORE?

The first two Critical Questions are addressed on a species-specific basis in Sections 4.7.3 through 4.7.6. The third and fourth Critical Questions are addressed with maps and associated spatial data in Section 4.7.7 (Figure 4.7.1, Figure 4.7.2 and Figure 4.7.3).

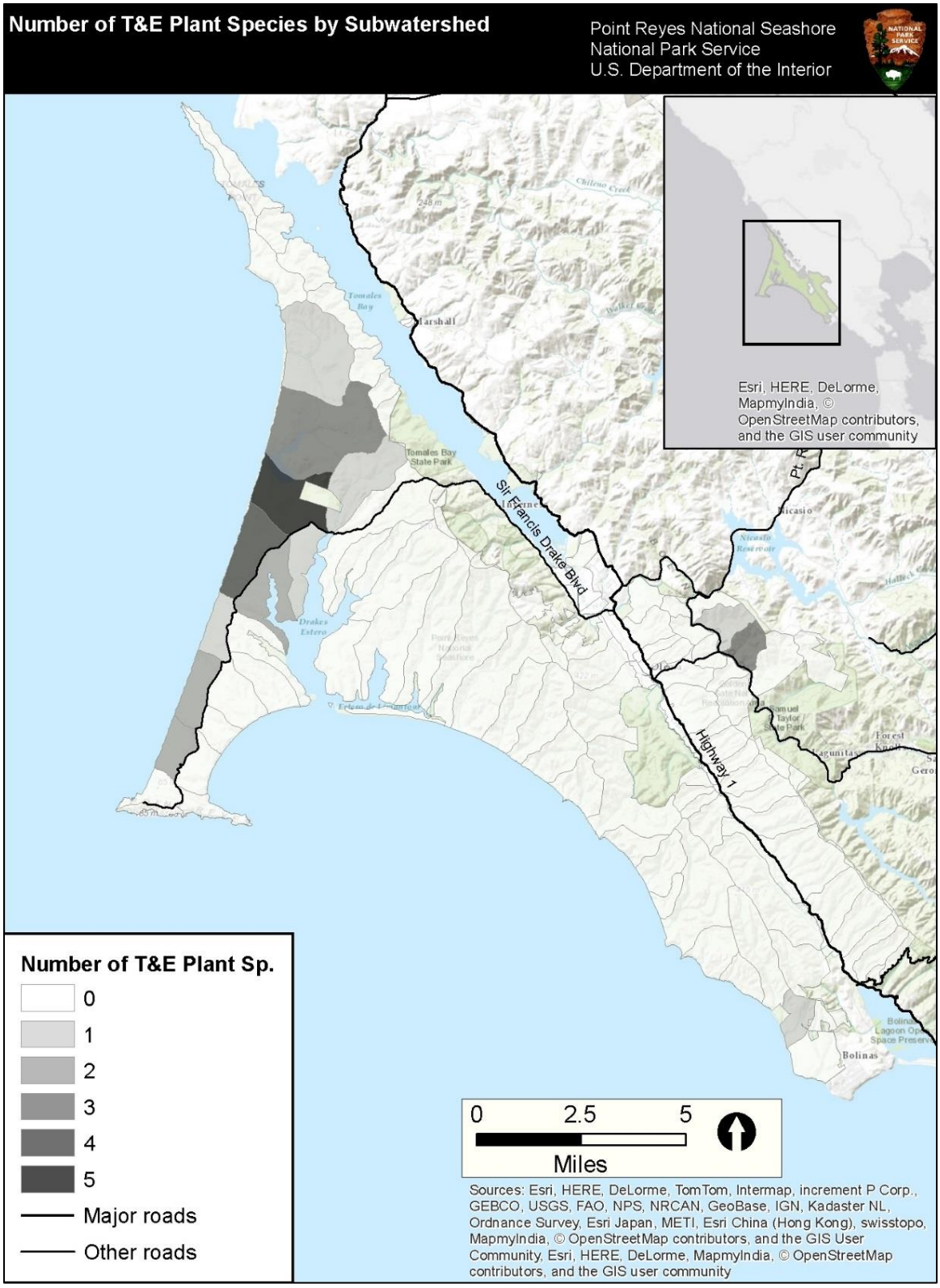


Figure 4.7.1. Density of Rare Plant Taxa by Subwatershed

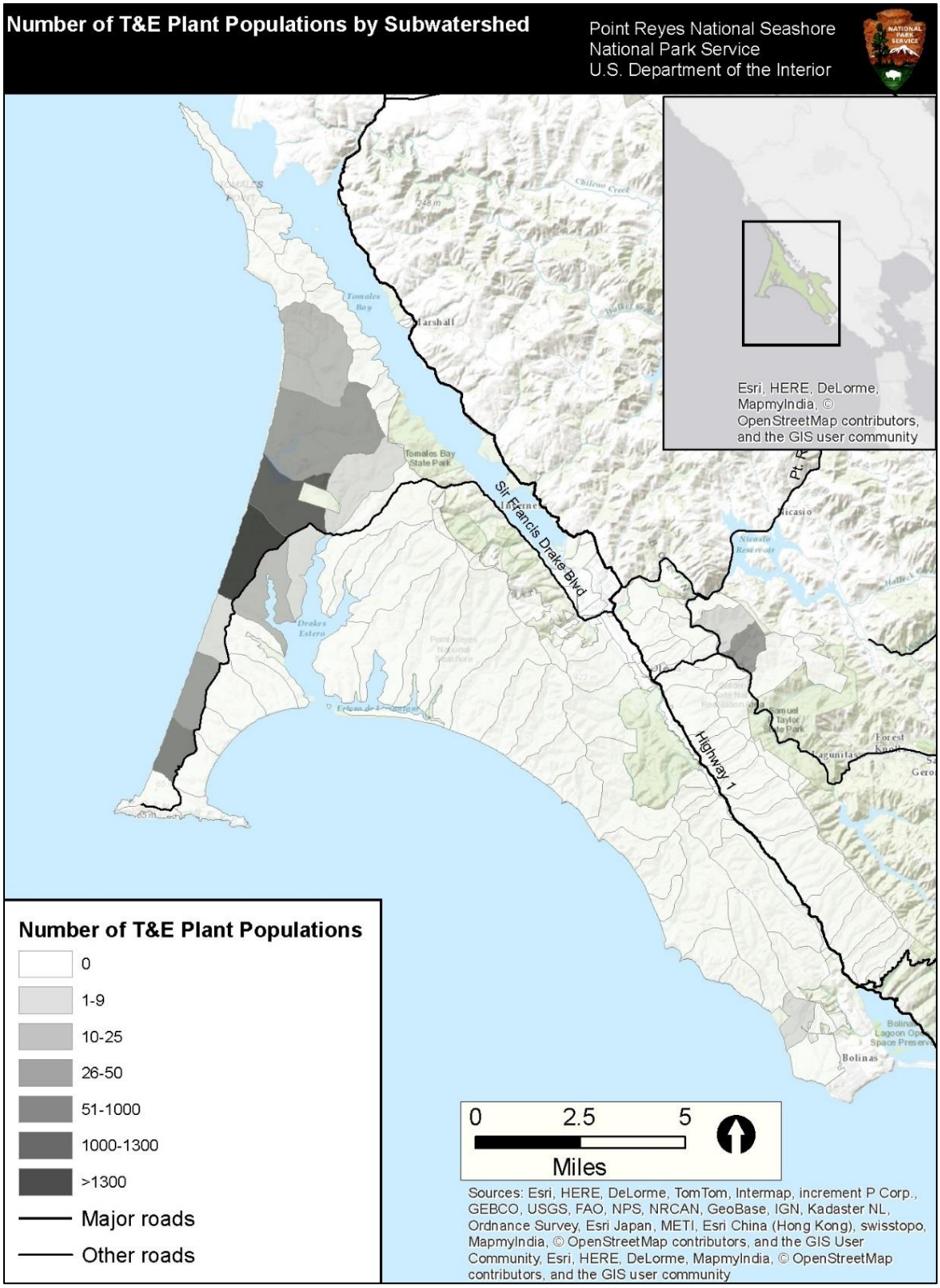


Figure 4.7.2. Number of Rare Plant Populations Mapped by Subwatershed

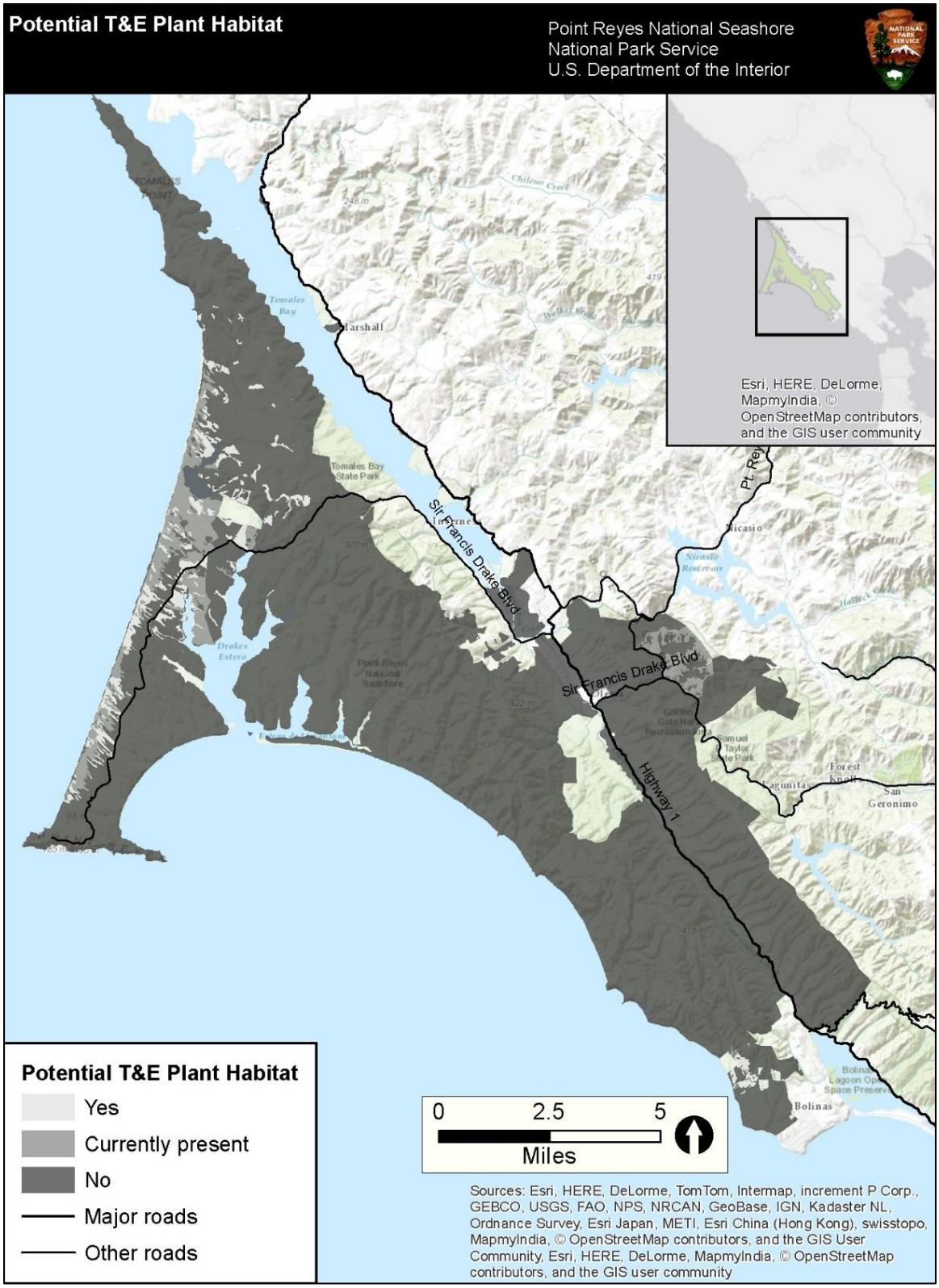


Figure 4.7.3. Potential Rare Plant Habitat

4.7.2. How Focal Resource Was Assessed

Measures

The measures used to determine the condition of plant taxa of interest mirror the critical questions. A literature review addressed the current status, distribution, and stressors for each of the of the four plant taxa of interest. The following indicators and measures were created in collaboration with NPS staff to capture the condition of rare plant species of interest on PORE lands (Tables 4.7.1a – c).

Table 4.7.1a. Measures used to answer: How many of the natural populations of rare plants observed since PORE management began are still extant?

Specific Measure	Condition Categories	Confidence Categories
Proportion of extant natural populations. Populations considered extirpated if not observed in last 10 years (2004-2013); considered potentially extirpated if not observed last 2 years (2012-2013); considered extant if observed in 2012-2013.	Green: 66-100% natural populations considered extant	High: All populations monitored annually with consistent methodology since discovery
	Yellow: 33-66% natural populations considered extant	Medium: 50-99% populations monitored as above
	Red: 0-33% natural populations considered extant	Low: 0-50% populations monitored as above

Table 4.7.1b. Measures used to answer: Have introduction efforts of rare plants been successful?

Specific Measure	Condition Categories	Confidence Categories
Proportion of successful introductions into new sites. This does not include natural populations.	Green: 66-100% of introduced populations extant	High: All populations monitored annually with consistent methodology since discovery
	Yellow: 33-66%	Medium: 50-99% populations monitored as above, or consistent monitoring plans have been adopted in recent years
	Red: 0-33%	Low: 0-50% populations monitored as above

Table 4.7.1c. Measures used to answer: Have the USFWS Recovery Plan goals been fulfilled for populations of rare plants within PORE lands?

Specific Measure	Condition Categories	Confidence Categories
Proportion of interim and long-term goals realized or in progress. Goals carried out by other entities will not be counted toward score.	Green: 66-100% of recovery criteria met or in progress	High: Score based on 2013 or more recent USFWS 5-year Report and 2013 or more recent NPS report to USFWS
	Yellow: 33-66%	Medium: Score based on 2012 or earlier USFWS 5-year Report and 2013 or more recent NPS report to USFWS
	Red: 0-33%	Low: USFWS 5-year Report and/or 2013 NPS report not available

Data Sources and Methods

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 PORE as 'of interest', which includes beach layia (*Layia carnosa*), Sonoma spineflower (*Chorizanthe valida*), Tidestrom's lupine (*Lupinus tidestromii*), and Sonoma alopecurus (*Alopecurus aequalis* var. *sonomensis*). 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
- Listed by the California Native Plant Society (CNPS) as rare, threatened or endangered in California and Elsewhere (Rank 1B)

CNPS designations were obtained from the California Native Plant Society's Inventory of Rare and Endangered Plants (CNPS 2014). This inventory gives federal and state designations as well as CNPS ranking status. Nomenclature is based on the updated Jepson Manual (Baldwin et al. 2012).

Data sources used to determine the distribution of species of interest within PORE are limited to NPS and affiliate survey data reported in status summaries submitted to the US Fish and Wildlife Service (USFWS), and 5-year Reviews and Recovery Plans issued by USFWS. In the case of the Tidestrom's lupine, much of the NPS data was gathered by researchers from Washington University.

Data sources used to determine the spatial distribution of species of interest within PORE was limited to NPS survey data. Rare plant survey protocols are described in reports to USFWS. Vegetation community data was based on 1994 polygon shapefiles from PORE. The vegetation community data were used to characterize the habitat types for species of interest.

In order to address Critical Question 3, regarding distribution of rare plants, the rare plant occurrence data was summarized by subwatershed. Critical Question 4 was addressed by summarizing rare plant occurrence data by subwatershed and plant community association. GIS metadata associated with final geospatial products contain a detailed methodology.

Reference Conditions/Values

Reference conditions for the rare plants described in this chapter are based on the 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, where available, 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.

4.7.3. Sonoma spineflower (Chorizanthe valida) Condition Assessment

Sonoma spineflower (*Chorizanthe valida*), in the buckwheat family (Polygonaceae), is an annual herb found in sandy coastal prairie. This California endemic herb blooms from June to August and occurs at 10 to 305 m of elevation. It occurs in well-dried Pleistocene dune sand, and it is not known whether or not it can survive in other soil types (Ryan and Parsons 2014a). The spineflower 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

Historically, the spineflower was noted in 1840-1841 on the California coast, although the exact location of the type specimen has been contested. The last known occurrence was near the historical site of the Point Reyes Post Office (Reveal and Hardham 1989). The specific species' historical abundance and distribution on the Point Reyes peninsula is not known (Ryan and Parsons 2014a). Two other occurrences were historically noted near Petaluma and Sebastopol, but these populations differed in flower color (USFWS 2010). After this, the Sonoma spineflower was considered extinct until rediscovered in 1980 in Point Reyes National Seashore at Abbott's Lagoon. In 1998, this species was reduced to one known population with a maximum of 30,000 individuals (USFWS 1998). The Abbott's Lagoon population consists of two spatially separated subpopulations, the largest of which is designated the "main population." The smallest population is referred to as the "subpopulation," and is a fourth of the size of the main population (USFWS 2010). This population occupies an area that fluctuates seasonally, although the overall area does not seem to be contracting (Williams 2008).

Experimental seeding and reintroduction plots were established about 100-200 m from the current colonies and at Bull Point where the last known specimen was collected (near the Point Reyes Post Office; Rogers 2005). Seed was sourced from the populations at Abbott's Lagoon. Of the six experimental plots at Abbott's Lagoon, two plots persisted and demonstrated viability with a potential for expansion (USFWS 2010). Additional seeds were sown into new plots at Bull Point, and have been monitored since then (Ryan and Parsons 2014a).

Since 2005, a macroplot has been used to sample the main population at Abbott's lagoon by the Point Reyes National Seashore staff. This population reached 710,460 individuals in 2009 from 62,580 in 2006 (USFWS 2010). Overall reintroduction plots near Abbott's Lagoon have seen an increase in both the abundance and extent of Sonoma spineflower, indicating that the expansion of the Abbott's Lagoon population may be possible (USFWS 2010).

Stressors

Of the threats defined in the original USFWS recovery plan from 1998, inappropriate levels of livestock grazing and invasive plant species are still considerable threats (Ryan and Parsons 2014a). Because endemic and reintroduced populations of the Sonoma spineflower occur within a National Seashore, development of land, trampling by equestrians, sand mining, and disposal of dredged materials are no longer threats to the species (USFWS 2010). In 2009, the Point Reyes National Seashore was awarded with a $58,850 grant to prevent extinction of the Sonoma spineflower by combating these threats and establishing seed reintroduction plots (USFWS 2010). This grant also funded a project to realign dirt roads that run through the habitat, monitor cattle grazing and its effects, and survey soils and other biological and physical information to select better reintroduction sites (USFWS 2010). Since 2010, the realignment of the road that bisected the Abbott's Lagoon population has reduced the threat or off-road vehicles (USFWS 2010).

Genetic Drift and Stochastic Events

The species is at risk from demographic and environmental stochasticity, which has a greater effect on populations with limited distribution and fluctuating population sizes. Problematic factors include prolonged drought, fire, disease, and other unforeseen causes of extinction (USFWS 2010). Its rarity makes it extremely vulnerable to such disturbances (USFWS 1998).

Grazing

The Abbott's Lagoon site consists of federally-leased cattle pasture which has been grazed for over a century. Cattle do not preferentially graze on the unpalatable spineflower. The long-term effects of grazing on the Sonoma spineflower are unknown (Ryan and Parsons 2014a). Evidence suggests that the species does better on grazed land, possibly due to the reduction of competition between Sonoma spineflower and other more palatable plants (Ryan and Parsons 2014a). However, damage due to trampling from cattle and other grazers has been noted (Ryan and Parsons 2014a).

In 1992, Davis and Sherman conducted experiments to attempt to determine the effects of cattle grazing on the Sonoma spineflower population at Abbott's Lagoon. PORE staff monitored exclosures of the existing population in areas where grazing occurred year-round (Davis and Sherman 1992). Introduction plots were established near the existing population and within grassland cattle pasture area in 1988. Growth inside and around the plots of Sonoma spineflower was measured throughout the duration of the study (Davis and Sherman 1992). Over the course of four years, the grazed population saw a great increase in growth, while the non-grazed population decreased until 1991 when it slightly recovered. However, plants in the non-grazed area were 3-4 inches taller and had a greater number of inflorescences (Davis and Sherman 1992). It was also noted that the intensity of the grazing was likely to have an effect on the plants, possibly due to the negative effects of trampling by grazers. However, grazing intensity and trampling were not studied due to a lack in variation of grazing intensity within the years of study (Davis and Sherman 1992).

Invasive Plants

Invasive plant threats to the Sonoma spineflower include non-native annual grasses, common velvetgrass (*Holcus lanatus*), and yellow bush lupine (*Lupinus arboreus*). While common velvetgrass is not currently a primary threat, evidence suggests that in the event of climate change it might begin to creep into the habitat of the Sonoma spineflower and outcompete the species. Yellow bush lupine, which is often introduced into dune habitats to help solidify them, is known to facilitate invasion by non-native species (Ryan and Parsons 2014a). While in the 20th century the Sonoma spineflower population had no contact with this species, it is currently surrounded by it. The yellow bush lupine has been removed and is managed by PORE natural resource staff (L. Parsons pers. comm. 2015).

Sonoma spineflower occurs in a habitat dominated by non-native annual grasses and forbs such as *Festuca bromoides, Bromus hordeaceus, Aira caryophyllea,* and *Cynosurus echinatus,* and is known to be adversely affected by competition with such grasses (Ryan and Parsons 2014a). Annual grasses and forbs alternate in abundance from year to year, with annual grasses tending to do better in years with continuous moisture. The abundance of such grasses and non-native species may be pertinent in Sonoma spineflower management due to the potential for competition (Ryan and Parsons 2014a).

Competition by invasive species also affects the number of Sonoma spineflower seeds that survive to germinate in the next year (Ryan and Parsons 2014a).

Climate Change

The species may be affected by climate change, but specific impacts remain conjectural. Rising ocean levels could cause inland migration of coastal habitats (Cayan et al. 2008a). Alteration of average and extreme temperature and precipitation patterns could also cause a shift in spatial distribution of suitable climate habitats (Ackerly et al. 2010). Changing distribution of suitable climate variables may disproportionately affect the spineflower due to its reliance on Pleistocene dune soil, a rare soil type (USFWS 2010). Climate change will likely have additional indirect effects on the success on the spineflower wild and introduced populations. Inter-species competition may become more pronounced with potential shifting distributions and abundances of yellow bush lupin, velvetgrass, and other competitors (Ryan and Parsons 2014a). Unknown effects of interactions between different stressors, including grazing, competition and climate change, may adversely affect the potential for the spineflower to shift to a future suitable habitat range. All climate change predictions are inherently hypothetical, and specific effects on coastal plant communities remain unknown.

Level of confidence in assessment

Since its re-discovery in 1980, the Sonoma spineflower has been heavily monitored in its single location at Abbott's Lagoon by the Point Reyes National Seashore staff. The USFWS and PORE have encouraged and funded detailed studies and restoration projects (USFWS 2010, Ryan and Parsons 2014a, Davis and Sherman 1992). Currently, monitoring of the wild population, introduction plots, and invasive species densities occurs on a near-yearly basis (Ryan and Parsons 2014a). The majority of this assessment was based on the PORE annual report submitted to the USFWS, as well as the USFWS Recovery Plan for this species from 1998 and a subsequent 5-year Review in 2010. The PORE Rare Plant Report demonstrates that the experiments and assessments have been meticulous (Ryan and Parsons 2014a).

Gaps in understanding

Historically, monitoring strategies for the Sonoma spineflower have focused on the monitoring and maintenance of existing wild populations, the introduction of new populations, monitoring of potential threats such as overgrazing and invasive species, and the collection of seeds for long-term accession from botanical facilities (Ryan and Parsons 2014a).

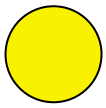
The extent of the wild Sonoma spineflower population occurs every one or two years. Currently, mapping of encroachment by common velvetgrass occurs every five years, with the next scheduled mapping to occur in 2017. Continued monitoring of the Sonoma spineflower should occur until a baseline of seasonal fluctuation can be established (Ryan and Parsons 2014a).

No attempt has been made to experiment with the effects of fire in the management of Sonoma spineflower, and monitoring of pollinators is too recent to understand the dynamics of pollination (USFWS 2010, Ryan and Parsons 2014a). Volunteers from the California Native Plant Society monitor rare plant populations at PORE, but unlike other monitoring, this does not occur on an

annual basis (USFWS 2010). As the effects of cattle grazing seem dependent on intensity and timing, research could look into further defining what range of intensity is optimal for growth, and at what point the effects of trampling counteract the benefits of grazing (Ryan and Parsons 2014a).

The success of rare annual plants is tied to climate and yearly conditions. As such, climate change may pose a serious threat to the Sonoma spineflower (Table 4.7.2). Further research might also focus on determining how serious this risk is, and what might be done to protect the species in the event of climate change. Lack of fog under future climate scenarios might constitute a risk as many coastal plants rely on fog for summer moisture (Ryan and Parsons 2014a).

Table 4.7.2. Condition summary for Sonoma spineflower (*Chorizanthe valida*)

Indicator of Condition	Specific Measure	Condition Status	Rationale
How many of the natural populations observed since PORE management began are still extant?	Proportion of extant natural populations. Populations considered extirpated if not observed in last 10 years (2004-2013); considered potentially extirpated if not observed last 2 years (2012-2013); considered extant if observed in 2012-2013.		The wild population has been monitored with a macroplot since 2005, and has shown great variability in population size.
Have introduction efforts been successful?	Proportion of successful introductions into new sites. This does not include natural populations.		New populations have been introduced to 22 sites between 1988 through 2011. Three populations were not monitored in 2012 and/or 2013. 12 were observed in both 2012 and 2013 (63%). Three introductions had 0 individuals in 2012 and/or 2013 (16%). Four populations (21%) have not been observed in the past 10 years (2004-2013).
Have the USFWS Recovery Plan goals been fulfilled for populations within PORE 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 Recovery Plan criteria, all six have been met or are in progress (land secure, threat management, monitoring management, establishment of additional populations with habitat, creation of management plan, and establishment of two viable populations).

Sonoma spineflower is naturally established in only one area, and may be subject to extinction in future years due to invasive species. The cause of fluctuations in population size is unknown. Continued monitoring will establish a baseline for annual fluctuations in population (Ryan and Parsons 2014a).

The status of the Sonoma spineflower is very closely monitored, and much work has been put into increasing the size of the wild population, increasing the number of successful introductions and decreasing potential threats. Although the endemic population has seen a decrease in population

since 2010, the introduced populations are at their highest level since 2005 (Ryan and Parsons 2014a).

4.7.4. Beach layia (Layia carnosa) Condition Assessment

Beach layia (*Layia carnosa*) is an annual herb found in sandy coastal scrub and coastal dunes. This California endemic herb blooms from March to July, occurring at 0 to 60 m of elevation in patches that change in number annually (Botanica Northwest Associates 1992). This layia 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

Historically, the beach layia occurred in San Francisco, Humboldt, and Monterey Counties in five occurrences that are thought to be extirpated. Since the plant's listing, no significant change in distribution has occurred (USFWS 2011). Beach layia is distributed in California over seven dune systems which stretch from Santa Barbara County to Humboldt County, in sixteen extant occurrences (USFWS 2012). Ninety-one percent of this dune system habitat is federally or state owned, and is considered safe from direct developmental impacts (USFWS 2012). The remaining habitat is considered protected by committed private landowners (USFWS 2012). All federal and state agencies that own land on which beach layia is present are obligated to aid its recovery (USFWS 2012). Future funding for such protection is discretionary, except in the case of Asilomar State Beach, which has designated long-term funding devoted to this purpose (USFWS 2012).

Almost 85% of the land in which beach layia occurs in is subject to management that emphasizes conservation, and 52% is subject to management focused on specifically aiding recovery (USFWS 2012). Cover from associated plant species protects beach layia from the effects of sand dune movement and erosion. Such associated species include coast buckwheat, beach pea, beach sagewort, dune bluegrass, dune goldenrod, sand verbena, and beach-bur (USFWS 1998).

The beach layia currently occupies a habitat that doubled in size from 2003 to 2006 to a final area of more than 75 acres (BLM 2003, 2006). The designation of habitat in this case includes beach layia seed bank, but no known established plants (USFWS 2012). However, no significant change in distribution has occurred since the listing of this species as endangered (USFWS 2012).

Stressors

The classification of beach layia habitat as either public or protected by local zoning ordinances and resource management plans has reduced previous stresses from pedestrians and off-road vehicles. However, illegal trespass of off-road vehicles still occurs, particularly in areas that are designated for public use, or near such areas (USFWS 2012). Pedestrian and equestrian trail usage may be beneficial to beach layia, which often grows on trail edges in areas where it is not otherwise seen (USFWS 2012). The biggest threats to beach layia populations are: invasive species, isolated populations, and potential climate change.

Invasive Species

Invasive species are the biggest factor leading to degradation of beach layia habitat (USFWS 2012). Principal invasive species include European beachgrass (*Ammophila arenaria)*, bush lupine (*Lupinus arboreus*), and iceplant (*Carpobrotus* spp), depending on the location. However, over 30 listed sites of beach layia are undergoing specific invasive species removal projects, and the threat has been reduced notably at least in the short term by current management efforts (USFWS 2012).

Isolated Populations

Populations of beach layia are subject to variation in reproductive success given its annual reproductive pattern. Individual population extinction risk due to the annual life history of beach layia is coupled with the species' vulnerability to harsh weather (USFWS 2012). There has also been notable difficulty in establishing outplanting sites near existing populations due to resistance from private landowners and lack of suitable environments (USFWS 2012).

Climate Change

The hypothetical nature of climate change predictions indicate that potential species-specific effects remain conjectural but may inform adaptive management. Potential direct effects of climate change include greater impact of storm surge waves (Cayan et al. 2008a, Dettinger 2011). Rising sea level could also shift suitable layia habitat inland (Cayan et al. 2008a, USFWS 2012). Variation in average and extreme temperature and precipitation events could also shift suitable habitat for the beach layia (Ackerly et al. 2010). Some climate change prediction models anticipate warmer temperatures and a drier climate and loss of coastal fog, which may also shift suitable habitat along climate gradients (USFWS 2012). Indirect effects of climate include interactions of climate variables with other stressors, particularly competitive plant species. Predicting shifts of appropriate beach layia habitat remains fraught with a high degree of error but offers insight into potential scenarios and call for implementing flexible adaptive management systems.

Level of confidence in assessment

The findings in this report are primarily based on the 2012 USFWS 5-year Review for the beach layia. This report notes the extensive amount of habitat for this species that is protected by and managed by federal and state agencies. The occupied habitat of beach layia was estimated based on its mapped distribution in key areas over a time period ranging from 1999 to 2010 (USFWS 2012; Imper 2011). It is also notable that the population size estimates are only currently statistically valid for a portion of Humboldt County (USFWS 2012).

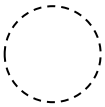
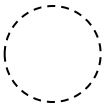
Gaps in understanding

Though the species is heavily monitored, there are a number of management actions and research topics that could be explored. The population at Point Pinos has been undetected since 1919 (USFWS 2012), and yet was not included in the restoration plan that accompanied the transfer of the property from the US Coast Guard to the City of Pacific Grove. Further attempts should be made to reintroduce beach layia to this site, as well as near other historical occurrences such as that at the mouth of Little River (pers. comm. M. Forys 16 May 2007). A study might also examine factors that limit the range of the species that have been historically difficult to manipulate, such as temperature and sand mineralogy (USFWS 2012).

Habitats owned by the USFWS, Bureau of Land Management, City of Eureka, Manila CSD, Point Reyes, California Department of Parks and Recreation, and Pebble Beach Company have been the focus of restoration projects. These projects will require future monitoring with consistent methods so that trends may be evaluated in order to provide feedback on the results of conservation efforts. This is also important to determine whether the management employed benefits the species (USFWS 2012).

Disturbance appears beneficial to growth of beach layia. However, as too much or too little disturbance is detrimental, further research might explore appropriate levels of disturbance in order to inform management actions and public access control (USFWS 2012; Table 4.7.3). In the case of privately-owned habitat, further work is needed to determine a method that will secure long-term agreements for the preservation of the species (USFWS 2012).

Table 4.7.3. Condition summary for Beach layia (*Layia carnosa*)

Indicator of Condition	Specific Measure	Condition Status	Rationale
How many of the natural populations observed since PORE management began are still extant?	Proportion of extant natural populations. Populations considered extirpated if not observed in last 10 years (2004-2013); considered potentially extirpated if not observed last 2 years (2012-2013); considered extant if observed in 2012-2013.		The most recent data is from the 5-year report by the USFWS (2011). No NPS report submitted to USFWS was included in this analysis.
Have introduction efforts been successful?	Proportion of successful introductions into new sites. This does not include natural populations.		No information is given that suggests new populations have been established (USFWS 2011).
Have the USFWS Recovery Plan goals been fulfilled for populations within PORE lands?	Proportion of interim and long-term goals realized or in progress. Goals carried out by other entities will not be counted toward score.		For the PORE-managed populations, three downlisting criteria have been met or are in process (securing habitat, managing threats, monitoring invasive removal), and one is completed by other entities (securing restored habitat). The additional criteria specific to PORE is in progress. Other general downlisting criteria beyond the four listed are not considered in the indicator status as they generally overlap with other criteria.

The beach layia is protected in its current habitat, and is well-regulated therein. It ranges over much of California's coast in dune environments and along trails. It is often found it small patches, which makes it vulnerable to extinction (USFWS 2012). Competition from invasive species is a major threat to beach layia, and is the focus of current restoration efforts (USFWS 2012). Its other main risk

is due to future rising ocean levels. Further research should focus on the prevention of species loss due to changing ocean levels as well as investment of resources into reestablishment of the plant in its historical locations (USFWS 2012).

4.7.5. Tidestrom's lupine (Lupinus tidestromii) Condition Assessment

Tidestrom's lupine (*Lupinus tidestromii*), also known as clover lupine, is a perennial rhizomatous herb found in coastal dunes. This California endemic herb blooms from April to June and occurs at 0 to 100 m of elevation (CNPS 2014). It is most likely pollinated by bees. Tidestrom's lupine is associated with four other rare plant species: the beach layia (*Layia carnosa*), the sand gilia (*Gilia capitata* ssp. *chamissonis*), curly-leaved monardella (*Monardella sinuata* ssp. *nigrescens*), and woolly-headed spineflower (*Chorizanthe cuspidata* var. *villosa*) (Parsons and Minnick 2014). 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

Historically, the Tidestrom's lupine existed in the three spatially separate populations which occur today, as well as a now-extirpated fourth population occurring at Dillon Beach (USFWS 2010). Of the extant occurrences of Tidestrom's lupine, ten occur within the Point Reyes National Seashore. Five of the other eight occurrences are found on private property; one is on coast guard property; and two exist within California State Beach property. This lupine occurs in two distinct areas: Monterey Peninsula in Monterey Bay, and along the Russian River northwest of Marin County (Parsons and Minnick 2014).

Within PORE, Tidestrom's lupine exists in a fragmented dune habitat surrounded by invasive species such as European beachgrass (*Ammophila arenaria)* and iceplant (*Carpobrotus* spp) (Parsons and Minnick 2014). The lupine was suggested as a secondary-successional species in research by Dr. Tiffany Dwight (USFWS 2009). Recent evidence from a dune restoration project, focused on removal of European beachgrass, has demonstrated that the lupine will readily extend into primary successional habitats, and can withstand sandblasted areas as well as sand burial (Parsons and Minnick 2014).

In Asilomar State park, Tidestrom's lupine has shown potential to hybridize with chamisso lupine (*Lupinus chamissonis*), but this has not been observed within the Point Reyes populations located south of Abbott's Lagoon (Tom Moss, CDPR, pers. comm., as cited in Parsons and Minnick 2014). Monitoring over the last 20 years has suggested that while substantial numbers of Tidestrom's lupine exist within the Point Reyes National Seashore, individual occurrences remain threatened by encroachment of invasive species and habitat loss (Washington University, unpublished data, as cited in Parsons and Minnick 2014).

Of the Point Reyes populations, only two have viable populations. Data compiled by researchers from Washington University suggests that these two populations are also at risk due to consumption of seeds pre and post dispersal. With the removal of seed predation, the populations may stabilize (Dangremond et al. 2010).

Stressors

Anthropogenic disturbance

Within coastal northern California, Tidestrom's lupine has been subject to damage from commercial development (Parsons and Minnick 2014). Monterey County populations have also been threatened by equestrian use, residential use, and trampling by hikers (USFWS 1998). Within Monterey County, grazing by cattle has also been historically prevalent but in recent years efforts have been made to limit cattle within the dune areas and potential negative effects from trampling (Washington University unpub. data, as cited in Parsons and Minnick 2014).

Native Herbivory

At PORE, seeds of the Tidestrom's lupine are consumed by native deer mice (*Peromyscus maniculatus*). These mice have been seen to eat up to 82% of the seeds produced by the lupine, both pre- and post-dispersal. Seed-eating activity by deer mice has been seen more extensively in areas where European beachgrass are present, as this plant provides cover that protects the mouse from predation (Pitts and Barbour 1979). This effective herbivory reduced the species' successful reproduction. Because of this extensive predation, all of the populations except for the Abbott's Lagoon population and one population at the AT&T Radio tower are note considered viable. These two remaining populations are considered barely stable (Dangremond et al. 2010).

Invasive Species

European beachgrass and iceplant encroachment into Tidestrom's lupine habitat are the greatest threat to the species. These species were originally introduced in the 1800s to stabilize shifting sand dunes. Over 70% of the park's dune habitat is inhabited by these two species. All of the Tidestrom's lupine populations exist within islands of native dune habitat surrounded by European beachgrass and iceplant. The prevention of dune shifting by these species leads to an "aging" which gives the dunes more late-successional character. Due to the success of Tidestrom's lupine in early successional areas, this dune aging may be detrimental to its success. Removal of these two species is crucial to the success of the lupine (Parsons and Minnick 2014, Dangremond et al. 2010).

Genetic Drift

Isolated populations of Tidestrom's lupine are also subject to the common threats of small population size, such as decrease in genetic variation within populations and greater threat from stochastic events (Dangremond et al. 2010, Parsons and Minnick 2014). In small enough populations, pollination cannot occur effectively (Forsyth 2003).

Level of confidence in assessment

The majority of this report is based on the annual species report written by the National Parks Service for the US Fish and Wildlife Service in 2014 (Parsons and Minnick 2014), as well as the original recovery plan established in 1998 (USFWS 1998) and the 5-year Review written in 2009 (USFWS 2009). All of these reports indicate that Tidestrom's lupine has been closely monitored within PORE-managed lands. The detail of these reports and recent reporting indicate that the information presented in both is sound and well-researched.

The involvement of PORE in the preservation of this species within PORE lands has also been noted in the most recent report by the National Parks Service (Parsons and Minnick 2014). The national park's involvement in the preservation of the species through other studies noted within Parson and Minnick's report also indicates the soundness of the results of other experiments which Parson and Minnick cite in their report.

However, it should be noted that in recent years, due to funding constraints, monitoring activities have not been consistent. Furthermore, Washington University, which historically had assisted studies of Tidestrom's lupine, was forced to reduce their research in 2012 due to lack of funding (Parsons and Minnick 2014).

Gaps in understanding

Active removal of European beachgrass and iceplant is imperative to the survival of isolated populations of Tidestrom's lupine within the Point Reyes National Seashore. Given the small and isolated lupine populations, restoration efforts will be required to keep current extant populations from extinction (Parsons and Minnick 2014). The Point Reyes National Seashore recently received funding to continue non-native species removal in the Tidestrom's lupine habitat and plans to focus further efforts on the removal of invasive species in the next few years. Projects using these funds began in 2013-2014 (Parsons and Minnick 2014).

However, much of the research into the Tidestrom's lupine has been scaled back since 2012 due to insufficient research funding for Washington University researchers (Parsons and Minnick 2014). Further research should focus on developing comprehensive, accurate knowledge of the fluctuations in population size as well as the biological and environmental mechanisms effecting population dynamics and subsequent species viability within PORE (Parsons and Minnick 2014).

Because of the small size of the individual populations of Tidestrom's lupine, there is continued potential for inbreeding depression and the reduced ability of attract pollinators. Traditional management that focuses only on the creation of more potential habitat, and not important associated factors, may not expand population (Table 4.7.4). Further studies must look into the mechanisms that govern small plant populations and the requirements necessary for population expansion (Parsons and Minnick 2014).

The Tidestrom's lupine has a small number of extant occurrences within dune habitats on the central California coast. Its populations are still significantly threatened by native herbivory and the encroachment of European beachgrass and iceplant. Small population sizes can increase the risk of extinction due to loss of genetic variation and potential loss of pollinators. PORE has received funding for the restoration of Tidestrom's lupine habitat via the removal of invasive species (Parsons and Minnick 2014).

Table. 4.7.4. Condition summary for Tidestrom's lupine (*Lupinus tidestromii*)

Indicator of Condition	Specific Measure	Condition Status	Rationale
How many of the natural populations observed since PORE management began are still extant?	Proportion of extant natural populations. Populations considered extirpated if not observed in last 10 years (2004-2013); considered potentially extirpated if not observed last 2 years (2012-2013); considered extant if observed in 2012-2013.		Of the 11 natural populations, three have not been monitored in the last two or more years; 7 monitored populations have >0 individuals in last survey year; and one has been extirpated.
Have introduction efforts been successful?	Proportion of successful introductions into new sites. This does not include natural populations.		One introduced population (#12) was planted in 2003 and monitored for three years following planting. The population showed major decline to 0-3 individuals in the last two years monitored (2010 and 2011).
Have the USFWS Recovery Plan goals been fulfilled for populations within PORE lands?	Proportion of interim and long-term goals realized or in progress. Goals carried out by other entities will not be counted toward score.		As of the 5 year report (USFWS 2010), all four downlisting criteria were met or in progress in PORE (secure habitat, management plan, monitoring for recovery, habitat restoration). Of the long-term criteria, four were met or in progress (15 year monitoring, new populations introduced, weed removal, minimum population size), one was not met (Dillon Beach introduction), and one was conducted by other parties (protecting private lands).

4.7.6. Sonoma alopecurus (Alopecurus aequalis var. sonomensis) Condition Assessment

Sonoma alopecurus (*Alopecurus aequalis* var. *sonomensis*) is a perennial herb found in freshwater marshes and swamps, as well as riparian scrub. The Sonoma alopecurus has been seen to exhibit up to 80 inflorescences per plant, and grows in spreading mats (USFWS 2011). This California endemic herb blooms from May to July and occurs at 5 to 365 m of elevation. Within PORE, the extant populations are found on Sirdrak variant, Rodeo clay loam, and Dune lands (Ryan and Parsons 2014b). It 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'. Historical localities are in need of updated field surveys (CNPS 2014).

Condition and Trend

Historically, sixteen populations of the Sonoma alopecurus existed within Marin and Sonoma Counties. Eight of these were considered natural populations by the time of the final listing (USFWS 2011). Three populations were privately owned, one was on a private inholding within the Point Reyes National Seashore, and four were on federal land within PNRS (USFWS 2011). Of the 22

occurrences now listed, 14 have not been observed in at least 20 years and are considered historical (USFWS 2011). The difficulty of older records makes it hard to determine if some of the occurrences are duplicates (USFWS 2011).

As of 2014, extant occurrences of Sonoma alopecurus have dropped to seven, with six of these occurring within the Point Reyes National Seashore (Ryan and Parsons 2014b). These populations are clustered in a small area between Abbott's Lagoon and Creamery Bay on the Point Reyes peninsula. The plant has been federally listed as endangered since 1997 (USFWS 1997). It is considered to be one of the species most in danger of extinction within the Point Reyes National Seashore, and is threatened by multiple stressors (Ryan and Parsons 2014b).

Between 1983 and 2000, the Sonoma alopecurus populations varied widely in number of inflorescences (USFWS 2011). This has made it difficult to distinguish and monitor individual plants and analyze population viability (Ryan and Parsons 2014b). It is not known whether the species blooms more than once in a blooming season, or if phenology is determined by rainfall and timing of inundation. In ideal conditions, the alopecurus has shown significant seed viability (Ryan and Parsons 2014b).

The Sonoma alopecurus typically lives on sandy soils in perennial wetlands dominated by sedges, grasses, and freshwater emergent hydrophytes. Ideal habitat has been difficult to determine due to the limited number of extant occurrences, although increased soil moisture has been found to increase population viability (Gennet 2004).

Stressors

Grazing

Cattle grazing is one of the most complex management tools that has potential to improve or degrade necessary habitat conditions for the Sonoma alopecurus. Though populations have been extirpated upon the complete removal of cattle grazing, in other cases, grazing was associated with a reduction of almost 90% of the inflorescences in a population (Ryan and Parsons 2014b). In one population (#3), seasonal grazing was determined to be tentatively helpful, but results were inconclusive. In Population 5, benefit from continuous grazing was also considered inconclusive (Ryan and Parsons 2014b). Future monitoring in 2014 may improve understanding of how seasonal grazing might be beneficial in Population 5 (Ryan and Parsons 2014b).

Cattle grazing in itself is not necessarily a threat, but the extent of cattle grazing that is advantageous for the alopecurus is unknown and so the potential for inappropriate cattle grazing remains (Ryan and Parsons 2014b). Studies have shown that the Sonoma alopecurus may be a disturbance colonizer and a poor competitor. Hence cattle grazing, which removes biomass of more competitive plant species, may be beneficial to the Sonoma alopecurus. A 2004 study by Gennet supports this claim, and notes that it seems grazing may be more helpful and beneficial in early phases of growth as opposed to later (Gennet 2004).

Climate Change

Species-specific effects of climate change on the Sonoma alopecurus is not well understood. Climate predictions for coastal California also remain unknown. As a marsh and riparian associated species, the alopecurus may be adversely affected by increasing sea level, rising high tide elevations, and increased impact from storm surges (Cayan et al. 2008a). The predicted effect of climate change on precipitation and temperature patterns on the coast may be unique from the rest of the state of California: increased temperatures inland may result in decreased temperatures on the coast (Snyder 2008). This may lead to an increase in coastal fog (Johnstone and Dawson 2010). Overall temperature, precipitation, and solar radiation will likely change at least seasonally (Ryan and Parsons 2014b).

Site-specific Factors

Besides grazing, soil moisture, water depth, and other site-specific factors may potentially affect the success of Sonoma alopecurus populations (Ryan and Parsons 2014b). One population of the alopecurus has been impacted by an increase in dune movement near Abbott's lagoon due to efforts to remove European beachgrass (*Ammophila arenaria*) from the dunes. This has greatly decreased the number of inflorescences noted at these sites (Ryan and Parsons 2014b). In 2013-2014, NPS staff created a new drainage swale near the area previously inhabited by the buried populations. Genetic material from the buried populations was introduced into this site in the winter of 2014. The success of this technique and reintroduced population are unknown (Ryan and Parsons 2014b).

Level of confidence in assessment

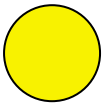
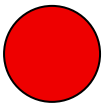
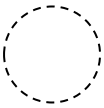
The majority of this report was written from information included in an annual report on Sonoma alopecurus submitted by the Point Reyes National Seashore staff to the USFWS in 2014 (Ryan and Parsons 2014b). Additional information was included from the original USFWS Determination Finding (USFWS 1997) and the USFWS 5-year Review (USFWS 2011). Based on the detail and legitimacy of these reports, it is assumed that the reports and the experiments cited within are founded on sound data.

Gaps in understanding

In the years from 1983 to 2000, species monitoring was intermittent. However, monitoring has become more intensive since 2000 (Ryan and Parsons 2014b). Since 2008, with funding from the USFWS, PORE has engaged in more extensive monitoring. Since 2013, groundwater monitoring wells, hydrology, and floristic monitoring occur at various population sites within the Point Reyes National Seashore (Ryan and Parsons 2014b).

In 2012 and 2013, the Sonoma alopecurus exhibited extreme variability in inflorescence abundance between populations (Ryan and Parsons 2014b). This difference may be due to a combination of factors that are not well understood, such as climatic variables, grazing, and management actions, including dune restoration (Ryan and Parsons 2014; Table 4.7.5). These factors are all variable, which makes it difficult to determine any adverse or positive effects to the alopecurus (Ryan and Parsons 2014b). Further research should look into strategies to control one or more of these factors in order to isolate the effect of each factor in question.

Table 4.7.5. Condition Summary for Sonoma alopecurus (*Alopecurus aequalis* var. *sonomensis*)

Indicator of Condition	Specific Measure	Condition Status	Rationale
How many of the natural populations observed since PORE management began are still extant?	Proportion of extant natural populations. Populations considered extirpated if not observed in last 10 years (2004-2013); considered potentially extirpated if not observed last 2 years (2012-2013); considered extant if observed in 2012-2013.		Of the 9 natural populations, one was considered to recorded by accident. Five populations were observed in 2012 and 2013 (62%); two were not observed in 2012 or 2013 (25%) and one was considered extirpated and no longer monitored (13%). Population monitoring efforts have varied over time in methodology and frequency.
Have introduction efforts been successful?	Proportion of successful introductions into new sites. This does not include natural populations.		Two reintroduction efforts done in 1987 and 2002 failed within seven years after planting. Plans for a 2014/2015 reintroduction are not considered in this report.
Have the USFWS Recovery Plan goals been fulfilled for populations within PORE lands?	Proportion of interim and long-term goals realized or in progress. Goals carried out by other entities will not be counted toward score.		No final recovery plan has been submitted or is planned for the future.

The Sonoma alopecurus remains endangered and has few extant occurrences. Because of the extreme levels of variability in inflorescences between and during the year, it is difficult to determine the status of the extant populations. The species is threatened by site-specific factors and potentially inappropriate grazing levels, mostly because the true effects of these factors are not known. In the future, climate change may help or hinder this plant via shifts in precipitation, temperature, and solar radiation. Further research into the effects of individual factors is needed to determine the best ways to further the success of the Sonoma alopecurus. A better understanding of the ideal conditions for the species may also aid in the introduction of the species into new places so that the number of extant occurrences might increase. This introduction of new populations is funded by the National Park Service and is cited as a planned future activity (Ryan and Parsons 2014b).

4.7.7. Distribution of Rare Plant Habitat

This section addresses the third and fourth Critical Questions: What habitats or regions within PORE have a high incidence of endangered and threatened plant populations of interest? How are these taxa distributed? Also, are the areas of greatest known rare species occurrences within certain habitat types that may have a larger distribution within PORE?

Critical Question 3 was addressed by mapping the frequency of rare plants within PORE-managed lands (Figure 4.7.1 and Figure 4.7.2). This mapping effort includes threatened, endangered, and rare plant species of interest to PORE management. The maps and associated spatial data will support management decisions regarding known rare plant occurrences.

Critical Question 4 was addressed by mapping known occurrences of threatened and endangered plants within vegetation types that occur in PORE-managed lands (Table 4.7.6, Figure 4.7.3). Precise locations of known rare plant populations can serve as indicators of habitat preferences or requirements. Those preferences can then be used to identify other potential habitats for survey or rare plant introduction efforts. The maps and supporting spatial data support PORE rare plant management, habitat restoration, and inform future survey efforts.

The majority of unique subwatershed and vegetation association combinations were found to support populations of threatened and endangered plant species (Table 4.7.6). However, some unique combinations of subwatershed and dominant plant community types, such as California Annual Grassland and Coyote Brush, did not support known rare plant populations. These common vegetation types are widespread throughout California and are not specific to unique edaphic or environmental conditions that would be associated with specialized rare plant species. The distribution of the few unoccupied subwatershed/vegetation combinations represent a large area in the PORE managed lands (Figure 4.7.3). Further studies should investigate the distribution of potential habitat based on plant association alone or in combination with management type, soil type, climate variables, etc.

Table 4.7.6. Distribution of Rare Plant Occurrence within Subwatersheds and Plant Community Types

Subwatershed	Vegetation Association[1]	Potential Habitat[2]
GGNRA27-2	California Annual Grassland Mapping Unit - NA	match
PORE1-45	California Annual Grassland Mapping Unit - NA	no
PORE1-45	Coyote Brush - B.p. consanguinea/Non-native grassland Association (preliminary)	no
PORE1-45	Coyote Brush - B.p. consanguinea/Rubus ursinus/Weedy	match
PORE1-47	California Annual Grassland Mapping Unit - NA	no
PORE5-14	California Annual Grassland Mapping Unit - NA	match
PORE6-11	Dune Sagewort - Goldenbush Complex Mapping Unit - NA	match
PORE6-11	European Dunegrass - NA	match
PORE6-11	Iceplant (Carpobrotus edulus) - NA	match
PORE6-12	California Annual Grassland Mapping Unit - NA	match
PORE6-12	Coyote Brush - B.p. consanguinea/Lupinus arboreus /Lupinus chamissonis	match
PORE6-12	Rush - NA	match
PORE6-13	Coyote Brush - B.p. consanguinea/Carex obnupta /Juncus patens	match
PORE6-13	Coyote Brush - B.p. consanguinea/Lupinus arboreus /Lupinus chamissonis	match
PORE6-13	Dune Sagewort - Goldenbush Complex Mapping Unit - NA	match
PORE6-13	Dunes - NA	match
PORE6-13	European Dunegrass - NA	match

[1] Vegetation Association column includes Calveg plant association first and includes the associated 1994 Plant Association where mapped; if no 1994 association, marked as NA

[2] 'match' = yes, there are unoccupied locations; 'no' = no matching unoccupied locations

Table 4.7.6 (continued). Distribution of Rare Plant Occurrence within Subwatersheds and Plant Community Types

Subwatershed	Vegetation Association[1]	Potential Habitat[2]
PORE6-13	Iceplant (Carpobrotus edulus) - NA	match
PORE6-13	Pacific Reedgrass - C. nutkaensis/Carex/Juncus	match
PORE6-13	Rush - NA	match
PORE6-14	Rush - NA	match
PORE6-15	California Annual Grassland Mapping Unit - NA	match
PORE6-15	Dune Sagewort - Goldenbush Complex Mapping Unit - NA	match
PORE6-15	Dunes - NA	no
PORE6-15	European Dunegrass - NA	match
PORE6-15	Pacific Reedgrass - C. nutkaensis/Carex/Juncus	match
PORE6-15	Rush - NA	match
PORE6-15	Tufted Hairgrass - NA	match
PORE6-16	Coyote Brush - B.p. consanguinea/Lupinus arboreus /Lupinus chamissonis	match
PORE6-16	Dune Sagewort - Goldenbush Complex Mapping Unit - NA	match
PORE6-16	Dunes - NA	no
PORE6-16	European Dunegrass - NA	match
PORE6-16	Rush - NA	match
PORE6-5	Coyote Brush - B.p. consanguinea/Lupinus arboreus /Lupinus chamissonis	match
PORE6-5	Dune Sagewort - Goldenbush Complex Mapping Unit - NA	match
PORE6-5	Dunes - NA	match
PORE6-5	European Dunegrass - NA	match
PORE6-7	Coyote Brush - B.p. consanguinea/Lupinus arboreus /Lupinus chamissonis	match
PORE6-7	Dune Sagewort - Goldenbush Complex Mapping Unit - NA	match
PORE6-7	European Dunegrass - NA	match
PORE6-7	Iceplant (Carpobrotus edulus) - NA	match
PORE6-7	Tufted Hairgrass - NA	no
PORE7-1	Coyote Brush - B.p. consanguinea/Lupinus arboreus /Lupinus chamissonis	match
PORE7-1	Dune Sagewort - Goldenbush Complex Mapping Unit - NA	match
PORE7-1	Yellow bush lupine - NA	match

[1] Vegetation Association column includes Calveg plant association first and includes the associated 1994 Plant Association where mapped; if no 1994 association, marked as NA

[2] 'match' = yes, there are unoccupied locations; 'no' = no matching unoccupied locations

4.7.8. Summary of Resource Condition

The Critical Questions posed for rare plant resources at PORE were the following:

1. What is the current status and distribution of rare species of interest within PORE?
2. What significant stressors are currently affecting these species?

3. What habitats or regions within PORE have a high incidence of endangered and threatened plants of interest? How are these areas distributed?
4. Are the areas of greatest known rare species occurrences within certain habitat types that may have a larger distribution within PORE?

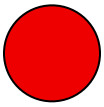
The first two Critical Questions were addressed in Section 4.7.3 to 4.7.6 for each of the four species of interest: beach layia (*Layia carnosa*), Sonoma spineflower (*Chorizanthe valida*), Tidestrom's lupine (*Lupinus tidestromii*), and Sonoma alopecurus (*Alopecurus aequalis* var. *sonomensis*). The condition of four 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 (Section 4.7.7). The condition and confidence in assessment for each of the three indicators are summarized below.

In general, the natural populations that had been observed within PORE lands (excluding historical observations) continued to persist under PORE management and monitoring. The condition of the Sonoma alopecurus natural wild populations warranted moderate concern as one population was considered extirpated and two had not been observed in recent years, indicating potential extirpation. However, two new Sonoma alopecurus population have been found in recent years (L. Parsons pers. comm. 2015). Recent NPS reporting was missing for beach layia and was unable to supplement the USFWS 5-year Report (USFWS 2012). Therefore, the current condition of the natural populations and any introduction efforts was therefore unknown and omitted from the summary of condition status for the first two indicators.

Although the one introduction attempt of Tidestrom's lupine failed, the failure is offset by the fact that restoration at Abbotts opened up 80 new acres for colonization, and more than 74,000 plants have become established (L. Parsons pers. comm. 2015). The success of recent Sonoma alopecurus introductions can't be determined at this point (L. Parsons pers. comm. 2015). The Sonoma spineflower planting efforts proved overall successful as evidenced in population monitoring in the years since planting, although a large effort in 2011 had only been monitored for two to three years (Table 4.7.7).

Many of the recovery criteria outlined in Recovery Plans for the species of interest were in progress or met for PORE populations. Most criteria involved preservation of habitat, management of threats, and introduction of new populations. No Recovery Plan has been created for Sonoma alopecurus. Therefore, no recovery criteria were available for this review.

Table 4.7.7. Resource condition summary for rare plants at Point Reyes National Seashore.

Indicator of Condition	Specific Measure	Condition Status	Rationale
How many of the natural populations observed since 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 four species of interest, two were in good condition, and one had a condition that warranted moderate concern. One condition was unknown. Three conditions had moderate confidence in the rating and one had low confidence. The unknown condition was omitted from this summary.
Have introduction efforts been successful?	Proportion of successful introductions into new sites. This does not include natural populations.		Of the four species of interest, the condition of one warranted moderate concern, and two warranted significant concern. One condition was unknown. Two conditions had moderate confidence in the rating and one had low confidence. The unknown condition was omitted from this summary.
Have the USFWS Recovery Plan goals been fulfilled for populations within PORE 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 four species of interest, three were in good condition. One condition was unknown. Three conditions had moderate confidence in the rating and one had low confidence. The unknown condition was omitted from this summary.
Overall condition and trend of rare plants			–

4.7.9. 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, personal communication with NPS staff, and data collected by NPS or affiliates. Selection of indicator conditions and specific measures were chosen in consultation with PORE staff in order to represent the condition of the species of interest.

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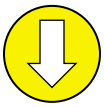
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4.8. Salmonids/Steelhead Trout



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.

4.8.1. 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 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). 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 for informing 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.

4.8.2. 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, DW 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 D along with watershed/creek characteristics. We also provide a more detailed account of each survey location and corresponding fish data in Carlisle Et al. 2018. 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 Carlisle Et al. 2018 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 SFAN 2018 for description of barrier classification). For example, if a report indicated the presence of a barrier, we included it in SFAN 2018on 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, and remediated barriers that have not been examined to determine passability, and barriers where passability is unknown. CFPAD barrier data can be found in SFAN 2018 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 D, found at the end of this document, 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. Carlisle Et al. 2018 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 SFAN 2018 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 (Figure 4.8.1 and Figure 4.8.2) and San Mateo counties (Figure 4.8.3 and Figure 4.8.4) and maps that show the location of barriers in Marin (Figure 4.8.5 and Figure 4.8.6) and San Mateo (Figure 4.8.7 and Figure 4.8.8) counties. 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.

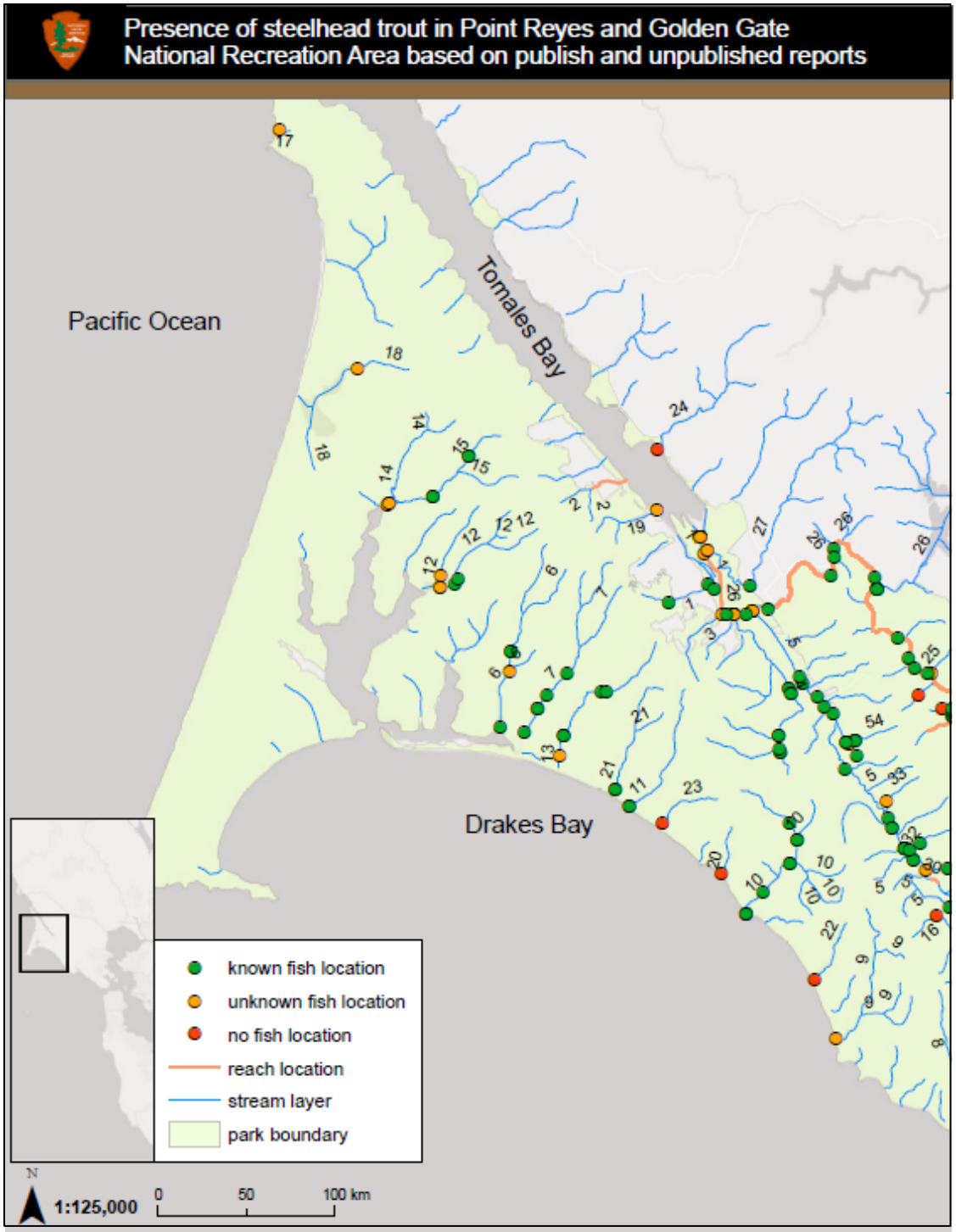


Figure 4.8.1. Map showing location of steelhead survey data for sites in northern Marin County. “Known fish location” represents survey data taken at a specified site within a stream. “Unknown fish location” represents survey data from a specific stream, but where no finer-scale information was provided 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”.

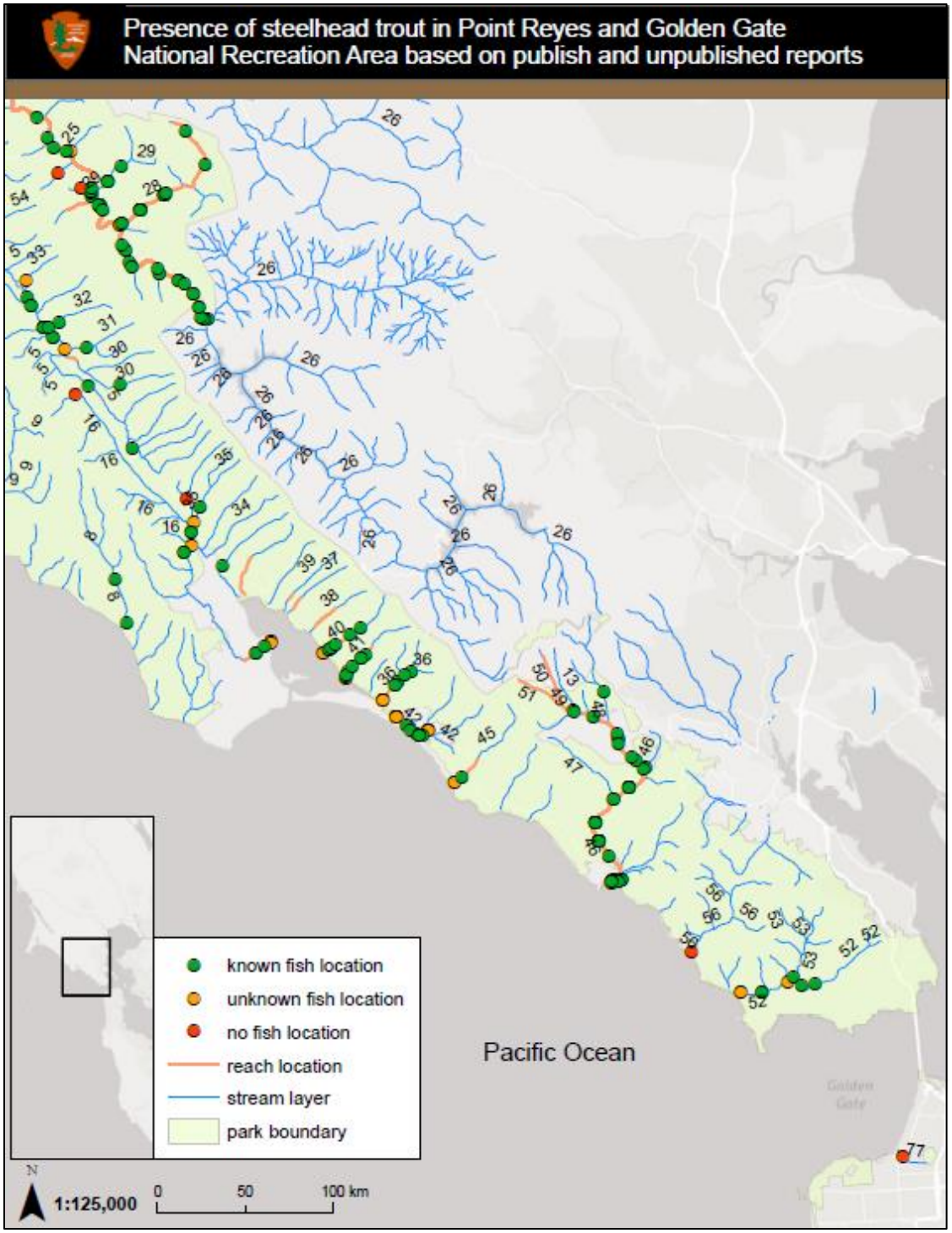


Figure 4.8.2. Map showing location of steelhead survey data for sites in southern Marin County. “Known fish location” represents survey data taken at a specified site within a stream. “Unknown fish location” represents survey data from a specific stream, but where no finer-scale information was provided 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”.

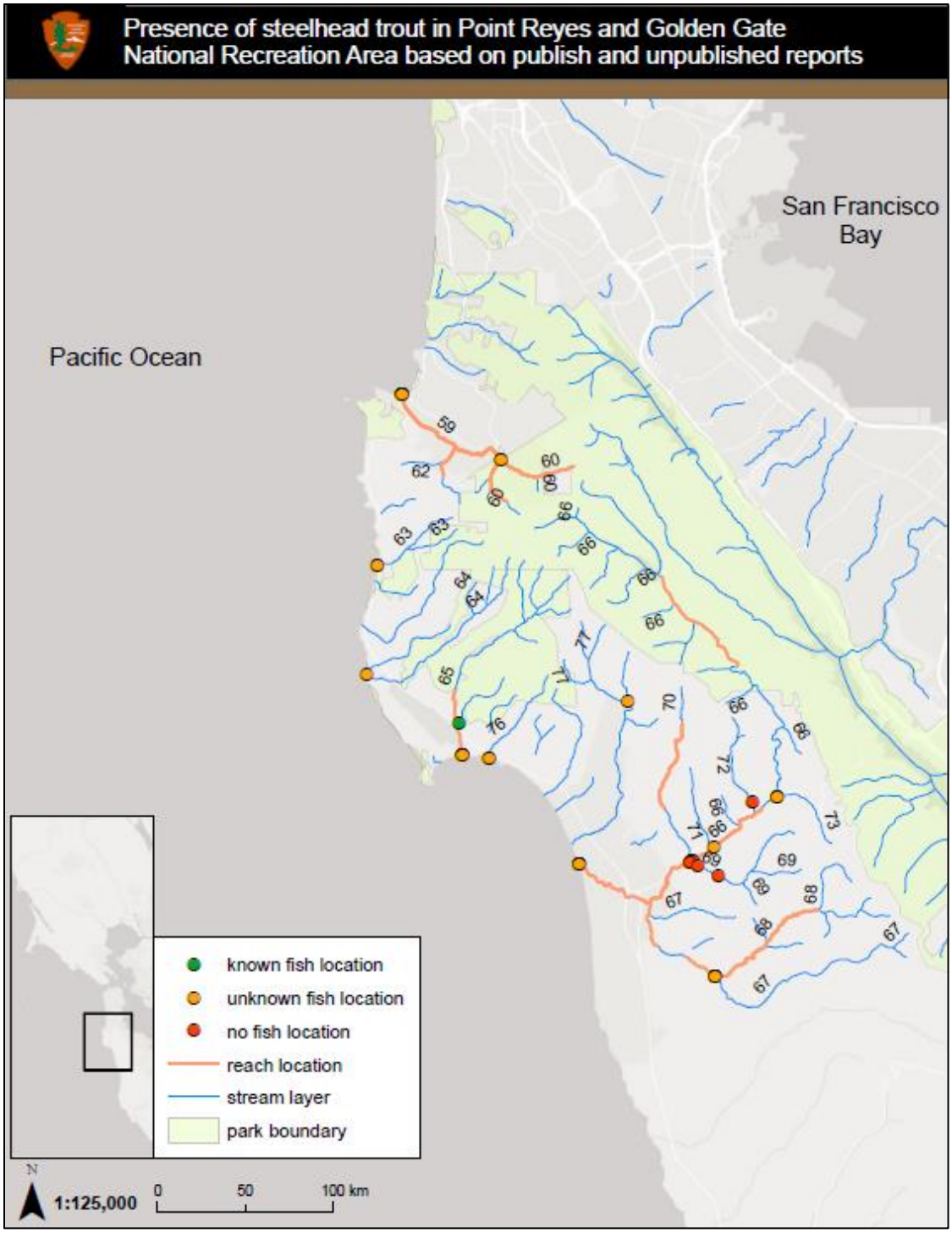


Figure 4.8.3. Map showing location of steelhead survey data for sites in northern San Mateo County. "Known fish location" represents survey data taken at a specified site within a stream. "Unknown fish location" represents survey data from a specific stream, but where no finer-scale information was provided 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".

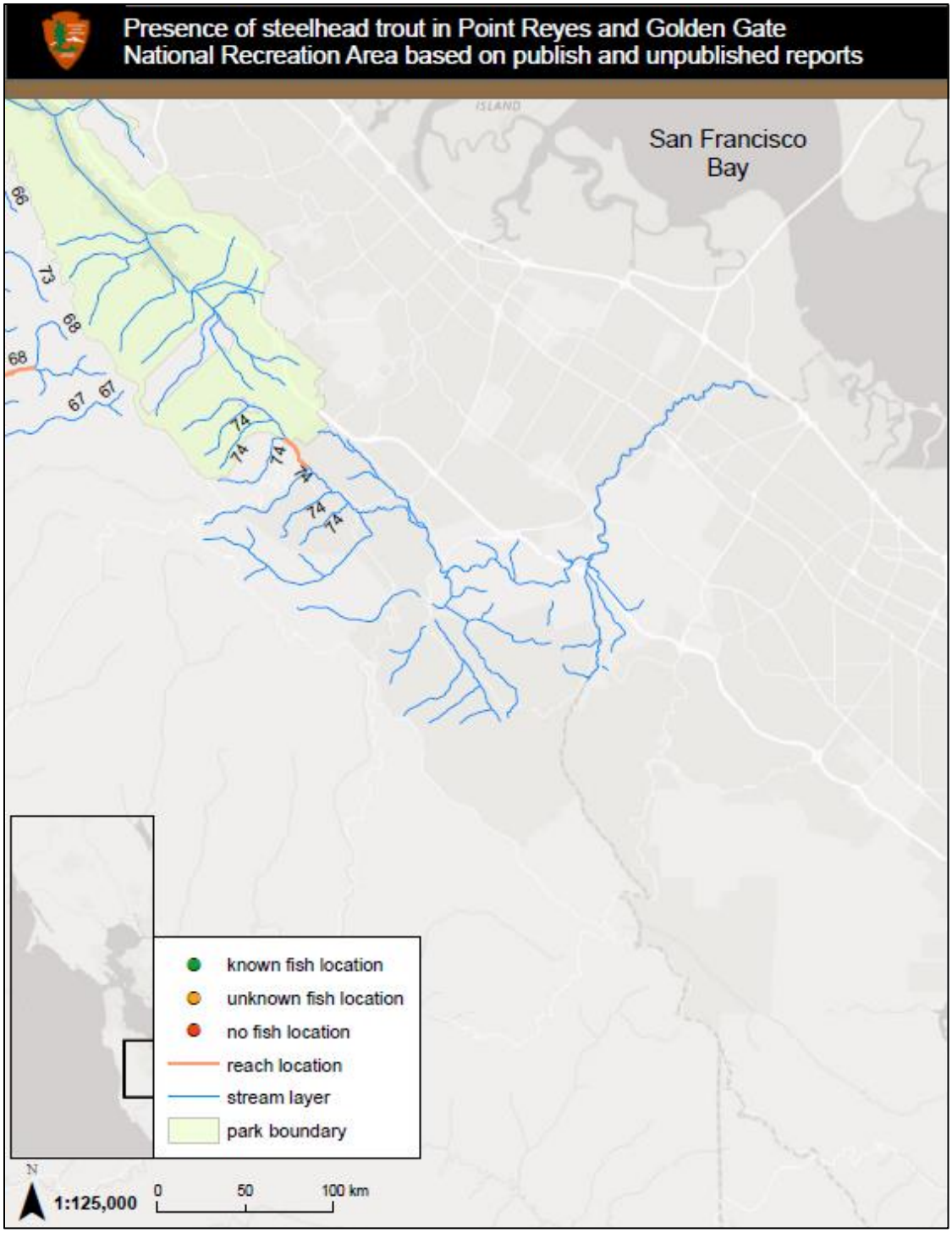


Figure 4.8.4. Map showing location of steelhead survey data for sites in southern San Mateo County. "Known fish location" represents survey data taken at a specified site within a stream. "Unknown fish location" represents survey data from a specific stream, but where no finer-scale information was provided 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".

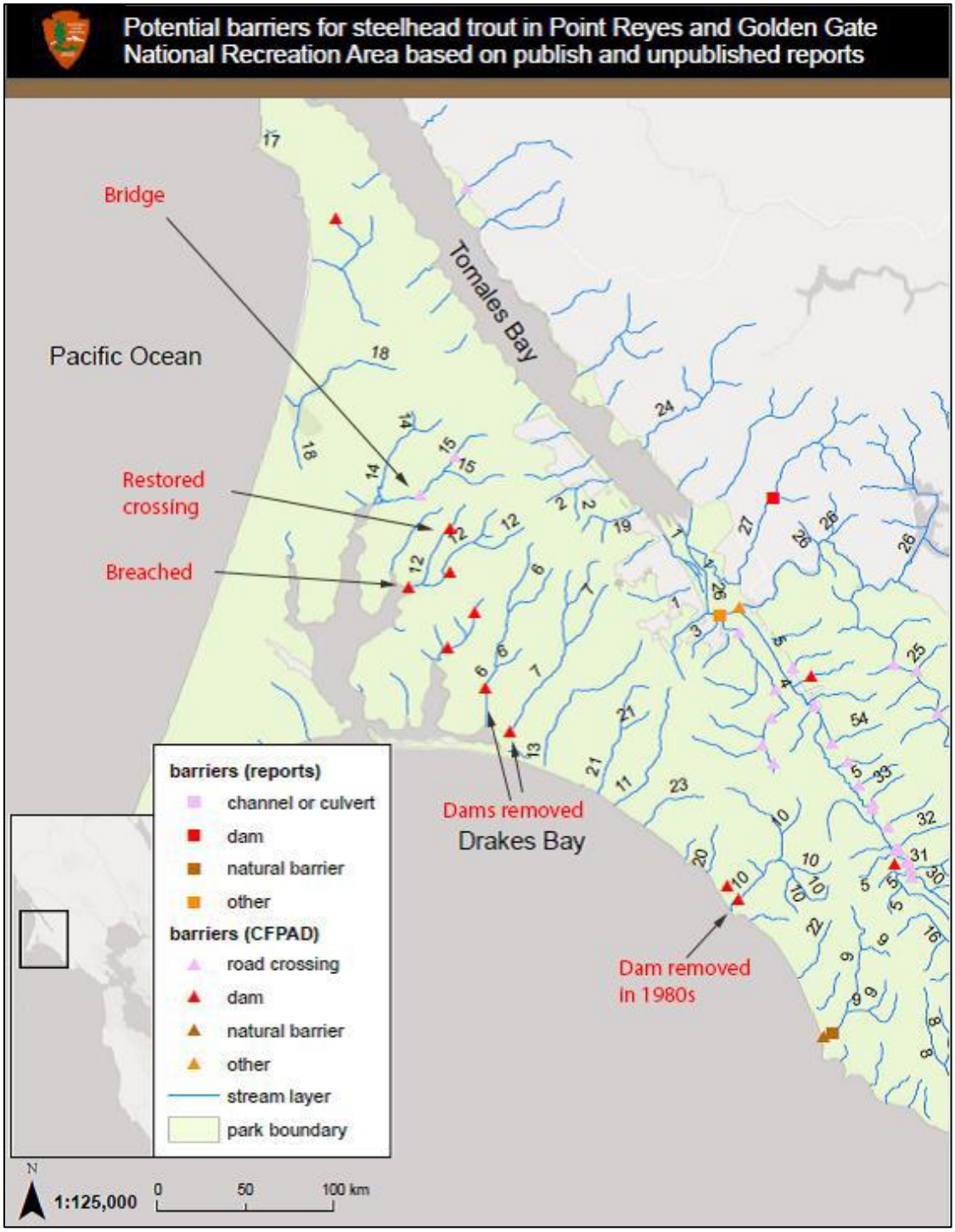


Figure 4.8.5. Map showing barrier data for sites in northern Marin County. Squares represent barrier data obtained through a literature search and via personal communications. Triangles represent data collected from the California Fish Passage Assessment Database (CFPAD). Colors represent different barrier types. Recent efforts of Point Reyes National Seashore to remove and restore barriers are noted.

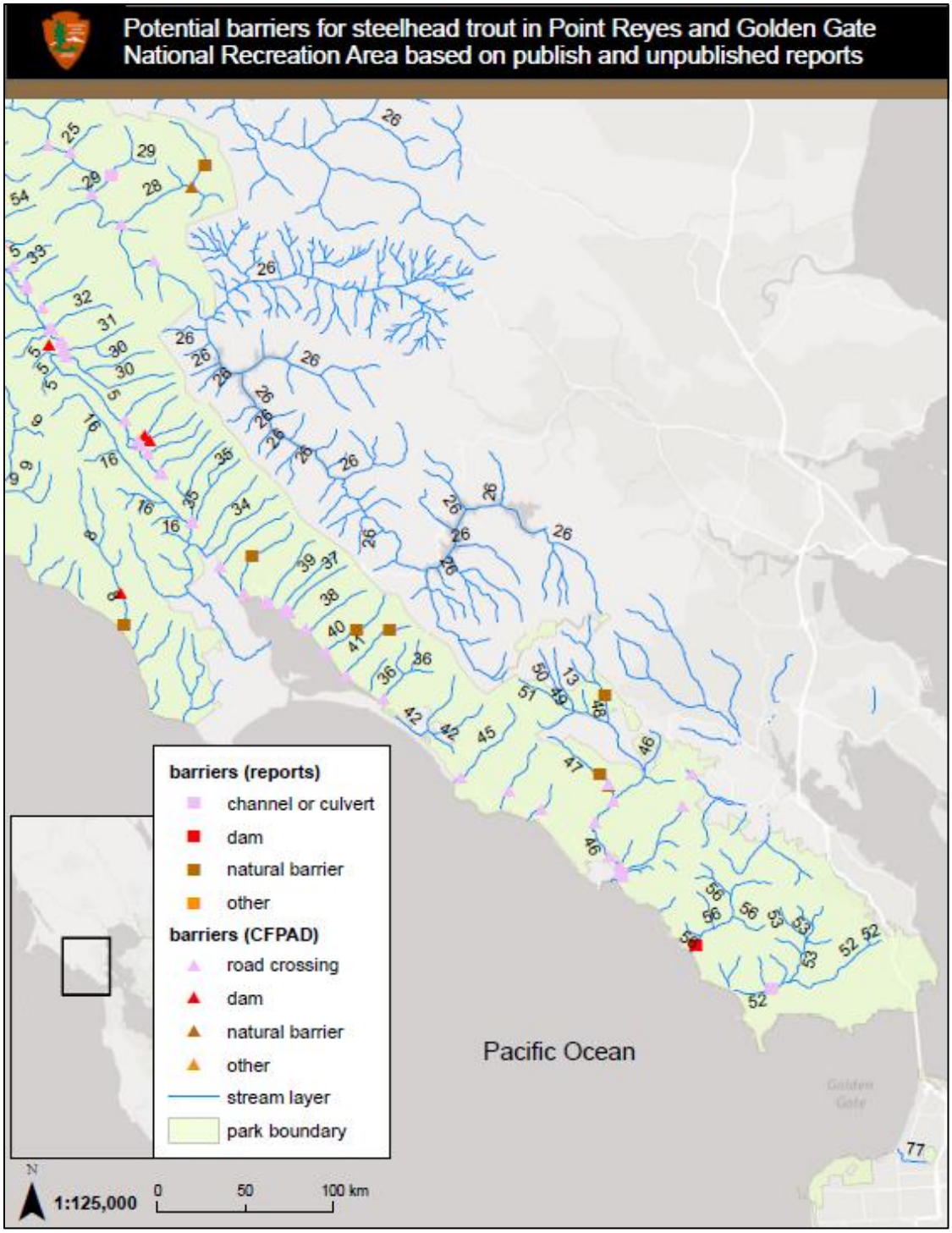


Figure 4.8.6. Map showing barrier data for sites in the southernmost region of Marin County. Squares represent barrier data obtained through a literature search and via personal communications. Triangles represent data collected from the California Fish Passage Assessment Database (CFPAD). Colors represent different barrier types.

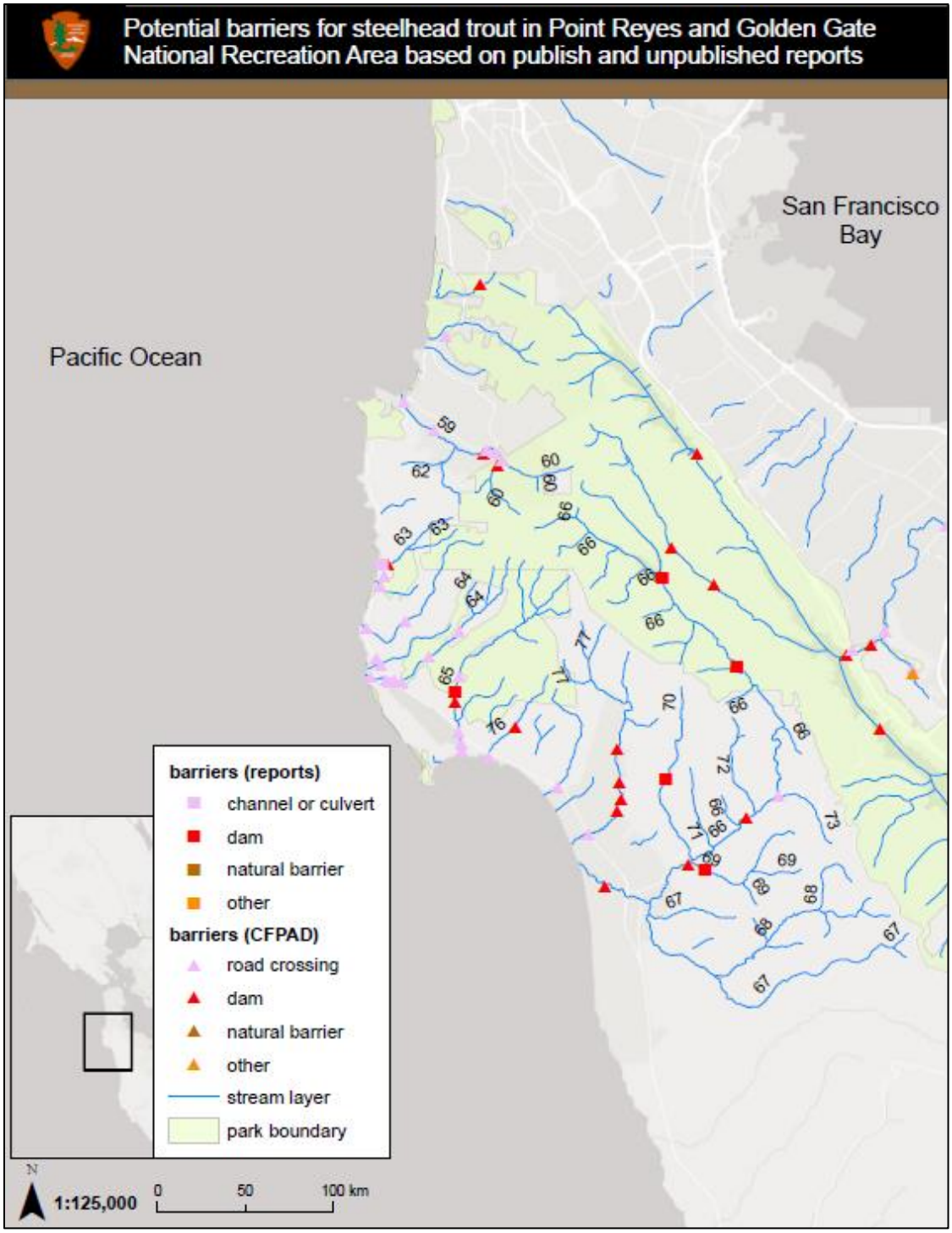


Figure 4.8.7. Map showing barrier data for sites in the northernmost region of San Mateo County. Squares represent barrier data obtained through a literature search and via personal communications. Triangles represent data collected from the California Fish Passage Assessment Database (CFPAD). Colors represent different barrier types.

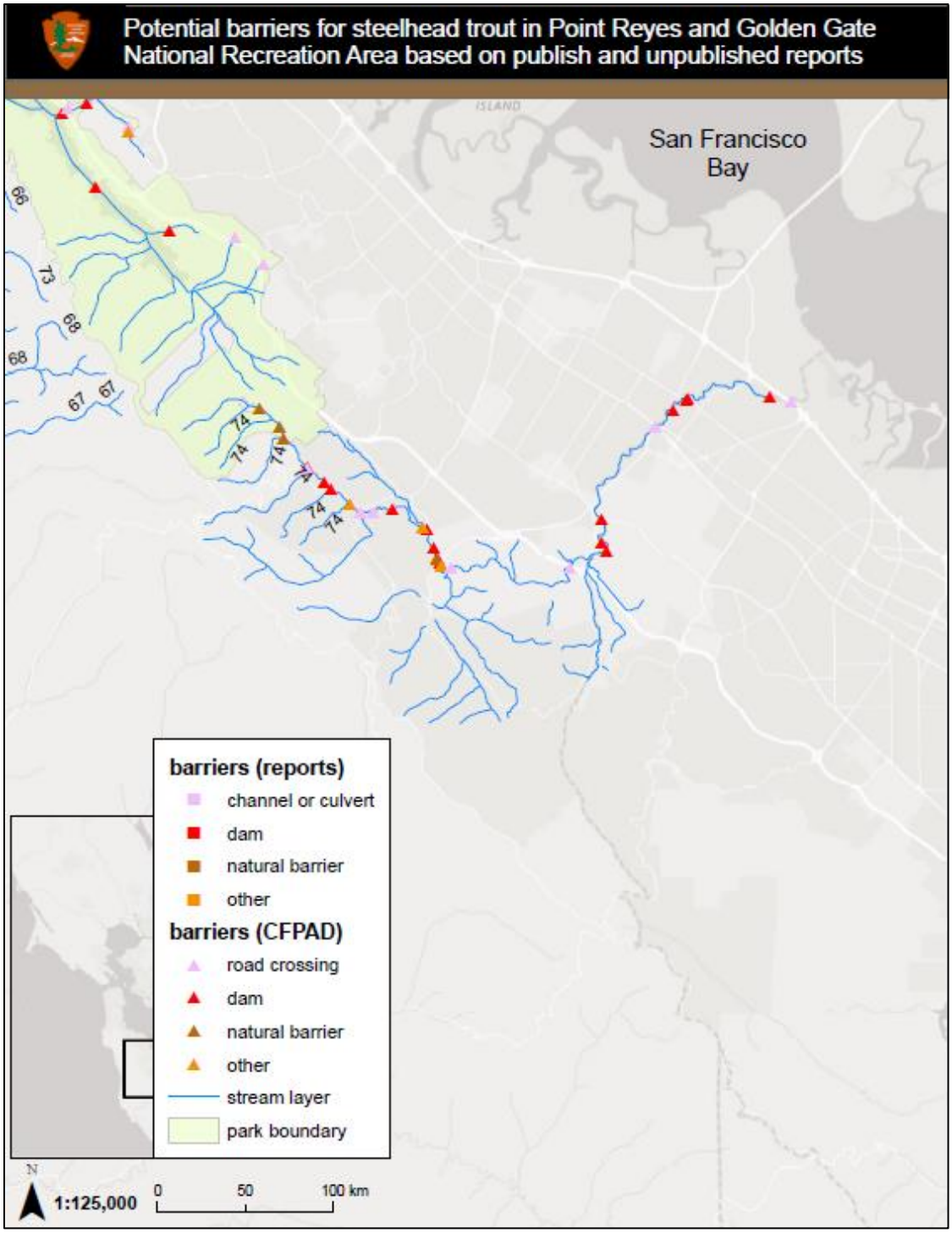


Figure 4.8.8. Map showing barrier data for sites in the southernmost region of San Mateo County. Squares represent barrier data obtained through a literature search and via personal communications. Triangles represent data collected from the California Fish Passage Assessment Database (CFPAD). Colors represent different barrier types.

4.8.3. 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 Carlisle Et al. 2018). 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 D.

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 (Figure 4.8.1 and Figure 4.8.2). In San Mateo County, we estimated that there were approximately 13 streams, and we were able to find information on 12 of these (Figure 4.8.3 and Figure 4.8.4). 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 Carlisle Et al. 2018) 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 (Figure 4.8.5 and Figure 4.8.6), 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 4.8.7), 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 4.4.8) 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 2007). 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 D.

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 Carlisle Et al. 2018), 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

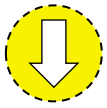
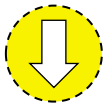
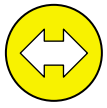
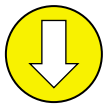
presence, including after the drought breaks, will be important for understanding the trajectory of steelhead in PORE and GOGA lands.

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.

Summary of Resource Condition

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 (Table 4.8.1). 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 2012) and the relatively short time frame (20 years represents ~5 steelhead generations).

Table 4.8.1. Resource condition summary for steelhead at Point Reyes National Seashore.

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		
Migration barriers	Number of invasive species		Improved fish passage in some streams; many barriers remain
Overall condition and trend of steelhead			–

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.

4.8.4. 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

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- 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.

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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 Point Reyes National Seashore. 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 5.1.1. 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.

Table 5.1.1. 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.

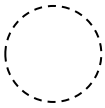
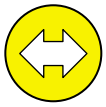
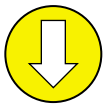
Focal Resource	Condition Status/Trend	Rationale
Amphibians		Pond-breeding amphibians are widespread, but little is known about stream-breeding amphibians or terrestrial salamanders. California red-legged frogs are widespread in multiple habitats. American bullfrogs are present and negatively affect native species but are limited to a small proportion of sites.
Breeding Landbird Diversity		When riparian species population trends are compared between GOGA/PORE and the larger regional dataset of the California Breeding Bird Survey, the GOGA/PORE populations reflect a greater stability over all species. Low confidence results from lack of data for assessing population trends in other habitats.
Coastal Dunes		PORE has a significant portion of the remaining native dune vegetation in Northern California. The Seashore is continuing exotic species management on selected sites. There is a need for quantitative information in a framework that will allow for better community descriptions, assessment of condition trends, and adaptive management.

Table 5.1.1 (continued). 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
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.
Grasslands		Exotic plants have increased in frequency and abundance in the coastal grasslands and coyote brush may be encroaching. A coastal prairie indicator species, California oatgrass, has declined in frequency and abundance.
Invasive Plants		The total number of invasive plant species and the number of new introductions are high enough to warrant significant concern. Confidence in existing data varies by indicator and is limited by the relatively short time span.
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 warrant moderate concern and are in decline in the region. Fish passage has been improved for some streams; however, numerous barriers still remain. Additionally, other stressors that were not assessed pose a significant threat to populations in this region and elsewhere.

The majority of the focal natural resources at PORE were determined to be in moderate or good condition (Table 5.1.1). Of the eight resources featured in this assessment, three were rated as being in moderate condition: forests, grasslands, and steelhead. Three resources, breeding birds, amphibians and rare plants, were categorized as being in good condition and only the condition of invasive plants was considered to be of significant concern. There was not sufficient information available to determine the condition of the coastal dunes. For the five resources with sufficient information to determine a trend in condition, two exhibited a declining trend (grasslands and steelhead populations) and three were categorized as exhibiting a stable trend (amphibian populations, breeding bird diversity, and forest resources; Table 5.1.1). It is also important to note that none of the resources had a high confidence ranking for the assessment. The confidence associated with each assessment was ranked as medium for all resources, except for breeding bird diversity, coastal dunes, 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 PORE management zone (i.e., natural lands, wilderness, and pastoral lands; see Figure 3.2.1 for the locations of these zones within PORE).

In the final assessment, only coastal grasslands, invasive plants 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 the management zones (i.e., some resources were located primarily in one management zone). While limited, 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 Natural Zone had the largest number of invasive species of the three management zones both by absolute number and when considered relative to the total area in each zone. The Wilderness Zone had the lowest number of invasive plant species with 64 recorded species. However, few trends or big picture conclusions emerged from the management zone analyses, in part, due to lack of variation in condition assessment by management zone. Further, the wide variations 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.

Determining an overall condition of PORE 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 Point Reyes National Seashore NRCA focused on species or communities (i.e., little focus on air and climate, water quality, landscape, and human use categories). All eight of the focal natural resources selected for inclusion in the PORE NRCA were focal species or communities classified in the biological integrity category of the NPS Ecological Monitoring Framework. Lastly, due to its ecological diversity 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. Howerver for the subset of resources included, the resource condition assessments suggest that Point Reyes National Seashore is generally in moderate or good condition. However there is wide variation in the assessed condition of the studied resources and within the indicators assessed for each resource.

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 Point Reyes National Seashore's NRCA framework is summarized in the tables and resource briefs included 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 16 of the 25 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

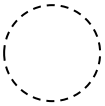
Amphibian declines are a nearly worldwide phenomenon (Blaustein and Wake 1990, Wake 1991, 2012, Stuart et al. 2004, Wake and Vredenburg 2008, Adams et al. 2003). In California, declines of several species, including California red-legged frogs (*Rana draytonii*), southern mountain yellow-legged frogs (*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 (Table 5.1.2). 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. 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 5.1.2. Resource condition summary for amphibians at Point Reyes National Seashore.

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 and trend of amphibians			–

5.1.2. Resource Brief: Breeding Landbirds

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 and PORE (Flannery et al. 2001, Gardali et al. 2010). Riparian landbird population trends appear to have a general pattern of stability (Table 5.1.3). When riparian species population trends are compared between GOGA/PORE and the larger regional dataset of California Breeding Bird Survey, the trends from GOGA/PORE reflect a greater stability overall species. Therefore, the

condition of the landbird focal resource including all habitats for GOGA/PORE warrants low concern.

Table 5.1.3. Resource condition summary for breeding landbirds at Point Reyes National Seashore.

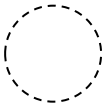
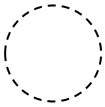
Indicators of Condition	Specific Measures	Condition Status	Rationale
Understanding of Status	Spatial and temporal distribution of survey effort		Survey effort and timing used replicated techniques and were distributed throughout the habitat of interest.
Habitats analyzed	Number of habitats with trend 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 trend models are a mix of declining, increasing and neutral trends. No other population trends available.
Overall condition and trend of breeding landbirds			–

5.1.3. Resource Brief: Coastal Dunes

Coastal Dunes at Point Reyes are an important resource element with high regional conservation value. Coastal dunes also present formidable problems for conservation, management, and restoration at multiple spatial and temporal scales. Goals, management practices, and monitoring methods need careful development in a highly dynamic environment dominated by sharp physical gradients and rapid changes in the biota. Dunes have long been significantly affected by human activities (Table 5.1.4).

The strongest influence on coastal dune biota is the physical substrate of mobile sand. European beachgrass (*Ammophila arenaria*), which produces rhizomes and is favored by less substrate mobility, was widely planted in the mid-20th century in an attempt to stabilize coastal dunes but is now recognized as a major threat to natural processes and native species There is widespread support for the notion that exotic species, especially European beachgrass and iceplant, now dominate some parts of the Dune environment. Control of the two most common exotic plants is feasible. Control should be implemented and followed through effectiveness monitoring and adaptive management. This monitoring will work best if directly tied to Ecological Site Descriptions and well-developed state and transition models. Not enough information was available to determine the current condition and trend of the coastal dunes in PORE.

Table 5.1.4. Resource condition summary for coastal dunes at Point Reyes National Seashore.

Indicator of Condition	Specific Measure	Condition Status	Rationale
Are Ecological Site Descriptions with associated state and transition models likely to offer good predictions for the effects of management and environmental change on coastal dunes?	Ecological Site Descriptions with associated state and transition models		Data not provided sufficient to initiate development of ESDs
Overall condition and trend of coastal dunes			–

5.1.4. Resource Brief: Forests

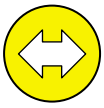
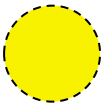
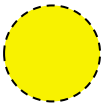
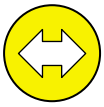
Collectively the forests at PORE provide essential structure and function to the ecosystem. The trees along the slopes of Inverness and Bolinas ridges greatly diversify the available habitat that in turn supports a wide range of organisms including threatened and endangered species like the northern spotted owl (*Strix occidentalis*, Forrestel et al. 2015) and the Point Reyes mountain beaver (*Aplodontia rufa phaea*, Fellers et al. 2004). 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). The forests account the vast majority (95%) of the 910 Gg of carbon stored in the aboveground live vegetation at PORE (Gonzalez et al. 2015).

Primary risks to the forest at PORE include climate change, an altered fire regime, and the spread of exotic pathogens. By one account, shifts in vegetation resulting from projected changes in climate could result in the near elimination of the mixed evergreen forest by 2100 (Hameed et al. 2013). Fire is a major driver of vegetation in the American West and the natural fire regime has been greatly disrupted but its role in these coastal forests is complex (Forrestel 2013). In contrast, there is no doubt regarding the impact of the introduced pathogen, *Phytophthora ramorum*, the causal agent of Sudden Oak Death (SOD). It has resulted in the widespread mortality of tanoak at PORE (Ramage et al. 2010, Ramage et al. 2011) and has the potential to impact coast live oak as well (McPherson et al. 2010). More recently, another exotic forest pathogen has arrived. Pitch canker (*Fusarium circinatum*) has spread to the bishop pine forests (Harvey et al. 2014). Given that pitch canker disperses widely in coastal regions (Ganley et al. 2009) and the susceptibility of bishop pine (UC IPM 2013), the disease has the potential to hasten the demise of the older stands and disrupt the ongoing recovery from the Vision Fire (Harvey and Holzman 2014).

The ecological integrity of forests is an integrative measure that considers the structure, composition and function of the forest (Tierney et al. 2009). At PORE, the progression of *P. ramorum* in the Douglas-fir/Coast Redwood Forest and the Hardwood Forest is having a widespread impact via the increased mortality of susceptible tree species (Table 5.1.5). The declines in tanoak and coast live oak 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 a 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 PORE lacks the comprehensive site-specific data needed to assign high confidence to this assessment.

Table 5.1.5. Resource condition summary for forests at Point Reyes National Seashore.

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 high intensity fire	Fire hazard model		Existing models differ on the extent of the hazard posed but agree that the dense stands of bishop pine established after the Vision Fire face severe fire hazard. Impacts of wildfire mitigated by suppression
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 and trend of forests			–

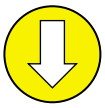
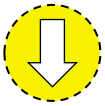
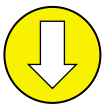
5.1.5. Resource Brief: Coastal Grasslands

Coastal grasslands form a major landscape component at PORE. Grasslands are the primary resource for sustaining authorized pastoral activities and are also of high conservation interest and value. California's coastal prairie has been subjected to many disturbances including cultivation, land

development, invasive species, and livestock grazing. These factors have had variable effects on resource condition, which need assessment and should inform updating of older plans (e.g., Shook 1990). Statewide, the type has been considerably reduced in general extent, and the National Park Service has an important role to play in protecting and enhancing this resource (Ford and Hayes 2007, Hopkinson and Bartolome 2009).

Exotic plants have extensively invaded and occupied PORE coastal grassland, especially rye grass (*Festuca perennis*) and common velvet grass (*Holcus lanatus*). The prospects for significantly reducing common exotic annuals are poor. In addition, the native shrub coyote brush (*Baccharis pilularis*) has encroached into PORE coastal grasslands. An important coastal prairie native grass, California oatgrass (*Danthonia californica*), declined significantly at PORE between 1988 and 2011, decreasing on 24 of the 37 transects on which it occurred. These factors resulted in an assessment of moderate concern with a declining trend for coastal grasslands.

Table 5.1.6. Resource condition summary for grasslands at Point Reyes National Seashore.

Indicator of Condition	Specific Measure	Condition Status	Rationale
Invasion of exotic plant species	An increase in exotic plant species on 51 transect plots in grazed areas of Point Reyes.		The most common species observed was an exotic, rye grass (*Festuca perennis*), although no trend in abundance observed. Exotic annual grass false brome (*Brachypodium distachyon*) significantly increased. Invasive perennial grass common velvet grass (*Holcus lanatus*) present on 23 transects and increased between 1988 and 2011 on 15 of those transects.
Encroachment of shrub/tree species	An increase in shrub frequency/abundance on 51 transect plots in grazed areas		On 6 transects, coyote brush (*Baccharis pilularis*) increased significantly by 2010, although these 6 transects were grazed during this period. Dataset limited.
Decrease in frequency/ abundance of desired native plant species	A decrease in frequency/abundance of desired native plant species on 51 transect plots in grazed areas		Native perennial bunchgrass California oatgrass (*Danthonia californica*) declined significantly between 1988 and 2011, decreasing on 24 of the 37 transects. Dataset limited.
Overall condition and trend of grasslands			–

5.1.7. Resource Brief: Invasive Plants

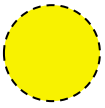
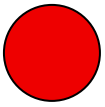
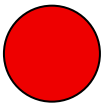
The current rate of invasive species introductions is unprecedented, and the dramatic impacts of invasive plant species on community and ecosystem function have been well documented (Vitousek and Walker 1989, D'Antonio and Vitousek 1992, Gordon 1998, Mack et al. 2000). Invasive species have been directly 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 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." 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). PORE has a great interest in understanding how invasive plants occur on the landscape. Introductions and rates of invasion may be reduced by identifying invasion pathways and prioritizing the species and areas most in need of management.

PORE has a high number of invasive plant species and new introductions recorded from 2011 to 2014 (Table 5.1.7). These indicators suggest that invasive plants in PORE are a significant concern. The condition of each individual indicator was ranked as either moderate or significant concern for each management zone. The data likely underestimates plant invasion indicators because of the limited area surveyed. In addition, the accuracy of comparisons among management zones is reduced because the percent of land area surveyed in each zone varied. Confidence in existing data varies by indicator and is limited by the relatively short span of Early Detection surveys.

Table 5.1.7. Resource condition summary for invasive plants at Point Reyes National Seashore

Indicators of Condition	Specific Measures	Condition Status	Rationale
Propagule pressure/invasibility	Number of new introductions		5 additional invasive species documented since 2011
Potential for spread	Number of invasive species		More than 100 invasive plant species documented
Overall condition and trend of invasive plants			–

5.1.7. 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-

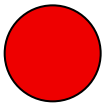
rare Mediterranean climate have allowed for the diversification of a unique assemblage of plant species (Médail and Pierre Quézel 1999, Calsbeek et al. 2003). California, and the San Francisco Bay Area in particular, is under major development pressure to support a growing population (Lewis and Neiman 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 populations in California (Falk and Holsinger 1991). The conservation of public lands by the National Park Service, including PORE, protects landscapes and their associated rare flora, while providing for management of those species.

Four rare plant taxa found within PORE-managed lands were selected for a review of status and distribution: Beach layia (*Layia carnosa*), Sonoma spineflower (*Chorizanthe valida*), Tidestrom's lupine (*Lupinus tidestromii*), and Sonoma alopecurus (*Alopecurus aequalis* var. *sonomensis*) (Table 5.1.8). Additional rare plant taxa were selected for a more general geospatial analysis of habitat and distribution. These four species are of interest due to the small size of their populations as well as the unknown effects that grazing, climate change, and invasive plant species may have on their abundance and distribution. The Sonoma spineflower and Sonoma alopecurus occur in cattle grazed landscapes where grazing seems to be beneficial. However, the effects of grazing management practices should be monitored to ensure that the grazing practices benefit or have no negative effect on the species. All four species are being outcompeted by native and/or non-native invasive plants. This is particularly serious in the case of Tidestrom's lupine, where the invasive species not only outcompete the lupine for resources, but also shelter small mammalian predators which consume the lupine's seeds both pre and post dispersal.

In general, the natural populations that had been observed within PORE lands continued to persist under PORE management and monitoring. The condition of the Sonoma alopecurus natural wild populations warranted moderate concern as one population was considered extirpated and two had not been observed in recent years, indicating potential extirpation. However, two new Sonoma alopecurus population have been found in recent years (L. Parsons pers. comm. 2015). Recent NPS reporting was missing for beach layia and was unable to supplement the USFWS 5-year Report (USFWS 2012). Therefore, the current condition of the natural populations and any introduction efforts was therefore unknown and omitted from the summary of condition status for the first two indicators.

Although the one introduction attempt of Tidestrom's lupine failed, the failure is offset by the fact that restoration at Abbotts opened up 80 new acres for colonization, and more than 74,000 plants have become established. The success of recent Sonoma alopecurus introductions can't be determined at this point (L. Parsons pers. comm. 2015). The Sonoma spineflower planting efforts proved overall successful as evidenced in population monitoring in the years since planting, although a large effort in 2011 had only been monitored for two to three years.

Table 5.1.8. Resource condition summary for rare plants at Point Reyes National Seashore.

Indicator of Condition	Specific Measure	Condition Status	Rationale
How many of the natural populations observed since PORE 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 four species of interest, two were in good condition, and one had a condition that warranted moderate concern. One condition was unknown. Three conditions had moderate confidence in the rating and one had low confidence.
Have introduction efforts been successful?	Proportion of successful introductions into new sites. This does not include natural populations.		Of the four species of interest, the condition of one warranted moderate concern, and two warranted significant concern. One condition was unknown. Two conditions had moderate confidence in the rating and one had low confidence.
Have the USFWS Recovery Plan goals been fulfilled for populations within PORE 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 four species of interest, three were in good condition. One condition was unknown. Three conditions had moderate confidence in the rating and one had low confidence.
Overall condition and trend of rare plants			–

Many of the recovery criteria outlined in Recovery Plans for the species of interest were in progress or met for PORE populations. Most criteria involved preservation of habitat, management of threats, and introduction of new populations. No Recovery Plan has been created for Sonoma alopecurus. Therefore, no recovery criteria were available for this review.

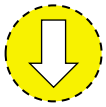
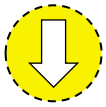
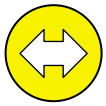
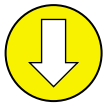
5.1.8. Resource Brief: Steelhead

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). We expect that such declines or local extirpations of 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).

The goal of this assessment was to determine the presence and abundance of steelhead within streams in the PORE and GOGA regions (Table 5.1.9). Such information could be useful to natural resource managers for informing 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. 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.

Table 5.1.9. Resource condition summary for steelhead at Point Reyes National Seashore.

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		
Migration barriers	Number of invasive species		Improved fish passage in some streams; many barriers remain
Overall condition and trend of steelhead			–

Of the 60 creeks in Marin County for which we were able to obtain 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 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.

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 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 2012). Our 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.

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 Point Reyes National Seashore. 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 the conditions of the important natural resources within Point Reyes National Seashore.

Several stressors were identified that influence the condition of multiple priority resources within PORE. Table 5.2.1 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, the presence of non-native species, and habitat loss due to human activity (Table 5.2.1). Improved understanding of these threats, and how they relate to the condition of the assessed focal resources, can help PORE to prioritize management objectives and better focus conservation strategies to maintain the integrity of park ecosystems.

Table 5.2.1. Summary of the stressors considered most significant for each of the assessed focal resource at Point Reyes National Seashore.

Stressor	Focal Resource
Climate change	• Breeding Landbird Diversity • Forests • Invasive Plants • Grasslands • Rare Plants
Pests, pathogens, disease	• Amphibians • Forests • Invasive plants • Rare Plants
Introduced species	• Amphibians • Coastal Dunes • Grasslands • Rare Plants
Habitat loss	• Amphibians • Rare Plants • Salmonids
Altered fire regime	• Forests • Invasive plants
Contaminants	• Amphibians

Table 5.2.1 (continued). Summary of the stressors considered most significant for each of the assessed focal resource at Point Reyes National Seashore.

Stressor	Focal Resource
Fragmentation	• Invasive plants
Overharvest	• Amphibians
Genetic bottleneck	• Rare plants
Migration barriers	• Salmonids
Shrub/Tree encroachment	• Grasslands

Perhaps the greatest threat to the resources within PORE 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, grasslands, and rare plants) and would likely have wide-ranging impacts on many other resources in PORE. 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 PORE's coastal habitats and species.

Another important aspect of climate change is the expected sea level rise. 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.

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 5.2.2 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).

Table 5.2.2. Summary of data and research needs identified for the assessed focal resources in PORE.

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
Coastal Dunes	• Monitoring of effectiveness of efforts to control the two most common exotic plants (European beachgrass and iceplant)
Forests	• Establishment of a forest monitoring network that is measured repeatedly over time • Assessment of surface fuel loads and distribution • 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 PORE forests
Grasslands	• Critical knowledge gaps include links to small scale variations in soil properties, site potential, effects of specific grazing practices, the role of fossorial vertebrates, and potential for further exotic species spread
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
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

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 PORE, 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 PORE's natural resources. The possible effects of sea level rise in lands managed by PORE 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 PORE 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.

5.3. Conclusions

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 focal natural resources at Point Reyes National Seashore were rated as requiring moderate to low concern. However, PORE faces some significant challenges in the coming decades including climate change, exotic pests and pathogens, the presence of non-native species, and habitat loss due to human activity. 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.

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Appendix A. Annotated Bibliography for Coastal Dune Vegetation

Kent Uehara, Undergraduate Research Apprentice, UC Berkeley Range Ecology Lab

1) Alvarez, Maria E. and J. Hall Cushman. 2002. Community-Level Consequences of a Plant Invasion: Effects on Three Habitats in Coastal California. Ecological Applications 12(5): 1434–1444.

- Coastal CA (GGNRA and Mouth Tamalpais State park)
- Invasive species study on three habitats in coastal CA, one of which was a coastal scrub habitat. Species in question was Cape ivy, an invasive evergreen vine native to South Africa. Focus of the study was on the variability of the effect of invaders across seasons and habitat types. Reduction experiment conducted on invaded plots. Treatment levels ivy reduction, soil/vegetation disturbance, and undisturbed. Blocks within each habitat were sampled for vegetation cover, rooted plant species richness, and seedling abundance.
- Cape Ivy colonization was correlated with reduced seedlings (native and nonnative), reduction in species richness or native as well as nonnative taxa, and reduction in plant species diversity (namely grass and forb species). There seemed to be no significant difference between the two sampling periods (summer and winter).
- Cape ivy reduction resulted in increases in native species and nonnative species, plant species richness, and species diversity. Its success across habitat types and seasons can be attributed to its rapid growth, clonal reproduction, and environmental tolerance, which allow it to monopolize limited resources. Differences in life history and resource use likely account for the different effects on forbs and shrubs by Cape ivy invasion. Significantly, Cape ivy seemed to have negative effects on both native and nonnative species, supported by both the comparative study and the reduction study. This suggests that Cape ivy removal may facilitate colonization by other nonnatives.
- Good background and information on Cape Ivy, a pervasive invader in coastal California.

2) Barbour, Michael G. 1972. Seedling Establishment of Cakile Maritima at Bodega Head, California. Bulletin of the Torrey Botanical Club 99(1): 11–16.

- Environmental factors correlated with establishment of sea rocket (*Cakile maritama*) seedlings in Bodega Head.
- Collected data on soil temperature at varying depths and daily rainfall data, ground cover of sea rocket clumps, soil nitrogen; monitored over four months.

3) Conser, Christiana and Edward F. Connor. Assessing the Residual Effects of Carpobrotus Edulis Invasion, Implications for Restoration. Biological Invasions 11(2): 349–358.

- California (UC Davis Bodega Marine Reserve, Bodega Bay, CA); Mediterranean climate.
- *Carpobrotus edulis* (invader); *Gilia millefoliata* (rare dune annual; 1B rare species by CA Native Plant Society).

- Study on residual effects of the *C. edulis* by measuring germination, survival, growth, and reproduction of *G. millefoliata* after removal of the invader. Two treatment patches: treatment (where there was *C. edulis*, but was removed) and control (native vegetation only); which were sown with *G. millefoliata* seeds, transplanted with seedlings, or unplanted. Soil samples also collected and analyzed for moisture content, organic content, and pH.
- Results: Measurements for germination, survival of transplants, growth, and reproduction were all significantly higher in uninvaded areas. Between soils, organic content was higher in invaded soils, and pH was significantly higher in uninvaded soils. Proposed mechanism for invasion of *C. edulis* is to outcompete and physically alter the soil of the invaded plots in such a way that affect survival, germination, growth, and reproduction of other plants.
- Most transplants died within 48h of planting. Difficult to establish new plant populations in restoration projects where *C. edulis* has invaded or even been removed. Transplants were more successful, so they may be the preferred restoration planting strategy.

4) Cushman, J. Hall, Jeffrey C. Waller, and Derek R. Hoak. 2010. Shrubs as Ecosystem Engineers in a Coastal Dune: Influences on Plant Populations, Communities and Ecosystems. Journal of Vegetation Science 21(5): 821–831.

- Study of two shrubs' (*Ericamerica ericoides* and *Lupinus chamissonis*) effect on biotic (dominant plant taxa, species richness, aboveground biomass) and abiotic (nitrogen pools, mineralization rates) factors. Concludes that both shrubs are ecosystem engineers in coastal dunes.

5) DeSimone, Sandra A. 2011. Balancing Active and Passive Restoration in a Nonchemical, Research-Based Approach to Coastal Sage Scrub Restoration in Southern California. Ecological Restoration 29(1-2): 45–51.

- Starr Ranch, Orange County, CA.
- Study on adaptive management approach to coastal sage shrub system restoration.
- Restoration methods included nonchemical control of nonnative Cynara cardunculus by cutting away photosynthetic surfaces; scrub restoration via seeding of native plants; soil tamping.
- Monitoring methods included, belt transects, digital photos, and trapping for small mammals.
- Measured for plant cover, density, and height of natives.
- After three seasons of active restoration, study sites reached 30-80% cover, where there was initially 0-5%. Vegetation height also improved.

6) Huntzinger, M., R. Karban, and J.H. Cushman. 2008. Negative Effects of Vertebrate Herbivores on Invertebrates in a Coastal Dune Community. Ecology 89(7): 1972–1980.

- Study on negative interactions between distantly related species (invertebrates and vertebrates) in a coastal dune. 4 out of 6 possible pair-wise interactions negative. Vertebrates eliminate vegetation that is necessary invertebrate success.

7) Levin, Noam, Giora J. Kidron, and Eyal Ben-Dor. 2008. A Field Quantification of Coastal Dune Perennial Plants as Indicators of Surface Stability, Erosion or Deposition. Sedimentology 55(4): 751–772.

- Israel.
- A study on erosion and deposition rates around various coastal dune plant species, categorizing them as indicative of a mobile or stable environment.
- Coastal sand dunes; Mediterranean climate.
- To measure sand erosion/deposition, transects perpendicular to the coastline were laid, with erosion pins in 50 m intervals. Vegetation cover, plant height, and total perennial vegetation cover for each quadrat area of 100 m*m.
- The most common species in the study area was *Artemisia monosperma*.
- The study found that sand movement becomes negligible at 50% plant coverage, although other studies find this threshold to be lower at different sites. Vegetation cover upwind, annual plant cover, vegetation height, and spatial distribution of plants are important effectors for erosion/deposition rates, but a higher resolution study is still needed.
- *Ammophila arenaria* revealed to be an indicator of accumulation, *Scrophularia succulenta* for sand erosion, and *Stipagrostis lanata* and *Retama raetam* for stabilization, with variable indicative power depending on their abundances.
- The methods and analyses used in this site/study may be used to uncover indicator species in other areas.

8) Lithgow, D. et al. 2013. Linking Restoration Ecology with Coastal Dune Restoration. Geomorphology 199: 214–224.

- Review article with many sources.

9) Maun, M.A. 1998. Adaptations of Plants to Burial in Coastal Sand Dunes.” Canadian Journal of Botany 76(5): 713–738.

- Synthesis paper on evolutionary impact of burial in sand dune habitats (not exclusively in CA).
- Information on dominant plant species of coastal dune systems (see Table 2 in article).
- Currently don't have: information on sand mobility; information on dormancy mechanism of deeply buried seeds; mechanism for growth stimulation following plant burial.
- Have: information on role of burial on abiotic factors temperature, moisture, bulk density, and organic matter; information on role of burial in vegetation zonation (burial as a selective force); seed and seedling burial, and presence of seed banks of coastal dunes; effects of burial on seedling emergence.

10) Nordstrom, Karl F. and Nancy L. Jackson. 2013. Foredune Restoration in Urban Settings. Pages 17-31 in Restoration of Coastal Dunes. Ed. M. Luisa Martínez, Juan B. Gallego-Fernández, and Patrick A. Hesp. Springer Series on Environmental Management. Springer Berlin Heidelberg.

- Book chapter on restoration of dunes in an urban setting.

11) Peinado, Manuel et al. 2011. A Phytosociological and Phytogeographical Survey of the Coastal Vegetation of Western North America: Beach and Dune Vegetation from Baja California to Alaska. Applied Vegetation Science 14.4 (2011): 464–484.

- Pacific North America (1,730 sites).
- Transects were laid from the shore inland to the limit of psammophilous vegetation, marked by changes in topography or significant changes in density, cover, and species composition.
- Northern California foredunes are characterized by *Ammophila arenaria*, a dune invader. Dune scrub is characterized by the order *Ambrocio chamissonis-Eriogonetalia latifolii*, which includes four alliances. Forested back dunes are composed of the conifers *Picea sitchensis* on wet sands or *Pseudotsuga menziesii* var. *menziesii* on dry sands.

12) Pickart, Andrea J., Linda M. Miller, and Thomas E. Duebendorfer. 1998. Yellow Bush Lupine Invasion in Northern California Coastal Dunes I. Ecological Impacts and Manual Restoration Techniques. Restoration Ecology 6(1): 59–68.

- Humboldt Bay, CA.
- *Lupinus arboreus* (invasive); *Ammophila arenaria* (invasive); *Vulpia bromoides* (nonnative); *Holcus lanatus* (nonnative); *Bromus* spp. (nonnative); *Aira* spp. (nonnative).
- Study investigating the effects of invader *L. arboreus*, and developing restoration strategies against it. Treatments included removal of lupine only and removal of all nonnatives in addition to litter and duff layer.
- Vegetation and soil samples collected from 15~80 m*m plots, tallying yellow bush lupine individuals by size class. Soil samples analyzed by ammonium, nitrate, and organic matter content. Visual estimation of cover in quadrats.
- Fairly continuous increase in native cover in response to lupine removal. Significant differences among soil samples. Lupine seedling emergence high following treatment. Restoration resulted in decrease in nonnatives, and increase in natives over a 4-year period. Differences in soil characteristics between treated and untreated plots largely insignificant after 4 years.
- Conclusion: Restoration protocol should be removal of lupine, other nonnatives, and litter/duff. Treatment repeated at least three years to deplete seed bank. Revegetation with natives may be necessary.

13) Pickart, Andrea J. 2013. Dune Restoration Over Two Decades at the Lanphere and Ma-Le'l Dunes in Northern California. Pages 159–171 in Restoration of Coastal Dunes. Ed. M. Luisa Martínez, Juan B. Gallego-Fernández, and Patrick A. Hesp. Springer Series on Environmental Management. Springer Berlin Heidelberg.

- Lanphere Dunes and Ma-le'l Dunes in Humboldt Bay NWR, CA.

- *Erysimum menziesii* ssp. *eurekense* (endangered); *Layia carnosa* (endangered); *Ammophila aernaria* (invasive); *Carpobrotus edulis* x *C. shilensis* hybrid (invasive); *Leymus mollis* herbaceous alliance.
- 20-year restoration of a coastal dune system in NorCal. Project to eradicate invasives and revegetate with natives. Amophila control through digging/pulling, with some native revegetating in areas where dunes were not as stable. Carpobrotus also removed manually.
- Vegetation cover, species composition, and native plant survival were monitored. Labor also monitored to assess costs.
- *Ammophila* largely dead after 2 year treatment, with sparse resprouts. Native species recover occurred early as first year. *Carpobrotus* largely dead after 5 years, with more frequent reinvasion. High variation and density by native plants after second year. Eradication required total of 3600 person-hours/ha in first year, decreasing dramatically in subsequent years.

14) Russell, Will, Jennifer Shulzitski, and Asha Setty. 2009. Evaluating Wildlife Response to Coastal Dune Habitat Restoration in San Francisco, California. Ecological Restoration 27(4): 439–448.

- Case study on restoration efforts in GGNRA.
- Four treatments, where 'Restricted" = exclusion of visitors and "Restored" = planting of native dune vegetation: (1) 9 ha restricted/restored, (2) 10-year, 4 ha restricted/unrestored, (3) 2-year, 5 ha restricted/unrestored, and (4) 7 ha unrestricted/unrestored. In each treatment, surveys were conducted for birds, terrestrial vertebrates, and vegetation.
- Results indicate a positive effect on richness and abundance of plants, birds, and vertebrate by restoration and restriction efforts, with the effects of the former being more pronounced than the latter. The researchers concluded that native plant restoration with removal of non-natives is essential for restoration of dune habitat, with visitor restriction alone yielding only limited results.
- Good paper for brief background on dune vegetation and restoration methods. Includes a list of species planted in the restored area and detailed methods and results.

Appendix B. List of priority invasive species at PORE in 2014

Table B-1. List of priority invasive species at PORE in 2014

Priority	Scientific Name	Common Name	Family
1	*Acroptilon [Centaurea] repens*	Russian knapweed	Asteraceae
1	*Aegilops triuncialis*	barbed goatgrass	Poaceae
1	*Ageratina adenophora*	thoroughwort, crofton weed	Asteraceae
1	*Albizia lophantha*	silk tree, cape wattle	Fabaceae
1	*Ajuga reptans*	common bugle	Lamiaceae
1	*Alisma lanceolatum*	lanceleaf water plantain	Alismataceae
1	*Anthoxanthum odoratum*	sweet vernalgrass	Poaceae
1	*Arundo donax*	giant reed	Poaceae
1	*Brachypodium distachyon*	purple false brome	Poaceae
1	*Carduus acanthoides*	plumeless thistle	Asteraceae
1	*Carex pendula*	hanging sedge	Cyperaceae
1	*Carthamus lanatus*	woolly distaff thistle	Asteraceae
1	*Centaurea calcitrapa*	purple starthistle	Asteraceae
1	*Centaurea iberica*	Iberian starthistle	Asteraceae
1	*Centaurea melitensis*	Napa thistle, tocalote	Asteraceae
1	*Centaurea solstitialis*	yellow starthistle	Asteraceae
1	*Conicosia pugioniformis*	narrow-leaved iceplant	Aizoaceae
1	*Cotoneaster franchetii*	orange cotoneaster	Roseaceae
1	*Cotoneaster pannosus*	silverleaf cotoneaster	Roseaceae
1	*Dittrichia graveolens*	stinkweed	Asteraceae
1	*Egeria densa*	Brazilian elodea or waterweed	Hydrocharitaceae
1	*Ehrharta calycina*	perennial veldt grass	Poaceae
1	*Euphorbia oblongata*	egglear or oblong spurge	Euphorbiaceae
1	*Helichrysum petiolare*	licorice plant	Asteraceae
1	*Hypericum grandifolium*	large-leaved Saint Johnswort	Hypericaceae
1	*Hypericum perforatum*	Klamathweed	Hypericaceae
1	*Iris pseudacorus*	yellow flag	Iridaceae
1	*Lepidium latifolium*	perennial pepperweed, tall whitetop	Brassicaceae
1	*Limonium ramosissimum*	Algeria sealavender	Plumbaginaceae
1	*Ludwigia hexapetala*	sixpetal water-primrose	Onagraceae
1	*Ludwigia peploides* ssp. *montevedensis*	floating primrose-willow	Onagraceae
1	*Marrubium vulgare*	horehound	Lamiaceae

Table B-1 (continued). List of priority invasive species at PORE in 2014

Priority	Scientific Name	Common Name	Family
1	*Myriophyllum aquaticum*	parrot's-feather	Haloragaceae
1	*Phalaris arundinacea*	reed canary grass	Poaceae
1	*Robinia pseudoacacia*	black locust	Fabaceae
1	*Rytidosperma penicillatum*	wallaby grass	Poaceae
1	*Romulea rosea* var. *australis*	rosy sandcrocus	Iridaceae
1	*Salsola soda*	oppositeleaf Russian thistle	Chenopodiaceae
1	*Senecio jacobaea*	tansy ragwort, stinking willie	Asteraceae
1	*Spartina alterniflora*	Atlantic or smooth cordgrass	Poaceae
1	*Stipa purpurata*	Bristly needle grass	Poaceae
1	*Trifolium angustifolium*	narrow leaved clover	Fabaceae
1	*Ulex europaeus*	gorse, furze	Fabaceae
2	*Acacia melanoxylon*	blackwood acacia	Fabaceae
2	*Arctotheca calendula*	capeweed	Asteraceae
2	*Arctotheca prostrata*	fertile capeweed	Asteraceae
2	*Berberis darwinii*	Darwin's berberis	Berberidaceae
2	*Cakile edentula*	European searocket	Brassicaceae
2	*Cystisus scoparius*	Scotch broom	Fabaceae
2	*Datura stramonium*	jimsonweed, thorn apple	Solanaceae
2	*Delairea odorata*	cape ivy	Asteraceae
2	*Echium candicans*	pride of Madeira	Boraginaceae
2	*Genista monspessulana*	French broom	Fabaceae
2	*Glyceria declinata*	waxy mannagrass	Poaceae
2	*Hedera helix*	English ivy	Araliaceae
2	*Ilex aquifolium*	English holly	Aquifoliaceae
2	*Lathyrus latifolius*	perennial pea	Fabaceae
2	*Leucanthemum vulgare*	ox-eye daisy	Asteraceae
2	*Linaria vulgaris*	butter and eggs	Scrophulariaceae
2	*Maytenus boaria*	Chilean mayten	Celeastraceae
2	*Oxalis pes-caprae*	Bermuda buttercup	Oxalidaceae
2	*Paspalum dilatum*	dallis grass	Poaceae
2	*Pennisetum clandestinum*	Kikuyu grass	Poaceae
2	*Phalaris elongata*	Kolea grass	Poaceae
2	*Pittosporum undulatum*	Victorian box	Pittosporaceae
2	*Rhamnus alaternus*	Italian buckthorn	Rhamnaceae
2	*Rubus discolor [procerus]*	Himalayan blackberry	Rosaceae
2	*Tetragonia tetragonoides*	New Zealand-spinach	Aizoaceae

Table B-1 (continued). List of priority invasive species at PORE in 2014

Priority	Scientific Name	Common Name	Family
2	*Vinca major*	periwinkle	Apocynaceae
2	*Xanthium spinosum*	spiny cockleburr	Asteraceae
3	*Acacia longifolia*	Sydney golden wattle	Fabaceae
3	*Acacia verticillata*	prickly Moses	Fabaceae
3	*Allium triquetrum*	threecorner leek	Liliaceae
3	*Ammophila arenaria*	European beachgrass	Poaceae
3	*Carpobrotus chilensis*	sea fig	Aizoaceae
3	*Carpobrotus edulis*	hottentot fig, freeway iceplant	Aizoaceae
3	*Cestrum parqui*	chilean jessamine	Solanaceae
3	*Conium maculatum*	poison hemlock	Apiaceae
3	*Cortaderia jubata*	jubata grass	Poaceae
3	*Cortaderia selloana*	Uruguayan pampas grass	Poaceae
3	*Cotoneaster lacteus*	milkflower cotoneaster	Rosaceae
3	*Crataegus monogyna*	singleseed hawthorn	Rosaceae
3	*Cupressus macrocarpa*	Monterey cypress	Cupressaceae
3	*Cynodon dactylon*	Bermudagrass	Poaceae
3	*Digitalis purpurea*	purple foxglove	Scrophulariaceae
3	*Dipsacus fullonum*	common or Fuller's teasel	Dipsacaceae
3	*Dipsacus sativus*	indian teasel	Dipsacaceae
3	*Drosanthemum floribundum*	showy dewflower	Aizoaceae
3	*Echium plantagineum*	salvation jane	Boraginaceae
3	*Ehrharta erecta*	panic veldt grass	Poaceae
3	*Eucalyptus globulus*	bluegum eucalyptus	Myrtaceae
3	*Euphorbia lathyris*	gopher plant, caper spurge	Euphorbiaceae
3	*Festuca arundinacea*	tall fescue	Poaceae
3	*Foeniculum vulgare*	sweet fennel	Apiaceae
3	*Hypericum calycinum*	Aaron's beard	Clusiaceae
3	*Lythrum hyssopifolia*	hyssop loosestrife	Lythraceae
3	*Mentha pulegium*	pennyroyal	Lamiaceae
3	*Myoporum laetum*	myoporum	Myoporaceae
3	*Phalaris aquatica*	Harding grass	Poaceae
3	*Pinus radiata*	Monterey pine	Pinaceae
3	*Populus alba*	white poplar	Salicaceae
3	*Pyracantha angustifolia*	narrowleaf firethorn	Rosaceae
3	*Rosa eglanteria*	sweetbriar rose	Rosaceae
3	*Scabiosa atropurpurea*	mourningbride	Dipsacaceae

Table B-1 (continued). List of priority invasive species at PORE in 2014

Priority	Scientific Name	Common Name	Family
3	*Sorghum halepense*	Johnson grass	Poaceae
3	*Sparaxis tricolor*	harlequinflower, wandflower	Iridaceae
3	*Tanacetum parthenium*	feverfew	Asteraceae
3	*Verbascum blattaria*	moth mullein	Scrophulariaceae
3	*Watsonia meriana*	bulbil bugle-lily	Iridaceae
3	*Zantedeschia aethiopica*	calla lily	Araceae
4	*Agrostis avenacea*	Pacific bentgrass	Poaceae
4	*Agrostis capillaris*	colonial bentgrass	Poaceae
4	*Agrostis stolonifera*	creeping bentgrass	Poaceae
4	*Agrostis viridis*	green bent	Poaceae
4	*Anthemis cotula*	chamomile, dog fennel	Asteraceae
4	*Aptenia cordifolia*	heartleaf iceplant	Aizoaceae
4	*Avena barbata*	slender oat	Poaceae
4	*Avena fatua*	wild oat	Poaceae
4	*Bellardia trixago*	bellardia	Scrophulariaceae
4	*Brassica nigra*	black mustard	Brassicaceae
4	*Brassica rapa*	field mustard	Brassicaceae
4	*Briza maxima*	big quakinggrass	Poaceae
4	*Briza minor*	little quakinggrass	Poaceae
4	*Bromus diandrus*	ripgut brome	Poaceae
4	*Bromus hordeaceus*	soft brome	Poaceae
4	*Bromus madritensis* ssp. *rubens*	red brome	Poaceae
4	*Cakile maritima*	European searocket	Brassicaceae
4	*Carduus pycnocephalus*	Italian thistle	Asteraceae
4	*Carduus tenuiflorus*	slender-flowered thisle	Asteraceae
4	*Cichorium intybus*	chicory	Asteraceae
4	*Cirsium vulgare*	bull thistle	Asteraceae
4	*Convolvulus arvensis*	field bindweed	Convolvulaceae
4	*Crocosmia x crocosmiiflora*	crocosmia, montbretia	Iridaceae
4	*Cynosurus echinatus*	hedgehog dogtail	Poaceae
4	*Dactylis glomerata*	orchard grass	Poaceae
4	*Erechtites glomerata*	cutleaf burnweed	Asteraceae
4	*Erechtites minima*	coastal burnweed	Asteraceae
4	*Geranium dissectum*	cutleaf geranium	Geraniaceae
4	*Hirschfeldia incana*	shortpod mustard	Brassicaceae

Table B-1 (continued). List of priority invasive species at PORE in 2014

Priority	Scientific Name	Common Name	Family
4	*Holcus lanatus*	velvet grass, Yorkshire fog	Poaceae
4	*Hordeum marinum* ssp. *gussonianum*	Mediterannean barley	Poaceae
4	*Hordeum murinum*	mouse barley	Poaceae
4	*Hypochaeris glabra*	smooth catsear	Asteraceae
4	*Hypochaeris radicata*	hairy cat's ear, false dandelion	Asteraceae
4	*Leontodon taraxacoides*	lesser hawkbit	Asteraceae
4	*Lepidium strictum*	upright pepperweed	Brassicaceae
4	*Leucanthemum maximum*	Shasta daisy and hybrids	Asteraceae
4	*Lolium multiflorum*	Italian or annual ryegrass	Poaceae
4	*Lolium perenne*	Italian or perennial ryegrass	Poaceae
4	*Lotus corniculatus*	Birdsfoot trefoil	Fabaceae
4	*Medicago polymorpha*	California burclover	Fabaceae
4	*Melilotus alba*	white sweetclover	Fabaceae
4	*Meliotus indica*	sourclover	Fabaceae
4	*Picris echioides*	bristly oxtongue	Asteraceae
4	*Plantago lanceolata*	English plantain	Plantaginaceae
4	*Poa pratensis* ssp. *pratensis*	Kentucky bluegrass	Poaceae
4	*Polypogon monspeliensis*	rabbitfoot beardgrass	Poaceae
4	*Raphanus raphanistrum*	wild radish	Brassicaceae
4	*Raphanus sativus*	wild radish	Brassicaceae
4	*Rosa canina*	dog rose	Rosaceae
4	*Rumex acetosella*	sheep sorrel	Polygonaceae
4	*Rumex crispus*	curly dock	Polygonaceae
4	*Silene gallica*	windmill catchfly	Caryophyllaceae
4	*Silybum marianum*	blessed milkthistle	Asteraceae
4	*Solanum nigrum*	black nightshade	Solanaceae
4	*Sonchus arvensis*	perennial sowthistle	Asteraceae
4	*Trifolium hirtum*	rose clover	Fabaceae

Appendix C. List of species newly documented in PORE managed lands and GOGA from 2011 to 2014

Table C-1. List of species newly documented in PORE managed lands and GOGA from 2011 to 2014.

Park	Name	Family	Year
PORE	*Dittrichia graveolens*	Asteraceae	2014
PORE	Fallopia japonica	Polygonaceae	2014
PORE	*Glyceria declinata*	Poaceae	2011
PORE	*Ligustrum vulgare*	Oleaceae	2014
PORE	*Lychnis coronaria*	Caryophyllaceae	2014
PORE	*Phalaris elongata*	Poaceae	2012
PORE	*Rhamnus alaternus*	Rhamnaceae	2013
PORE	*Sorghum halepense*	Poaceae	2014
PORE	*Stipa miliacea*	Poaceae	2014
PORE	*Symphytum officinale*	Boraginaceae	2014
PORE	*Trifolium angustifolium*	Fabaceae	2012
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 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* ssp. *montevidensis*	Onagraceae	2011
GOGA	*Mercurialis annua*	Euphorbiaceae	2012

Table C-1 (continued). List of species newly documented in PORE managed lands and GOGA from 2011 to 2014.

Park	Name	Family	Year
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
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

Appendix D. List of all creeks in focal regions with sources of information

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. 2015).

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. 2015).

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. 2015).

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. 2015).

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. 2015).

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. 2015).

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 2002a)

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. 2015).

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. 2015).

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. 2015).

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. 2015).

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. 2015). 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. 2015).

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. 2015).

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. 2015).

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. 2015).

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. 2015).

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 2002c).

Spawner surveys conducted by NPS staff in 1999 and 2000 indicated the presence of two redds in each year (NPS 2002c).

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. 2015).

Steelhead were also observed by NPS staff in annual surveys that occurred between 2005 and 2007 (Reichmuth pers. comm. 2015).

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 2002c)

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 2012).

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. 2015).

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 impassable.

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 2012).

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. 2015).

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 Cemetery.

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. 2015).

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. 2015).

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 km (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 passability 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 Irrigation
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

The Department of the Interior protects and manages the nation’s natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 612/150895, March 2019



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