National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Coastal Watershed Assessment for Golden Gate National Recreation Area and Point Reyes National Seashore

Natural Resource Report NPS/PWR/NRR—2013/641

ON THE COVER
Upper left: Drakes Estero, Point Reyes National Seashore (Photo: Robert. Campbell)
Upper right: Mori Point, Golden Gate National Recreation Area (Photo: NPS)
Lower right: snowy plover, Crissy Field, Golden Gate National Recreation Area (Photo: Jessica Weinberg)
Lower left: intertidal monitoring, Santa Maria Creek, Point Reyes National Seashore (Photo: Amy Henry)

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Anitra Pawley, Ph.D.

Floodsafe Environmental Stewardship and Statewide Resources Office
North Delta Restoration Program
P.O. Box 942836
Sacramento, CA 94236

Mui Lay

University of California, Davis
Department LAWR
One Shields Avenue
Davis, CA 95616

March 2013

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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This report received formal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, and whose background and expertise put them on par technically and scientifically with the authors of the information.

This report is available from the Water Resource Division of the National Park Service (http://nature.nps.gov/water/nrca/coastalreports.cfm) and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm/).

Please cite this publication as:

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.

NPS 641/120272, 612/120272, March 2013

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Acronyms and Abbreviations

ac	acre
ASBS	Area of Special Biological Significance
BCPUD	Bolinas Community Public Utility District
BOR	Bureau of Reclamation
CALWATER	California Watershed
CBNMS	Cordell Bank National Marine Sanctuary
CCA	critical coastal area
CDFG	California Department of Fish and Game
CDPH	California Department of Public Health
COCMP-NC	Coastal Ocean Currents Monitoring Program in Northern California
CRFS	California Recreational Fisheries Survey
CRWQCB	California Regional Water Quality Control Boards
CSMP	California Seafloor Mapping Program
CSUMB-SML	California State University Monterey Bay–Seafloor Mapping Lab
CWA	coastal watershed assessment
DO	dissolved oxygen
EIS/EIR	environmental impact statement/environmental impact report
EMAP	Environmental Monitoring and Assessment Program
ft	foot
gal	gallon
GFNMS	Gulf of the Farallones National Marine Sanctuary
GIS	Geographic Information System
GOGA	Golden Gate National Recreation Area
GPRA	Government Performance and Results Act
ha	hectares
HAB	harmful algal blooms
Horizon Report	NPS Baseline Water Quality Data Inventory and Analysis Report
in	inch
IQR	interquartile range
km	kilometer
L	liter
LTMS	long term management strategy
m	meter
MBCSD	Muir Beach Community Services District
mg	milligram
MGD	million gallons per day
mi	mile
µg	microgram
mL	milliliter
MLPA	Marine Life Protection Act
MMWD	Marin Municipal Water District
MPA	marine protected area
MPN	most probable number
MTCE	metric tons of carbon dioxide equivalent

MUWO	Muir Woods National Monument
N_2O	nitrous oxide
ND GOGA	North District of GOGA, managed by PORE
NH_3	un-ionized ammonia
NH_4^+	reactive ammonia
NMWD	North Marin Water District
NO_2^-	nitrite
NO_3^-	nitrate
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollution Discharge Elimination System
NPS	National Park Service
NRCS	National Resources Conservation Service
NSSP	National Shellfish Sanitation Program
NTU	nephelometric turbidity units
NWI	National Wetland Inventory
OEHHA	California State Office of Environmental Health Hazard Assessment
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyls
PISCO	Partnership for Interdisciplinary Studies of Coastal Oceans
PORE	Point Reyes National Seashore
ppb	parts per billion
ppm	parts per million
PRBO	Point Reyes Bird Observatory Conservation Science
PSP	paralytic shellfish poisoning
QA/QC	quality assurance/quality control
RWQCB	Regional Water Quality Control Board
s	second
SCCWRP	Southern California Coastal Water Research Project
SFAN	San Francisco Bay Area Network
SFPUC	San Francisco Public Utilities Commission
SFRWQCB	San Francisco Bay Region Water Quality Control Board
SIMON	Sanctuary Integrated Monitoring Network
SMCA	State Marine Conservation Area
SMR	State Marine Reserve
SOD	Sudden Oak Death
SOP	standard operating procedures
SPAWN	Salmon Watershed and Protection Network
State Water Board	State Water Resources Control Board
SWAMP	Surface Water Ambient Monitoring Program
SWOO	Southwest Ocean Outfall
TMDL	total maximum daily load
TSS	total suspended solids
US EPA	US Environmental Protection Agency
USFDA	US Food and Drug Administration
USGS	US Geological Survey

Executive Summary for Golden Gate National Recreation Area

The Golden Gate National Recreation Area (GOGA) extends 91 miles (mi) (146 kilometers [km]) along the central coast of California from Bolinas Lagoon, north of San Francisco Bay, to Mori Point, south of San Francisco. The northern lands of GOGA from Bolinas Lagoon north along the east side of Highway One and along the east shore of Tomales Bay are managed by Point Reyes National Seashore. Much of the 75,000 acre (ac) (304 km^2) GOGA, particularly the southern lands below the Golden Gate, is adjacent to dense urban areas along the San Francisco peninsula. GOGA is one of the largest urban national parks in the world. GOGA was established in 1972 as part of a trend to make national park resources more accessible to urban populations and bring "parks to the people."

The convergence of two marine ecological provinces (northern Oregonian and southern Californian) and the dynamic coastal marine interface create habitats that support an incredible diversity of flora and fauna seen few other places on earth. Over 45 percent of North American birds and nearly 18 percent of California's plant species occur within the park. The loss of wildland habitats elsewhere in California heightens the value of the natural resources. Windswept beaches along the Pacific Ocean shoreline, craggy coastal bluffs and headlands, marine terraces, coastal uplands, salt marshes, estuaries and forests are some of the most geologically and ecologically diverse areas of the National Park System. The park also includes a rich array of historic cultural landmarks no longer present in other areas around San Francisco Bay. From historic dairies and ranches to shoreline artillery batteries, the challenge is to protect these cultural landmarks while preserving and restoring natural ecosystems.

This report is a cooperative effort between the University of California Sea Grant Extension Program and the National Park Service to provide a summary of the status of coastal watershed resources in GOGA. Specific goals were to: 1) provide a preliminary assessment of the existing condition of the marine coastal and nearshore aquatic environments; 2) locate and examine existing water resources information pertaining to coastal water quality; 3) identify current anthropogenic stressors or threats that may affect the future condition of these resources; and 4) identify and make recommendations to fill existing information gaps. The geographic focus is on coastal watersheds and the land-water interface including coastal tributaries.

This assessment used a tiered approach that includes an introduction to park resources, a brief history of the land uses and biological and physical setting (see Park Description chapter); a general description of stressors (see Stressors chapter); a description of habitat condition using appropriate indicators[1] (see Habitats chapter); and water quality (see Water Quality chapter).

Stressors

Stressors are physical, chemical or biological variables that are either foreign to the system, or natural to the system, but present at levels that induce stress. Stressors are summarized for each watershed in Table 1. The relative ranking of stressors was conducted by park natural resource specialists. Like most coastal systems, GOGA is subject to large-scale perturbations such as

[1] Indicator is used loosely and includes key flora, fauna or physical variables that provide information on condition for specific habitats. The choices reflect available data.

climate change as well as natural disturbances such as earthquake and fire. Air quality related to ozone, particulate matter (PM) and carbon monoxide are significant concerns especially in the southern GOGA. Surrounding human population pressures impact nearly all park lands and visitation creates impacts ranging from increased traffic to conflicting recreational uses. New development pressures within parklands are fairly minimal, although there are some areas where park redevelopment may pose problems such as the Presidio and Fort Baker in GOGA.

Current and historical commercial uses that affect park resources include agriculture, fishing, shellfish aquaculture, dredging, mining and maritime shipping. Dairy and ranching practices are preserved through the park's founding legislation. In northern GOGA lands managed by PORE, cattle currently graze and in areas of concentration, cattle can degrade grassland and wet meadow habitats and create the potential for nutrient loading. To a lesser degree, high bacteria levels also occur at heavily used beaches along Muir and Ocean Beaches in GOGA due to stormwater runoff and sewage releases during heavy rainfall events.

The coastline is exposed to high wind and wave energy much of the year and many nearshore resources are poorly studied. Fishing within the park boundaries, though, is limited. Given the complexity of oceanic processes and larval recruitment dynamics, the lack of long-term data on fisheries resources and shared management authority, it is not surprising that the status of many local fish populations and potential impacts of human activities are poorly understood. Nonetheless, there is clear evidence of significant declines in some nearshore fish species but also encouraging signs that many of these species are rebounding under current management practices. Dredge disposal and sand mining activities are minimal within park boundaries; however, dredge disposal continues in the San Francisco Bay near Alcatraz Island. The coastline is one of the most heavily used shipping corridors along the Pacific Coast and the threat of accidents and oil spills is a constant concern.

Coastal watershed erosion is a naturally occurring process as slopes and coastal bluffs in the coast range are inherently unstable due to a combination of faulting, erosive soil types and locally intense rainfall. This condition is exacerbated by anthropogenic disturbances, such as trails, road cuts and vegetation clearing, that alter surface water drainages and frequently triggers slope failures. These problems are widespread and require significant expenditures by the park to fund mitigation and restoration efforts. Nearly all park watersheds are impacted by geomorphic and hydrologic alterations, though generally at restorable scales. The most heavily impacted areas tend to be in GOGA, particularly in Redwood Creek and watersheds south of the Golden Gate. Despite the fact that erosional processes are an issue, some beaches appear to be sediment starved. The upstream damming of the San Joaquin and Sacramento Rivers which flow into San Francisco Bay has reduced sediment delivery and created some sediment starved beaches along the central coast.

Water quality is degraded by point and non-point source contaminants originating both in and outside of park boundaries. External sources of pollution such as atmospheric deposition can acidify streams, and upstream sources of industrial, urban and agricultural pollutants are particular threats to urban parks such as GOGA. Legacy sources of pollutants from military operations and quarries, coupled with current recreational practices and land uses that were grand fathered in with the creation of GOGA continue to pose problems. Northern GOGA contains ranches and pasture lands that contribute to poor water quality through bacteria and nutrient loading from animal waste and runoff. Horse stables and corrals are also a source of elevated nutrients and failing septic system leach fields result in nutrient and pathogen loading in some areas (i.e., Lagunitas Creek and Redwood Creek). Additional information on these impacts is found in Stressors and Water Quality.

Invasive species create medium to high-level threats across much of the landscape. Studies are just beginning on invasive species impacts on the park's coastal resources, but these are well documented in San Francisco Bay, which is considered one of the most heavily invaded estuaries in the world. Maritime commerce and ballast water discharge in San Francisco Bay, and the high level of recreational boating make the area particularly susceptible to invasive introductions. Many terrestrial invasive species are well established and comprehensive mapping of their distribution is necessary to gauge whether removal programs are producing desired outcomes. The persistence and ability to rapidly spread by species such as *Ammophila* (European beach grass) may undermine removal efforts. A clear understanding of invasion dynamics in these situations is necessary to guide management decisions and investments.

Table 1 summarizes stressors by watershed for the park and illustrates the continuum from highly urbanized to rural landscapes. Much of the existing development in the southern GOGA is well established, so options to ameliorate problems are limited, and coordination with outside entities is essential. In some northern GOGA watersheds, many of the problems result from levels of visitation and cultural activities connected to the park's mission and are not as complex to address. At the other extreme, some stressors such as sea level rise are driven primarily by global processes and landscape factors that are exceedingly complex and difficult to affect. Stressors and their impacts vary across watersheds (Table 1).

Habitats and Associated Flora and Fauna

Habitats extending from the offshore coastal zone to upland watersheds are described. Broad habitat categories include nearshore, freshwater and upland designations; they are further subdivided to facilitate condition assessment. In general, much more is known about freshwater and terrestrial systems than the nearshore marine environment; however, greater knowledge of freshwater resources would be of value to park management.

The nearshore marine environment includes bay and estuarine habitats created by mudflats, tidal wetlands and rocky shorelines and extends through the intertidal to the subtidal zone of the continental shelf. The shelf extends far from the coast and upwelling occurs nearshore, so the coastal zone is a relatively shallow, highly productive habitat for fish, invertebrates, marine mammals and seabirds. The subtidal zone borders the federally protected Gulf of the Farallones National Marine Sanctuary to the north and the Monterey Bay National Marine Sanctuary to the south. The region is a biological hot spot and data for some species (seals, invertebrates [abalone], fish [rockfish] and shorebirds) indicate that most populations are slowly recovering from historic declines. Rocky and sandy substrates predominate with small kelp communities occurring in scattered areas, predominantly along the GOGA coastline north of San Francisco Bay. Research on physical processes is underway with promising new approaches for coastal benthic mapping, such as multibeam sonar, to elucidate nearshore habitat complexity. This knowledge is important for resource assessments to locate and predict species distributions.

Along the open coast, intertidal habitats are likely the most heavily impacted aquatic areas. Despite park protection, these habitats are impacted by recreational activities including boating, clamming, fishing, diving and trampling. The principal water quality threats include bacterial and nutrient pollution (ranches, septic and stormwater discharges), occasional oil spills from offshore ships and legacy military landfills. Though beach sampling and damage incident reports have identified many of these problems, the extent of these impacts on intertidal organisms is not well studied. Currently, there are several projects underway that will provide more comprehensive information on the park's nearshore and especially intertidal resources; however unless these inventories are repeated, they will be of too short a duration to provide information on trends relating to intertidal resource condition.

Estuaries, bays and lagoons provide rich habitats including subtidal seagrasses, tidal mudflats and marshes that support a rich diversity of wildlife. Historical construction of levees and seawalls disrupted tidal regimes and dramatically reduced the extent of tidal marsh coverage in the park. Inherently lower rates of hydrologic mixing in estuaries and especially in lagoons, enhances their vulnerability to pollution and invasive species.

Though not as well studied as San Francisco Bay, invasive species are established in estuaries and lagoons in GOGA but at much lower levels than San Francisco. GOGA estuaries, bays and lagoons have endured considerable physical disturbance and pollution due to their proximity to the highly urbanized City of San Francisco. Some areas were heavily modified in past eras, causing major changes in habitat structure, including Big Lagoon at Redwood Creek, Horseshoe Bay and Crissy Field. Restoration is either planned or already initiated in these areas. In the recent past, the San Francisco Peninsula experienced significant bacterial pollution from storm water runoff; however, treatment since the 1990s has significantly reduced pollution levels. High levels of PCBs, PAHs and heavy metals are still major issues facing San Francisco Bay coastal waters and restoration is likely to improve local water quality conditions in some areas like the nearshore Presidio.

Some embayments are accreting too much sediment. Though sedimentation is a natural process, Bolinas Lagoon appears to be experiencing higher than normal sedimentation rates. The evaluation of these complex tidal system dynamics and the possible impacts due to climate change will depend on accurate habitat mapping procedures. Currently, there is significant emphasis in GOGA on mapping wetland extent and quality; however, these efforts are not yet completed and historical information on wetland habitats is limited. Where efforts are being made to restore tidal marsh habitat such as Crissy Field, our understanding of these systems is improving.

GOGA has an abundant array of sandy beaches, some barely accessible narrow strips along the shoreline while others are large expanses readily accessed and heavily used. Beach wrack, thick tangles of kelp and sea grass that wash ashore during high tides supports an intricate food web and community. Until recently, beach wrack was removed from many park beaches although this practice has been discontinued. Recreational activities on park beaches, unleashed dogs and kayaks impact shorebird populations. Efforts to minimize disturbance during the past 5 to 10 years appear to have had some success and snowy plover winter populations seem stable after years of decline.

Although local data are not comprehensive, notable trends and observations for key indicators in California nearshore marine and estuarine habitats likely to occur in the park are:

- Declining populations of all California abalone
- Decline in rockfish species such as Boccaccio (*Sebastes paucispinus*)
- Decline in the extent of kelp forests from pollution, wave damage due to storms and El Niño warming.
- Stable Dungeness crab populations as a result of successful fisheries management.
- After declines in mid-1990s, snowy plover overwintering populations have stabilized (including establishment of a new site at Crissy Field beach)
- Decline in pelagic sea birds due to human disturbance including bycatch, nest disturbance and oil spills and recovery due to protection and restoration efforts and climate regime shifts.
- Increase in tidal marsh lands due to restoration activities and protective measures.

Freshwater resources include streams, lakes and freshwater wetlands. Most of the streams in GOGA are not large and their tributaries are frequently ephemeral. The overall condition of these resources results from more than a century of intensive human uses, combined with the instability associated with soil types and the highly active San Andreas Fault. The effects of past land use practices (development, logging, agriculture and grazing) have changed watershed conditions and reduced habitat for many aquatic invertebrates, fish and amphibians. Loss of native perennial vegetation, soil compaction and loss, hillside trailing, gullying, and incision of swales and meadows have changed the runoff patterns and reduced the capacity of the watershed to attenuate pollutant loading and surface runoff to streams. Channelization, water diversions and the increased water demands of growing urban areas have dramatically diminished the size of many streams and reduced instream and riparian species diversity. Although land use practices having lesser impacts are being increasingly adopted by landowners, present land use continues to influence water quality conditions within many watersheds.

Macroinvertebrates are commonly used as indicators of water quality and functional status of freshwater streams, but to date macroinvertebrate sampling has been infrequent and inconsistent across sites. Coho salmon have been more consistently monitored and their use as an indicator of stream condition is being evaluated.

Ponds and swales are also extremely important aquatic resources. California red-legged frogs occur in these habitats. Several breeding sites are artificial ponds. The largest populations in GOGA are in coastal drainages in San Mateo County just south of San Francisco.

A cursory review of upland habitats from coastal dunes and scrub, to grasslands and forests is included in the report. The underlying geologic formations, soil types and the influence of a moist, maritime climate determine the configuration and diversity of plant communities. Terrestrial vegetation has been mapped in some detail, providing a solid foundation for evaluating these communities. Poorly maintained legacy roads and trails, coupled with heavy use from high levels of visitation exacerbates erosion and disturbs habitat creating opportunities for invasive plant species to colonize nearly all habitat types. Pristine coastal grasslands dominated by perennial bunchgrasses are one of the most decimated ecosystems in California. Roughly non-native grasses currently dominate 80 percent of northern GOGA grasslands. Coastal dune habitat is also dominated by non-native species. Though a comprehensive assessment of riparian vegetation is needed, there is evidence that many areas of GOGA are severely impacted by historic development. Nearly one-third of the riparian shrub and herb species in the Redwood Creek riparian corridor are non-native. Woodlands and forested areas are no longer logged in upland areas; however, pathogens like *Phytophthora ramorum* responsible for Sudden Oak Death and air pollution, are current threats. Fires can significantly alter upland condition but are also important to maintain fire adapted plant communities.

Water Quality

This report presents a systematic review of water quality conditions and programs that measure water quality in or near the park. Nearshore water quality has rarely been monitored by the park; while freshwater and beach resources are measured mainly in areas where problems have been identified. The lack of a probabilistic (randomized) water sampling program means that generalizations should be made with care; a broad summary of park water quality or even watershed water quality is likely to overstate problems and overemphasize freshwater resources. To ameliorate this problem, data exceedances were analyzed over time for specific locations and graphs and maps were created with percent exceedances for key compounds (nitrogen, phosphorus, dissolved oxygen, turbidity and bacterial pathogens) at specific locations from 1999 to 2005.

Monitoring is distributed among many different organizations, and sources of pollution range from agriculture to urban land uses. The fragmented ownership, variety of land uses, and the lack of a consistent water quality program within the park system make water quality difficult to assess. Except for water quality measurements on beaches, most of the information consistently collected by NPS is limited to Redwood Creek, Tennessee Valley and the Rodeo Gerbode watersheds near horse stables.

Point source water quality discharges within the area are present but difficult to assess. Except for the Presidio, many of the datasets indicating point sources, such as mines and leaky tanks, should be updated. Nutrient and bacteria levels were the most prevalent problems in areas where stables exist. County monitoring of public beaches in GOGA indicate that less than 10 percent of all samples collected from nearly all beaches exceeded water quality objectives for total coliform.

Recommendations

Despite the fact that data for many aspects of coastal condition have only recently become accessible, it is encouraging that the park has started some very ambitious terrestrial and aquatic resource monitoring and assessment programs. The development of the San Francisco monitoring workgroup is an important development to standardize methods and identify priorities. Recommendations for studies, monitoring and actions to address existing and potential injuries are summarized below. Management recommendations specific to each watershed planning unit will be provided in a future addendum and are only addressed here through inclusion of broad topics

Other plans that will have bearing on this report but are not yet completed include the General Management Plan and the Resources Stewardship Strategy. GOGA has included in its draft General Management Plan an ocean stewardship policy that is meant to provide guidance towards the implementation of the broad strategies and goals of the NPS Ocean Park Stewardship Action Plan (NPS 2006) and the Pacific West Region's strategic plan. The park would develop an implementation plan that would contain specific actions intended to achieve the measures included below. The implementation plan is intended to be a living document with continuous updates as knowledge of and threats to ocean processes and resources grow and new management priorities are identified. Stewardship of the park's marine and estuarine natural and submerged cultural resources would follow an adaptive management framework.

Although a number of recent, ongoing and planned studies will significantly improve knowledge of the status of selected resources, significant gaps still exist in the characterization of many resources and in understanding the potential for impacts.

The following are recommendations for additional studies, monitoring and actions to address existing and potential injuries. The research questions have been developed from those identified in Table 14 and in watershed planning unit summaries.

Studies

Basic Oceanography/Water Resources

- What are the patterns of extreme storm cycles, waves, currents, runoff and sediment transport?
- What are the spatial and temporal trends in temperature, storm activity, nutrients, upwelling, light transmission, current patterns, sea levels, river input and cloud cover / fog?
- What is the paleo-oceanographic context of present day variability?
- Better characterize oceanic circulation and mixing patterns near the park's marine borders.
- Characterize the locations and intensity of groundwater removals and their impact on water resources.
- What are the rates and causes of dune and bluff erosion over time?
- How has the distribution and structure of bluff and dune systems change on long-term time scales?
- What are the effects of climate change (including shoreline change, sea surface temperature, ocean acidification or increased ENSO events) on local and regional species distribution, abundance and interactions with other species?
- Do ENSO events alter shoreline configuration and substrate?

Basic Ecology

- Collaborate with researchers working in the park to coordinate research and planned studies to create robust data on water quality and biological resources in the park.
- Where are species located geographically within habitats?

- What coastal habitats are found in the park and how have they been impacted?
- What are the temporal, spatial and geographic patterns of target taxa in rocky subtidal and intertidal habitats?
- What are the impacts of changes in activity, abundance and distribution of apex predators (e.g., sea otters and harbor seals)?
- What are the effects of long-term primary productivity changes on near-bottom and benthic communities?
- What is the impact of long-term water fluctuations on ecological systems?
- What are the sources and sinks of carbon and other material in nearshore habitats?
- Assess benthic invertebrates and other stream fauna
- Determine and review prime indicators of health for all habitats using a systematic framework
- Characterize recruitment rates of threatened and endangered invertebrate species in the park's nearshore environments
- Improve the characterization of ecosystem structure in the park's nearshore environments including subtidal, intertidal and sandy beach habitats
- Encourage USGS and other entities to complete multibeam bathymetric measurements in the subtidal nearshore and bay/estuarine environments to provide a platform for species distribution information
- Complete the mapping of freshwater wetlands distribution, their extent and quality and conduct the analysis every 5–10 years
- What are the sedimentary, biological, chemical inputs to the nearshore system from individual watersheds?
- What are the ecological effects of sedimentary, biological, chemical inputs to the nearshore system from individual watersheds?

Monitoring

- Evaluate the NPS sponsored biophysical inventory and other intertidal monitoring programs and determine whether the inventory should be repeated every 5 years
- Complete mapping of the extent and quality of tidal marsh habitat and conduct the analysis every 5–10 years
- Monitor groundwater quality at selected sites to provide an 'early warning' of contaminant inputs into the marine environment
- Expand water quality monitoring efforts in GOGA. Determine the feasibility of developing a probabilistic survey for the region. This should be coordinated with existing efforts such as EMAP
- Continue to monitor threatened and endangered species in the park, but evaluate to what extent these species provide information on probable causes for their decline. It may be

necessary to choose alternative indicator species to evaluate the effects of stressor reduction.

- Continue to coordinate with the Farallones Marine Sanctuary Beach Watch Monitoring program and determine to what extent the dataset can be used to determine visitor impacts
- In coordination with the SFAN monitoring program, continue the monitoring of harbor seals.
- In coordination with the SFAN monitoring program, continue to monitor salmon populations in all major creeks where they have been identified.

Threats Assessment

- What are the extent, types and impacts of direct exploitation on park resources (e.g., commercial and recreational fishing)?
- What are the impacts of non-consumptive disturbances (e.g., trampling, sonar) on intertidal and subtidal habitats?
- What are the select pathogen, pollutant and parasite (ppp) loads in sea mammals (live and dead), shellfish and birds?
- What are the impacts of chemical pollutants / contaminants on benthic habitats and communities?
- What are the major influences of fisheries and other stressors on distribution and abundance patterns of pelagic megafauna?
- What is the abundance and distribution of invasive species in nearshore environments?
- What is the abundance and distributions of sensitive species in nearshore environments?
- What are the impacts of habitat modification on coastal dune/bays and estuarine processes? (Beaches, Coastal Dunes, Mudflats, Tidal Marshes)

Management Actions

- Develop and implement scientifically-based watershed adaptive management programs.
- Limit the effect of recreational activities on foraging shorebirds.
- Protect wildlife resources from overflight and watercraft disturbances.
- Continue support for and expansion of public education and stewardship activities in the watershed.
- Continue support for water quality monitoring.
- Use best management practices (BMPs) to reduce stormwater runoff and erosion, improve water quality, protect ecological values and encourage water conservation and appropriate re-use.
- Rehabilitate undesignated trails.
- Develop a comprehensive trails assessment for GOGA. Evaluate, prioritize and implement measures to reduce erosion and sedimentation along roads and trails.

- Work with local municipalities to minimize the effects of development on coastal resources.
- Continue invasive plant species management in GOGA, including early detection and control and replacement with indigenous species.
- Continue to identify and mitigate contaminant sources.
- Create continuous wildlife corridors.

Table 1. Existing and potential injuries to coastal water resources in Golden Gate National Recreation Area. Problem level cause by stressor: H=high, M=medium, L=low, P=potential, Leg =legacy, na=not applicable. NPS=National Park Service.

	Golden Gate National Recreation Area Watersheds								
Stressors	**Bolinas & Stinson**	**Redwood Creek**	**Tennessee Valley**	**Gerbode & Rodeo**	**North Shore of SF Bay**	**Presidio**	**Fort Funston & Ocean Beach**	**Milagra & Sweeney**	**Mori Point**
Climate Change	P	P	P	P	P	P	P	P	P
Air Quality Degradation	L	L	L	L	L	M	L	L	L
Land Use Change/Development	M[1]	L	L	L/M	M[2]	H	H[3]	M?	M?
"Urban" Development	na	na	na	L/M[4]	L/M	H	H	H	M?
Rural Residential Development	H[5]	M	L	M[6]	na	na	na	M?	na?
Agricultural Development									
Dairies	na	na	na	na	na	na	na	na	na
Grazing	na	na	na	na	na	na	na	na	na
Cultivation	L[7]	L	na	na	na	na	na	L?	na
Aquaculture (e.g., oyster culture)	na	na	na	na	na	na	na	na	na
Equestrian Facilities	L*	L*	M	M	na	L	M[53]	na	na
Recreation									
Infrastructure (parking lots, bridges)	H[8]	H	L	H	M	M	M	M?	M?
Visitor use	H	H	L	M	M	M	M	M?	M?
Resource Extraction									
Dredging and sand mining	na	na	na	na	na	H?[9]	H?[10]	na	na
Military and industrial practices	na	na	na	P[11]	P[12]	P[13]	P[14]	P[15]	na?
Mining and oil development	P	P	P[16]	P	P	P	P	na	P
Logging	na, Leg	na, Leg	na	na	na	na	na	na	na
Fishing and harvesting	L	L	L	L	L[17]	M[18]	L	na	L

Table 1. Existing and potential injuries to coastal water resources in Golden Gate National Recreation Area (continued).

	Golden Gate National Recreation Area Watershed								
Stressors	**Bolinas & Stinson**	**Redwood Creek**	**Tennessee Valley**	**Gerbode & Rodeo**	**North Shore of SF Bay**	**Presidio**	**Fort Funston & Ocean Beach**	**Milagra & Sweeney**	**Mori Point**
Water Quality									
Nutrients	M[19]	M	L	M[20]	M	M	M[21]	L	M?[22]
Pathogens	M	H	L	M[23]	M[24]	M	M[25]	L	M?
Organic compounds	P	P	L	P	P	P	P	P?	P?
Heavy metals	P	P	L	P	P	P	P	P?	P?
Sediments	M	M	M[26]	M[27]	M	L[28]	M[1]	M	M/H
Water Diversion									
Surface water withdrawals	M[29]	M	L	na	na	H[30]	na	na	na
Groundwater withdrawals	M[31]	M	L[32]	na	P	P	M[33]	na	na
Soils and Geomorphologic Alteration (Hydro-modification)									
Dams and culverts	L	L	M/H[34]	M	L[35]	na	M[36]	?	M?[37]
Erosion/sedimentation	M	M	M	M	M	L	M	M	H
Channelization, levees	M	H	L	L	na	H[38]	H[39]	?	M?
Channel hardening	M	H	na	na	na	L/M[40]	L/M[41]	?	na?
Lost floodplain function	M	H	M/H	M	L	M	H[42]	?	?
Increased impervious surface	M	L	L	L	L/M	H	H	M	L
Invasive Species									
Freshwater aquatic species	L	L	M	L/M	na	L/M[43]	na	P	P
Marine and estuarine species	L	L	L	L	M/H[44]	M/H[45]	L	na	L
Terrestrial species	M	M	M	M	M	H	M	M	M

Table 1. Existing and potential injuries to coastal water resources in Golden Gate National Recreation Area (continued).

	Golden Gate National Recreation Area Watershed								
Stressors	**Bolinas & Stinson**	**Redwood Creek**	**Tennessee Valley**	**Gerbode & Rodeo**	**North Shore of SF Bay**	**Presidio**	**Fort Funston & Ocean Beach**	**Milagra & Sweeney**	**Mori Point**
Disturbed Lands									
Roads and trails	M	M	M/H[46]	M	M[47]	H	H	M	H
Legacy Infrastructure	M[48]	L	M[49]	M	M	H	H	M?	M?
Quarries	L	L	M	H[50]	M	M	L?	M?	H[51]
Park Management Activities	L/M	L/M	L/M	M	M	H	M	L	M?
Natural Disturbance (Fire, Landslide, Earthquake)	L	L	L	L	M/H[52]	M	M/H	L/M	M[53]

[1]change from beach rental to homeowner market
[2]Fort Baker Conference Center
[3]San Francisco and Daly City
[4]Ft. Cronkhite, Capehart, Ft. Barry
[5]largest rural residential "gateway" community to Golden Gate National Recreation Area
[6]Wolfback Ridge private development
[7]no cultivation on east side of lagoon
[8]largest parking lot in park
[9,10]unknown effects of dredging and sand disposal in littoral cell
[11-15]past military use
[16]offshore oil
[17]herring
[18]herring, crabs
[19]NPS leach fields to ocean
[20]birds, past/present sewers
[21,25]outfalls from San Francisco and Daly City
[22]residential and golf course
[23]birds, past/present sewers, algae
[24]Sausalito outfall to San Francisco Bay
[26,27]roads and trails, erosion
[28]mostly paved/in storm drains
[29]town diverts NPS surface waters
[30]Lobos Creek
[31]town diverts NPS groundwater
[32]developed springs
[33]groundwater development planned in Lake Merced area
[34]onstream impoundments; worst in Golden Gate National Recreation Area
[35]pond below Battery Spencer
[36]Lake Merced dammed upstream of park
[37]adjacent golf course pond
[38,39]most streams in storm drains
[40,41]storm drains and channels
[42]most streams in storm drains/channels; Daly City has flooding
[43]Mtn. Lake has non-native animals
[44-45]San Francisco Bay
[46]roads as quarries; Marincello Road
[47]includes Highway 1
[48]Stinson Beach Park all on top of historic wetlands
[49]Marincello Road
[50]more quarries
[51]entire site former quarry
[52]coastal bluffs, fires, landslides
[53]outside park

Executive Summary for Point Reyes National Seashore

The Point Reyes National Seashore (PORE) extends 100 mi (161 km) along the central coast of California from the tip of Tomales Point to Duxbury Reef. The 71,046 ac (28,751 hectares [ha]) PORE is rural, being insulated from urbanized east Marin and the Highway 101 corridor by extensive agricultural holdings and the northern portions of Golden Gate National Recreation Area (GOGA). PORE also manages the northern lands of GOGA from Bolinas Lagoon north along the east side of Highway One and along the east shore of Tomales Bay. PORE was established in 1962 to preserve and protect wilderness, natural ecosystems and cultural resources along this relatively undeveloped coastline north of San Francisco.

The convergence of two ecological provinces and the dynamic coastal marine interface create habitats that support an incredible diversity of flora and fauna seen few other places on earth. Over 45 percent of North American birds and nearly 18 percent of California's plant species are found within PORE. The loss of wildland habitats elsewhere in California heightens the value of these natural resources. Windswept beaches stretching along the Pacific Ocean shoreline, craggy coastal bluffs and headlands, marine terraces, coastal uplands, salt marshes, estuaries and forests are some of the most geologically and ecologically diverse areas of the National Park System. The park also includes a rich array of historic cultural landmarks no longer present in the region. From historic dairies and ranches to shoreline artillery batteries, the challenge is to protect these cultural landmarks while preserving and restoring natural ecosystems.

This report is a cooperative effort between the University of California Sea Grant Extension Program and the National Park Service to provide a summary of the current status of coastal watershed resources in PORE. Specific goals were to 1) provide a preliminary assessment of the existing condition of the marine coastal and nearshore aquatic environments; 2) locate and examine existing water resources information pertaining to coastal water quality; 3) identify current anthropogenic stressors or threats that may affect the future condition of these resources; and 4) identify and make recommendations to fill existing information gaps. The geographic focus is on coastal watersheds and the land water interface including coastal tributaries.

PORE manages 100 mi (161km) of shoreline. The different character of the park and surrounding landscapes preclude sweeping generalities about park conditions and the nature and impact of stressors on the landscape. As a result, this assessment was designed using a tiered approach that includes a general description of stressors (see Stressors chapter), a description of overall condition by habitats using appropriate indicators for specific habitat types[2] and water quality (see Water Quality chapter), followed by a more in depth summary highlighting unique conditions by watershed.

Stressors

Stressors are physical, chemical or biological variables that are either foreign to the system, or natural to the system but present at levels that induce stress. Stressors are characterized in the Stressors chapter and summarized for each watershed in Table 2. Like most coastal systems, PORE is subject to large-scale perturbations such as climate change as well as natural

[2] The term indicator is used loosely and includes key flora, fauna or physical variables that provide information on condition for specific habitats. These choices largely reflect available data.

disturbances such as earthquake and fire. Air quality related to ozone, particulate matter (PM) and carbon monoxide are significant concerns. Surrounding human population pressures impact nearly all park lands and visitation creates impacts ranging from increased traffic to conflicting recreational uses. New development pressures within parklands are fairly minimal.

Current and historical commercial uses that affect park resources include agriculture, fishing, shellfish aquaculture and maritime shipping. Dairy and ranching practices are preserved through the park's founding legislation. In PORE and managed GOGA lands, cattle currently graze on nearly 30 percent of park lands and in areas of concentration, cattle can degrade grassland and wet meadow habitats and create the potential for nutrient loading. Some Drakes Bay watersheds and Kehoe and Abbotts Lagoon periodically exhibit high bacterial counts affecting human uses including swimming and shellfish harvesting.

Crop agriculture is fairly limited with silage operations on approximately 950 ac (384 ha) in PORE. Fishing within the park boundaries is limited; however, offshore commercial and recreational fisheries are well developed. The coastline is exposed to high wind and wave energy much of the year and many nearshore resources are poorly studied. Given the complexity of oceanic processes and larval recruitment dynamics, the lack of long term data on fisheries resources and shared management authority, it is not surprising that the current status of many local fish populations and impacts of human activities are poorly understood. Nonetheless, there is clear evidence of significant declines in some nearshore fish species but also encouraging signs many of these species are rebounding under current management practices. The coastline is one of the most heavily used shipping corridors along the Pacific Coast and the threat of accidents and oil spills is a constant concern.

Coastal watershed erosion is a naturally occurring problem as slopes and coastal bluffs in the coast range are inherently unstable due to a combination of faulting, erosive soil types and locally intense rainfall. This condition is exacerbated by anthropogenic disturbances, such as trails, road cuts and vegetation clearing that alter surface water drainages and frequently trigger slope failures. These problems are widespread and require significant expenditures by the park to fund mitigation and restoration efforts. Nearly all park watersheds are impacted by geomorphic and hydrologic alterations, though generally at restorable scales. In watersheds in PORE there are inventories of infrastructure problems including dams, culverts and fish passage surveys that can be used to establish restoration priorities; however, many of these surveys are incomplete. Restoration has occurred with apparent success in areas such as Olema. Monitoring these projects should be a priority for informing future restoration efforts. Despite the fact that erosional processes are an issue, some beaches appear to be sediment starved. The upstream damming of the San Joaquin and Sacramento Rivers which flow into San Francisco Bay has reduced sediment delivery and created some sediment starved beaches along the central coast.

Water quality is degraded by point and non-point source contaminants originating both in and outside of park boundaries. External sources of pollution such as atmospheric deposition can acidify streams and upstream sources of industrial, urban and agricultural pollutants are particular threats. Legacy sources of pollutants from military operations and quarries, coupled with current recreational practices and land uses that were grand fathered in with the creation of PORE continue to pose problems. PORE and northern GOGA contain numerous ranches, dairies and pasture lands that contribute to water quality degradation through bacteria and nutrient loading from animal waste and runoff. Horse stables and corrals are also a source of elevated nutrients and failing septic system leach fields result in nutrient and pathogen loading in some areas (i.e., Lagunitas Creek in PORE). Additional information on these impacts is found in Stressors and Water Quality.

Invasive species create medium to high-level threats across much of the landscape. Studies are just beginning on invasive species impacts on the park's coastal resources, but these are well documented in San Francisco Bay, which is considered one of the most heavily invaded estuaries in the world. Maritime commerce and ballast water discharge in San Francisco Bay and the high level of recreational boating make the area particularly susceptible to invasive introductions. Many terrestrial invasive species are well established and comprehensive mapping of their distribution is necessary to gauge whether removal programs are producing desired outcomes. The persistence and ability to rapidly spread by species such as *Ammophila* spp. (European beach grass) may undermine removal efforts. A clear understanding of invasion dynamics in these situations is necessary to guide management decisions and investments.

Table 2 summarizes stressors by watershed for the park and illustrates the continuum from highly urbanized to rural landscapes. In PORE and some northern GOGA watersheds (managed by PORE), many of the problems result from levels of visitation and cultural activities connected to the park's mission and are not as complex to address. At the other extreme, some stressors such as sea level rise are driven primarily by global processes and landscape factors that are exceedingly complex and difficult to affect. Stressors and their impacts vary across watersheds.

Habitats and Associated Flora and Fauna

Habitats extending from the offshore coastal zone to upland watersheds are described in the Habitats chapter. Broad habitat categories include nearshore, freshwater and upland designations; they are further subdivided to facilitate condition assessment. In general, much more is known about freshwater and terrestrial systems than the nearshore marine environment; however, greater knowledge of freshwater resources would be of value to park management.

The nearshore marine environment includes bay and estuarine habitats created by mudflats, tidal wetlands and rocky shorelines and extends through the intertidal to the subtidal zone of the continental shelf. The shelf extends far from the coast and upwelling occurs nearshore, so the coastal zone is a relatively shallow, highly productive habitat for fish, invertebrates, marine mammals and seabirds. The subtidal zone abuts the federally protected Gulf of the Farallones National Marine Sanctuary to the north and the Monterey Bay National Marine Sanctuary to the south. The region is considered a biological hot spot and data that are available for some species (e.g., seals, invertebrates [abalone], fishes [rockfish] and shorebirds) indicate that most populations are slowly recovering from historic declines. Rocky and sandy substrates predominate with kelp communities occurring in scattered areas predominantly along the PORE coastline north of San Francisco Bay. Research on physical processes is underway with promising new approaches for coastal benthic mapping such as multibeam sonar helping to elucidate nearshore habitat complexity. This knowledge is important for resource assessments as an aid to locate and predict species distributions.

Along the open coast, intertidal habitats are likely the most heavily impacted aquatic areas. Despite park protection, these habitats are impacted by recreational activities including boating, clamming, fishing, diving and trampling. The principal water quality threats include bacterial and nutrient pollution (ranches, dairies, septic and stormwater discharges), occasional oil spills from offshore ships and legacy military landfills. Though beach sampling and damage incident reports have identified many of these problems, the extent of these impacts on intertidal organisms is not well studied. Currently, there are several new projects underway which will provide more comprehensive information on the park's nearshore and especially intertidal resources; however unless these inventories are repeated, they will be of too short a duration to provide information on trends relating to intertidal resource condition.

Estuaries, bays and lagoons provide rich habitats including subtidal seagrasses, tidal mudflats and marshes that support a rich diversity of wildlife. Historical construction of levies and seawalls disrupted tidal regimes and dramatically reduced the extent of tidal marsh coverage in the park. Inherently lower rates of hydrologic mixing in estuaries and especially in lagoons, enhances their vulnerability to pollution and invasive species.

Tomales Bay, Drakes Estero and Abbotts Lagoon of PORE and northern GOGA exhibit high levels of fecal coliform loading following heavy rainfall from sources including wildlife and cattle on ranches and dairies. This often results in harvest closures for cultured shellfish and must be monitored closely during rainy winter months.

Though not as well studied as San Francisco Bay, invasive species are established in estuaries and lagoons in PORE and northern GOGA, but at much lower levels than San Francisco. Despite these threats, Tomales Bay and Drakes Estero are considered relatively pristine and support variable but healthy biological communities. Wetland restoration projects such as the 563-acre Giacomini Ranch Restoration Project further enhance resource condition.

While active restoration efforts are reclaiming wetlands, some embayments are accreting too much sediment. Though sedimentation is a natural process, Tomales Bay, Drakes Bay and Bolinas Lagoon appear to be experiencing higher than normal sedimentation rates. The evaluation of these complex tidal system dynamics and the possible impacts due to climate change will depend on accurate habitat mapping procedures. Currently, there is significant emphasis in PORE on mapping wetland extent and quality; however, these efforts are not yet completed and historical information on wetland habitats is limited. Where efforts are being made to restore tidal marsh habitat such as the Giacomini Ranch, our understanding of these systems is improving.

PORE has an abundant array of sandy beaches, some barely accessible narrow strips along the shoreline while others are large expanses readily accessed and heavily used. Beach wrack, thick tangles of kelp and sea grass that wash ashore during high tides supports an intricate food web and community.

Although local data are not comprehensive, notable trends and observations for key indicators in California nearshore marine and estuarine habitats likely to occur in the park are:

- Declining populations of all California abalone
- Northern spread of the ricketsial-like bacterium responsible for withering syndrome in black abalone which was recently observed just south of GOGA.

- Decline in species of rockfish such as Boccaccio (*Sebastes paucispinus*)
- Decline in the extent of kelp forests from pollution, wave damage due to storms and El Niño warming.
- Stable Dungeness crab populations as a result of successful fisheries management.
- Stable population levels for harbor and elephant seals
- Decline and then recent increases in pelagic seabirds due to climate regime shifts and human disturbance including bycatch, nest disturbance and oil spills.
- Increase in tidal marsh lands due to restoration activities and protective measures.

Freshwater resources include streams, lakes and freshwater wetlands. Most of the rivers in PORE are not large and their tributaries are frequently ephemeral. The overall condition of these resources results from more than a century of intensive human uses, combined with the instability associated with soil types and the highly active San Andreas Fault. The effects of past land use practices (development, logging, agriculture and grazing) have changed watershed conditions and reduced habitat for many aquatic invertebrates, fish and amphibians. Loss of native perennial vegetation, soil compaction and loss, hillside trailing, gullying and incision of swales and meadows have changed the runoff patterns and reduced the capacity of the watershed to attenuate pollutant loading and surface runoff to streams. Dam construction, channelization, water diversions and the increased water demands of growing urban areas have dramatically diminished the size of many streams and reduced instream and riparian species diversity. Although land use practices having lesser impacts are being increasingly adopted by landowners, present land use continues to influence water quality conditions within many watersheds.

Macroinvertebrates are commonly used as indicators of water quality and functional status of freshwater streams, but to date, macroinvertebrate sampling has been infrequent and inconsistent across sites. Coho salmon have been monitored more consistently and their use as an indicator of stream condition is being evaluated. Positive signs recently observed are the recolonization of Pine Gulch Creek by coho salmon and population increases in Olema Creek.

Ponds and swales are also extremely important aquatic resources. As mentioned earlier, some of the largest endangered red-legged frog populations are in PORE and northern GOGA where there are more than 120 breeding sites with a total adult population of several thousand frogs. Most of the breeding sites are artificial stock ponds constructed on lands that have been grazed by cattle for 150 years.

A cursory review of upland habitats from coastal dunes and scrub, to grasslands and forests is included in the report. The underlying geologic formations, soil types and the influence of a moist, maritime climate determine the configuration and diversity of plant communities. Terrestrial vegetation has been mapped in some detail, providing a solid foundation for evaluating these communities. Poorly maintained legacy roads and trails, coupled with heavy use from high levels of visitation exacerbates erosion and disturbs habitat creating opportunities for invasive plant species to colonize nearly all habitat types. Pristine coastal grasslands dominated by perennial bunchgrasses are one of the most decimated ecosystems in California. Roughly non-native grasses currently dominate 80 percent of PORE and northern GOGA grasslands. Coastal dune habitat is also dominated by non-native species. Woodlands and forested areas are no longer logged in upland areas; however, pathogens like *Phytophthora ramorum* responsible for Sudden Oak Death and air pollution are current threats. Fires can significantly alter upland condition but are also important to maintain fire adapted plant communities. The 1995 Vision Fire in the Drakes Bay/Estero watershed resulted in significant bishop pine growth.

Water Quality

Section E provides a more systematic review of water quality conditions and programs that measure water quality in or near the park. In general, nearshore water quality has rarely been monitored by the park; while, freshwater and beach resources are measured principally in areas where problems have been identified. This lack of a probabilistic (randomized) water sampling program means that generalizations should be made with care; a broad summary of park water quality or even watershed water quality is likely to overstate problems and overemphasize freshwater resources. To ameliorate this problem, data exceedances were analyzed over time for specific locations and graphs and maps were created with percent exceedances for key compounds (nitrogen, phosphorus, dissolved oxygen, turbidity and bacterial pathogens) at specific locations from 1999 to 2005. The results can be summarized as follows:

Though monitoring is distributed among different organizations, PORE and northern GOGA have consistently monitored water quality in the following watersheds, Abbotts Kehoe, Drakes Bay/Drakes Estero and Olema. This facilitated fairly consistent data analyses for the watersheds.

The impairment designation of the California State Water Quality Control Board has indicated that Tomales Bay and its major tributary, Lagunitas Creek, are impaired by pathogens, sediment and nutrients. Tomales Bay is also impaired by mercury due to legacy mining on Walker Creek, which is outside of park boundaries.

There are few point source water quality discharges within PORE and the North District Lands of GOGA managed by PORE. Nearly all water quality problems are associated with non-point sources.

Nutrient and pathogen levels and their transport to streams and bays are by far the most prevalent problems in PORE. Agricultural runoff from dairy and range animals, wildlife and failing septic systems contribute to high levels of fecal coliform recorded in tributaries during the rainy season. Over 50 percent of the samples collected from 1999 to 2005 exceeded 1 mg/L (1 part per million [ppm]) nitrate and the contact recreation criteria for fecal coliform (400 MPN/100 mL). Extremely high turbidity occurred along the mainstem and tributaries of Olema Creek. Almost one-fourth of the measurements by NPS in PORE exceeded the WRD screening criteria of 50 nephelometric turbidity units (NTU).

County monitoring of public beaches in PORE and northern GOGA indicate that few beaches exceeded water quality objectives for total and fecal coliform. Chicken Ranch Beach on Tomales Bay and Kehoe Lagoon at Kehoe Beach exhibited the highest number of exceedances for all pathogen indicators.

Recommendations

Despite the fact that data for many aspects of coastal condition have only recently become accessible, it is encouraging that the park has started some very ambitious terrestrial and aquatic resource monitoring and assessment programs. The development of the San Francisco monitoring workgroup is an important development to standardize methods and identify priorities. Recommendations for studies, monitoring and actions to address existing and potential injuries are summarized below. Management recommendations specific to each watershed planning unit will be provided in a future addendum and are only addressed here through inclusion of broad topics

Although a number of recent, ongoing and planned studies will significantly improve knowledge of the status of selected resources, significant gaps still exist in the characterization of most resources and in understanding the potential for impacts.

The following are recommendations for additional studies, monitoring and actions to address existing and potential injuries. The research questions have been developed from those identified in Table 14 and in specific watershed planning unit summaries.

Studies

<u>Basic Oceanography/Water Resources</u>

- What are the patterns of extreme storm cycles, waves, currents, runoff and sediment transport?
- What are the spatial and temporal trends in temperature, storm activity, nutrients, upwelling, light transmission, current patterns, sea levels, river input and cloud cover / fog?
- What is the paleo-oceanographic context of present day variability?
- Better characterize oceanic circulation and mixing patterns near the park's marine borders.
- Characterize the locations and intensity of groundwater removals and their impact on water resources.
- What are the rates and causes of dune and bluff erosion over time?
- How has the distribution and structure of bluff and dune systems changed on long-term time scales?
- What are the effects of climate change (including shoreline change, sea surface temperature, ocean acidification or increased ENSO events) on local and regional species distribution, abundance and interactions with other species?
- Do ENSO events alter shoreline configuration and substrate?

<u>Basic Ecology</u>

- Collaborate with researchers working in the park to coordinate research and planned studies to create robust data on water quality and biological resources in the park.
- Where are species located geographically within habitats?

- What coastal habitats are found in the park and how have they been impacted?
- What are the temporal, spatial and geographic patterns of target taxa in rocky subtidal and intertidal habitats?
- What are the impacts of changes in activity, abundance and distribution of apex predators (e.g., sea otters and harbor seals)?
- What are the effects of long-term primary productivity changes on near-bottom and benthic communities?
- What is the impact of long-term water fluctuations on ecological systems?
- What are the sources and sinks of carbon and other material in nearshore habitats?
- Assess benthic invertebrates and other stream fauna.
- Determine and review prime indicators of health for all habitats using a systematic framework.
- Characterize recruitment rates of threatened and endangered marine invertebrate species in the park's nearshore environments.
- Improve the characterization of ecosystem structure in the park's nearshore environments including subtidal, intertidal and sandy beach habitats.
- Encourage USGS and other entities to complete multibeam bathymetric measurements in the subtidal nearshore and bay/estuarine environments to provide a platform for species distribution information.
- Complete the mapping of freshwater wetlands distribution, their extent and quality and conduct the analysis every 5–10 years.
- What are the sedimentary, biological, chemical inputs to the nearshore system from individual watersheds?
- What are the ecological effects of sedimentary, biological, chemical inputs to the nearshore system from individual watersheds?

Monitoring

- Evaluate the NPS-sponsored coastal biophysical inventory and other intertidal monitoring programs and determine whether the inventory should be repeated every 5 years.
- Complete mapping of the extent and quality of tidal marsh habitat and conduct the analysis every 5–10 years.
- Monitor groundwater quality at selected sites to provide an 'early warning' of contaminant inputs into the marine environment.
- Continue to monitor threatened and endangered species in the park, but evaluate to what extent these species provide information on probable causes for their decline. It may be necessary to choose alternative indicator species to evaluate the effects of stressor reduction.
- Continue to coordinate with the Farallones Marine Sanctuary Beach Watch Monitoring program and determine to what extent the dataset can be used to identify visitor impacts.

- In coordination with the SFAN monitoring program, continue monitoring of harbor seals.
- In coordination with the SFAN monitoring program, continue to monitor salmon populations in all major creeks where they have been identified.

Threats Assessment

- What are the extent, types and impacts of direct exploitation on park resources (e.g., commercial and recreational fishing)?
- What are the impacts of non-consumptive disturbances (e.g., trampling, sonar) on intertidal and subtidal habitats?
- What are the pathogen, pollutant and parasite (ppp) loads in sea mammals (live and dead), shellfish and birds?
- What are the impacts of chemical pollutants / contaminants on benthic habitats and communities?
- What are the major influences of fisheries and other stressors on distribution and abundance patterns of pelagic megafauna?
- What is the abundance and distribution of invasive species in nearshore environments?
- What is the abundance and distributions of sensitive species in nearshore environments?
- What are the impacts of habitat modification on coastal dune/bays and estuarine processes? (Beaches, Coastal Dunes, Mudflats, Tidal Marshes)

Management Actions

- Develop and implement scientifically-based watershed adaptive management programs.
- Limit the effect of recreational activities on foraging shorebirds and seabirds.
- Protect wildlife resources from overflight and watercraft disturbances.
- Continue support for and expansion of public education and stewardship activities in the watershed.
- Continue support for water quality monitoring.
- Use best management practices (BMPs) to reduce stormwater runoff and erosion, improve water quality, protect ecological values and encourage water conservation and appropriate re-use.
- Rehabilitate undesignated trails.
- Work with local municipalities to minimize the effects of development on coastal resources.
- Continue invasive plant species management in PORE, including early detection and control and replacement with indigenous species.
- Continue to identify and mitigate contaminant sources.
- Create continuous wildlife corridors.

Table 2. Existing and potential injuries to coastal water resources in Point Reyes National Seashore (PORE) and PORE-managed lands in Golden Gate National Recreation Area. Problem level cause by stressor: H=high, M=medium, L=low, P=potential, na=not applicable. NPS=National Park Service.

	Point Reyes National Seashore and PORE-Managed Gate National Recreation Area Watersheds							
Stressors	**Tomales Bay**	**Pacific Drainages Kehoe & Abbots**	**Drakes Bay & Limantour**	**Lagunitas**	**Olema**	**Alamere**	**Pine Gulch**	**Bolinas Lagoon**
Climate Change	P	P	P	P	P	P	P	P
Air quality Measurements	L	L	L	L	L	L	L	L
Land Use Change and Development	M[1]	L	L	M	L	L	L	L
"Urban" Development	na	na	na	na	na	na	na	na
Rural Residential	M[2]	na	na	M[3]	na	na	na	H
Agricultural operations and/or development								
Dairies	M[4]	H[5]	H[6]	na	na	na	na	na
Grazing	M[7]	M	M	M	M	M[8]	na	na
Cultivation (silage, row crops in PORE)	L[9]	M[10]	L[11]	L[12]	P[13]	P[14]	L[15]	na
Aquaculture (e.g. oyster culture)	M	na	M	na	na	na	na	na
Equestrian facilities	P[16]	na	na	P[17]	P[18]	P[19]	P[20]	P[21]
Recreation								
Infrastructure (parking lots, bridges)	M[22]	M[23]	H[24]	L	L	L	L	L
Visitor use	M[25]	M[26]	L[27]	M[28]	L[29]	H[30]	L[31]	M[32]
Resource Extraction								
Dredging and sand mining	L[33]	na	na	na	na	na	na	P
Military and industrial practices	na	na	na	na	na	P[34]	na	na
Mining and oil development	na	P[35]	P	P	P	P	L[36]	P
Logging	na	na	na	na[37]	na[37]	na[38]	na[39]	na[40]

Table 2. Existing and potential injuries to coastal water resources in Point Reyes National Seashore (PORE) and PORE-managed lands in Golden Gate National Recreation Area (continued).

	Point Reyes National Seashore and PORE-Managed Gate National Recreation Area Watersheds							
Stressors	**Tomales Bay**	**Pacific Drainages Kehoe & Abbots**	**Drakes Bay & Limantour**	**Lagunitas**	**Olema**	**Alamere**	**Pine Gulch**	**Bolinas Lagoon**
Water diversion								
Surface water withdrawals	L	L	L	M	L	L	M	L
Groundwater withdrawals	L	L	L	L	L	L	L	L
Soils and Geomorphologic Alteration (Hydro-modification)								
Dams and culverts	M[41]	L	M	M[42]	M	L	M	M
Erosion/sedimentation[50]	H[43]	L	M[44]	H[45]	H[46]	M[47]	L[48]	H[49]
Channelization, levees	M	L	L	L	M	L	M	M
Channel hardening[51]	L	L	L	L	L	L	L	L
Lost floodplain function	M	L	L	H	M	L	H[52]	H[53]
Increase impervious surface	P	L	L	L	L	L	L	L
Invasive Species								
Freshwater aquatic species	M[54]	L	L	M	M	M	L	L
Marine and estuarine species	H	L	M	na	na	na	na	M
Terrestrial species	M	M	M	M	M	M	M	M
Disturbed Lands								
Roads and trails	M	L	M	M	M	M	M	M
Legacy infrastructure	M[55]	L	L	L	L	L	L	L
Quarries	L	M	M	L?	L	L?	L	L
Park Management Activities	L	M[56]	M[57]	M [58]	M[59]	L	L	na
Natural disturbance (Fire, Landslide, Earthquake)	M	M	M	M	M	M	M	M

Table 2. Existing and potential injuries to coastal water resources in Point Reyes National Seashore (PORE) and PORE-managed lands in Golden Gate National Recreation Area (continued).

[1,2]threats to A60 zoning on east side	[20,21]on private lands
[3]see notes	[22]headquarters, currently evaluating Bear Valley Ck.
[4]Giacomini scheduled for restoration 2007, east side dairies on private lands	[23]North and South Beach parking lots, Pierce Point, Lighthouse paved parking
[5]Kehoe, McClure, L Ranch: improvements in Kehoe, McClure	[24]Ken Patrick Visitor Center parking lot/Waste Lagoon, Limantour Beach
[6]A,B,C Ranch: Improvements at A,C	[25]kayaks
[7]primarily east shore	[26]Kehoe beach dogs, North Beach visitors on plovers
[8]Niman lease only	[27]sandy beaches, not as much rocky intertidal so not as accessible
[9]east side only	[28]bed alteration due to summer swimmers, campers
[10]silage on Kehoe, McClure, Evans	[29]trail crossing due to horses, hikers
[11]no silage, limited row crop	[30]Agate Beach
[12]no info	[31]no access
[13,14]nothing current	[32]kayaks
[15]organic farm, active row crops on private lands, good practices	[33]not in park, Tomales dunes
[16]Tomales Bay TMDL source requirements; east side ranches potential for conversion	[34]Wildcat Air Strip
[17]TMDL source requirements; McIsaac, San Geronomo outside of park	[35]offsite oil development
[18]TMDL source requirements; Stewart, Five Brooks Stables	[36] legacy copper mine, sampled superficially but not an issue
[19]nothing current	[37-40]P, Legacy

Acknowledgements

Financial and logistical support for this report was provided by National Park Service-Water Resources Division and University of California Sea Grant Cooperative Extension. Dawn Adams, Jeffrey Cross, Mark Flora, Kristen Keteles, Cliff McCreedy and Paul Olin provided overall guidance, editing and review. Sarah Allen, Darren Fong, Brannon Ketcham, Tamara Williams and two anonymous reviewers provided feedback on various draft documents.

Introduction

Point Reyes National Seashore (PORE) and Golden Gate National Recreation Area (GOGA) cover 191 mi (307 km) of shoreline along the central coast of California from the entrance of Tomales Bay to Half Moon Bay, south of San Francisco. The convergence of two ecological provinces and the upland/marine margin result in high biological diversity and an abundance of plants and animals seen few places on earth. Over 45 percent of North American avian species and nearly 18 percent of California's plant species are found within the park(s) due to the large variety of habitat types and unique geology. As pristine habitat is lost elsewhere in California, the relevance of these parks, which straddle the highly urbanized San Francisco Bay, increase as protected areas with notable natural features. Windswept beaches stretching along the Pacific Ocean shoreline as well as craggy coastal cliffs and headlands, marine terraces and coastal uplands, salt marshes and estuaries and coniferous forests are some of the most geologically and ecologically diverse areas of the National Park Service (NPS). The area's rich and varied natural resources have attracted and supported people for over 5,000 years, a continuum of human use and changing land-use values.

The two parks are nearly equal in size and similar in their historical natural resources. However, they are very different in character due to differences in the level of development that has occurred near each park. PORE is much more rural in character, bounded on the east by Tomales Bay and the Highway 1 corridor; while southern GOGA abuts the highly urbanized City of San Francisco (Figure 1).

PORE was established by President John F. Kennedy on September 13, 1962 (Public Law 87-657, to preserve and protect wilderness, natural ecosystems and cultural resources along the diminishing undeveloped coastline of the western United States. PORE is a large, continuous expanse of land along the coast, which, except for a large agricultural presence (ranches), has few human inhabitants in or near its borders (Figure 1). PORE manages the northern portion of the GOGA. PORE includes more congressionally designated wilderness (25,370 ac [10,267 ha] or 36 percent of the park's total 71,000 ac [28,733 ha]) than any other national seashore. Located just an hour drive from a densely populated metropolitan area, PORE is a sanctuary for a myriad of plant and animal species. Through its enabling legislation and subsequent amendments, PORE is charged with balancing the need to protect the aquatic and ecological resources, while preserving agricultural operations, including ranching and dairy, which contribute substantially to the cultural landscape. The park attracts approximately 2.25 million visitors each year (NPS 2008). Twenty-nine federally-listed threatened or endangered species occur in the park, including; northern spotted owl (*Strix occidentalis caurina*), California red-legged frog (*Rana aurora draytonii*), coho salmon (*Oncorhynchus kisutch*), California freshwater shrimp (*Syncaris pacifica)*, tidewater goby (*Eucyclogobius newberryi)* and Myrtle's silverspot butterfly (*Speyeria zerene myrtleae*) (NPS 2009).

GOGA is one of the largest urban national parks in the world. Established in 1972, as part of a trend to make NPS resources more accessible to urban populations and bring "parks to the people," GOGA's 75,398 ac (30,512 ha) of land and water extend from Tomales Bay in the north in Marin County to the south in San Mateo County, encompassing 91 mi (146 km) of bay and ocean shoreline (Curdts 2011). The area attracts 16 million visitors each year, making GOGA one of the most highly-visited NPS units (NPS 2008). The North District of GOGA,

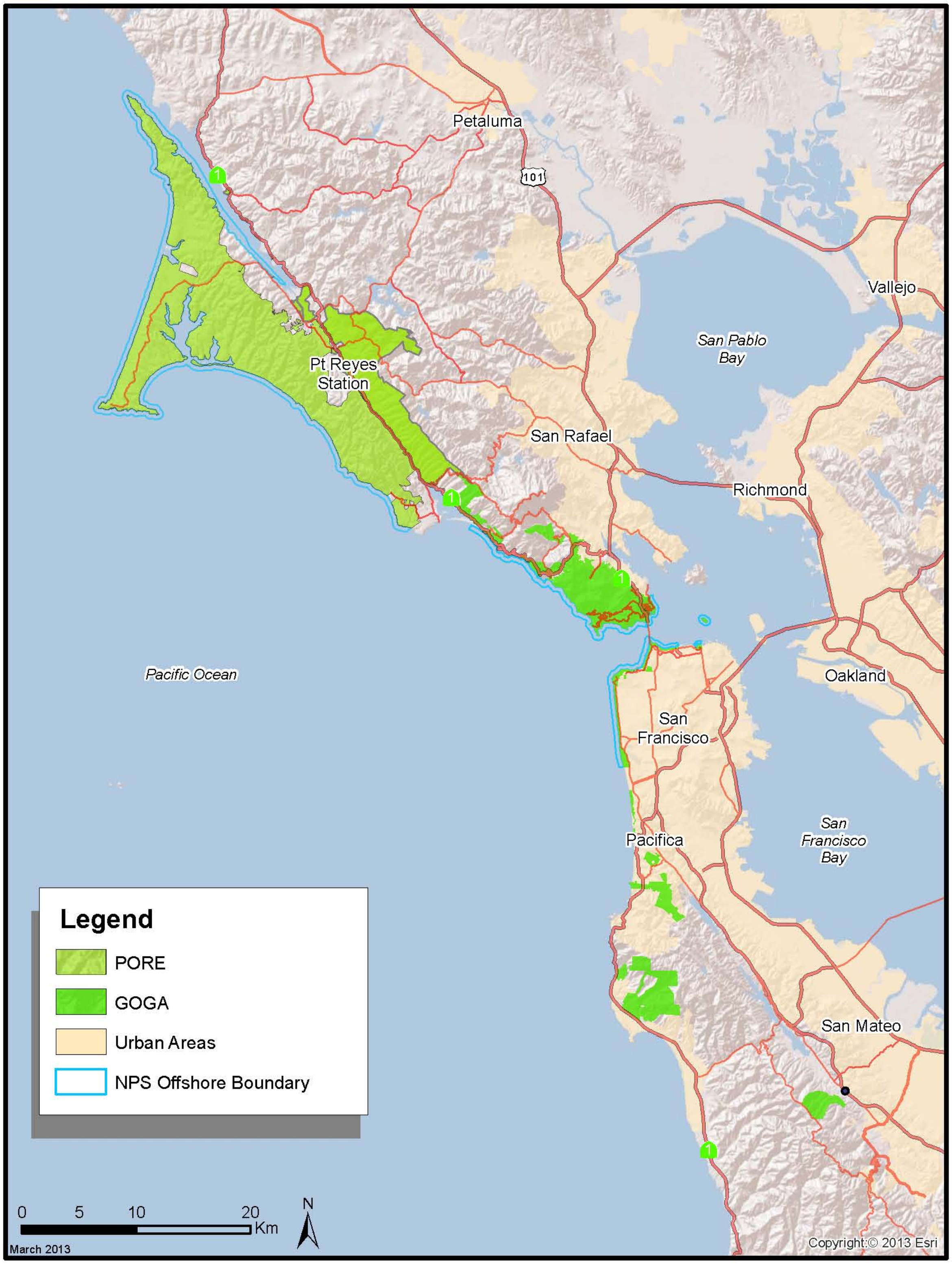

Figure 1. Areas managed by Point Reyes National Seashore (PORE) and Golden Gate National Recreation Area (GOGA).

19,265 ac (7,796 ha) of land north of the Bolinas-Fairfax Road, is managed by PORE under a Memorandum of Understanding.

GOGA contains numerous historical and cultural resources, including Alcatraz, Marin Headlands, Nike Missile Site, Fort Mason, as well as Muir Woods National Monument, Fort Point National Historic Site and the Presidio of San Francisco. These sites contain a variety of archeological sites, military forts and other historic structures which present a rich chronicle of 200 years of history including; Native American culture, the Spanish Empire frontier, the Mexican Republic, evolution of American coastal fortifications, maritime history, 18th century and early 20th century agriculture, military history, California Gold Rush, Buffalo Soldiers and the growth of urban San Francisco. Rich in natural resources it comprises 19 ecosystems and is home to 1,273 plant and animal species. With 36 threatened or endangered species including northern spotted owl, California red-legged frog and coho salmon, GOGA has the third largest number of federally-listed threatened or endangered species of all NPS units (NPS 2009).

Numerous special status designations emphasize the parks' collective importance as areas of biological significance. The Nature Conservancy has listed this region as one of the six most biologically significant areas in the United States, a biodiversity "hot spot" targeted by the global conservation community as key to preserving the world's ecosystems (Stein et al. 2000). Conservation International describes this portion of central California as one of the top 25 hotspots and the most threatened of all biologically rich terrestrial regions in the world. Encompassing PORE and GOGA, the Golden Gate Biosphere Reserve is one of 411 reserves designated by the United Nations Educational, Scientific and Cultural Organization's Man and the Biosphere Program to provide a global network representing the world's major ecosystem types. In 2001, the American Bird Conservancy named PORE to its 100 Globally Important Bird Areas list. This tribute recognizes the diverse nature of the bird fauna and the important research carried out in the park by Point Reyes Bird Observatory Conservation Science (PRBO), one of the premier bird research organizations in the world. The parks are also within the Northern California Coastal Forest eco-region defined by the World Wildlife Federation (Rickets et el. 1999) and the Northern California Coast Section/Marin Hills and Valley Subsection as defined by the U.S. Department of Agriculture (Goudey and Smith 1994). The areas adjoin several California State Areas of Biological Significance (CEPA 2009) and Critical Coastal Areas (California Coastal Commission 2009).

Coastal Watershed Assessment Goals

The coastal watershed assessment (CWA) assesses the condition of resources managed by PORE (including the North District GOGA) and GOGA. GOGA comprises NPS lands south of Bolinas-Fairfax Road and include Muir Woods National Monument, Fort Point National Historic Site and the Presidio of San Francisco. The CWA extends a varying distance offshore from the tip of Tomales Bay to Mori Point[3]. The goal of the project was to assess the parks' coastal resources and to identify the state of knowledge of resource condition and the effects of natural and anthropogenic factors on those resources. The objectives were to: 1) locate and examine existing water resources relating information on to coastal water quality; 2) provide a assessment of the existing condition of the marine coastal and nearshore aquatic environments; 3) identify current

[3] A coastal area south of Mori Point was added to the park system in 2002 and was not included in this analysis.

anthropogenic stressors or threats that may affect the future condition of these resources; and 4) identify and make recommendations to fill in existing information gaps. Our focus is on coastal watersheds, particularly the impacts of anthropogenic stressors on aquatic habitats and associated biota. Coastal habitats and special status species are very similar across the two parks, which facilitated grouping the park systems in the analysis.

Document Overview

The CWA is separated into the following chapters:

- **Park Description** introduces park resources, providing a brief history of the land uses and an overview of the climatic, geologic and topographic features that define the ark systems.
- **Stressors** provides an overview of the anthropogenic stressors that affect park resources, a wide array of factors common to many national parks; and a summary table of their unique effects in the PORE and GOGA watersheds.
- **Habitats** provides an in depth description of the habitats and associated flora and fauna, the context for evaluating key indicators of watershed health.
- **Water Quality** provides an overview of water quality monitoring and condition in both parks, using several water quality indicators as an organizing theme.

The water quality summaries use the CALWATER super-planning watersheds as the context for visually depicting water quality results. Because PORE manages the northern GOGA lands these are assessed as one unit (see Figure 6 in Park Description chapter); while GOGA lands are managed separately (see Figure 7 in Park Description). The watershed assessment summaries are based on standardized methods for evaluating watershed conditions. The “Pressure-State-Response” model (Figure 2) describes how human activities (Pressure) such as land, water and chemical use affect water quality and associated beneficial uses (State). In turn, changes in management of these human activities (Response) affect the types and magnitudes of the “pressures” and the resultant water quality and beneficial use “state.”

The state or condition can be further described using a generalized conceptual framework that supports the Clean Water Act (Figure 3), and a similar framework developed by the US Environmental Protection Agency (US EPA) Science Advisory Board (2002; Figure 4). The broad conceptual framework in Figure 3 suggests a way to organize the information needed to assess condition into the following categories: Habitat Extent and Structure, Hydrology and Geomorphology (Flow Regime), Water Quality (Physical and Chemical variables) and Biotic Factors. The US EPA Science Advisory Board expanded on this framework to create an assessment framework that utilizes environmental condition indicators (US EPA 2002).

The similarity between the conceptual models is striking; however, the US EPA Science Advisory Board Framework (Figure 4) added natural disturbance regimes as an important assessment category because anthropogenic stressors also affect natural disturbance patterns.

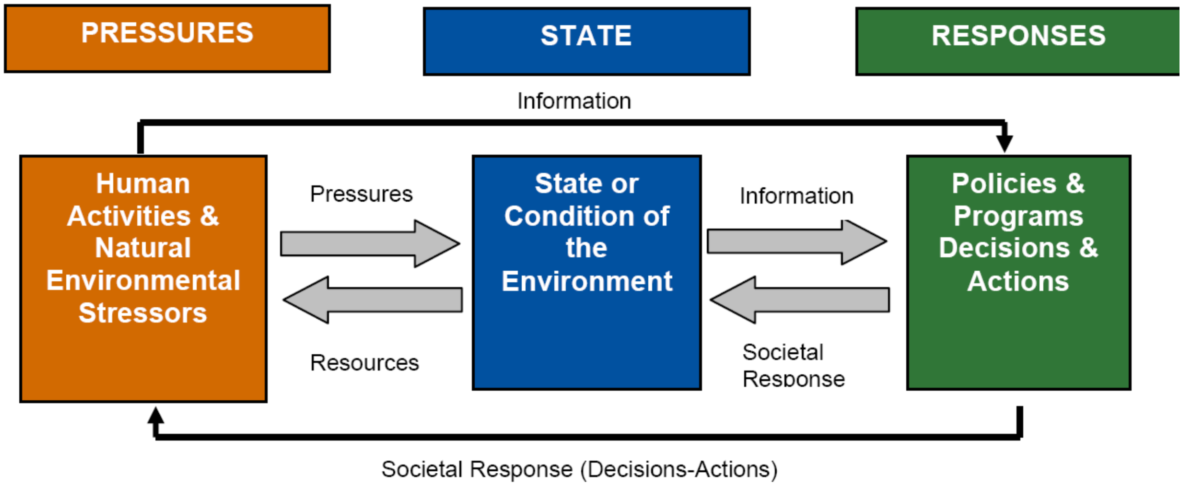

Figure 2. Example of a pressure-state-response model framework (modified from OECD 1993).

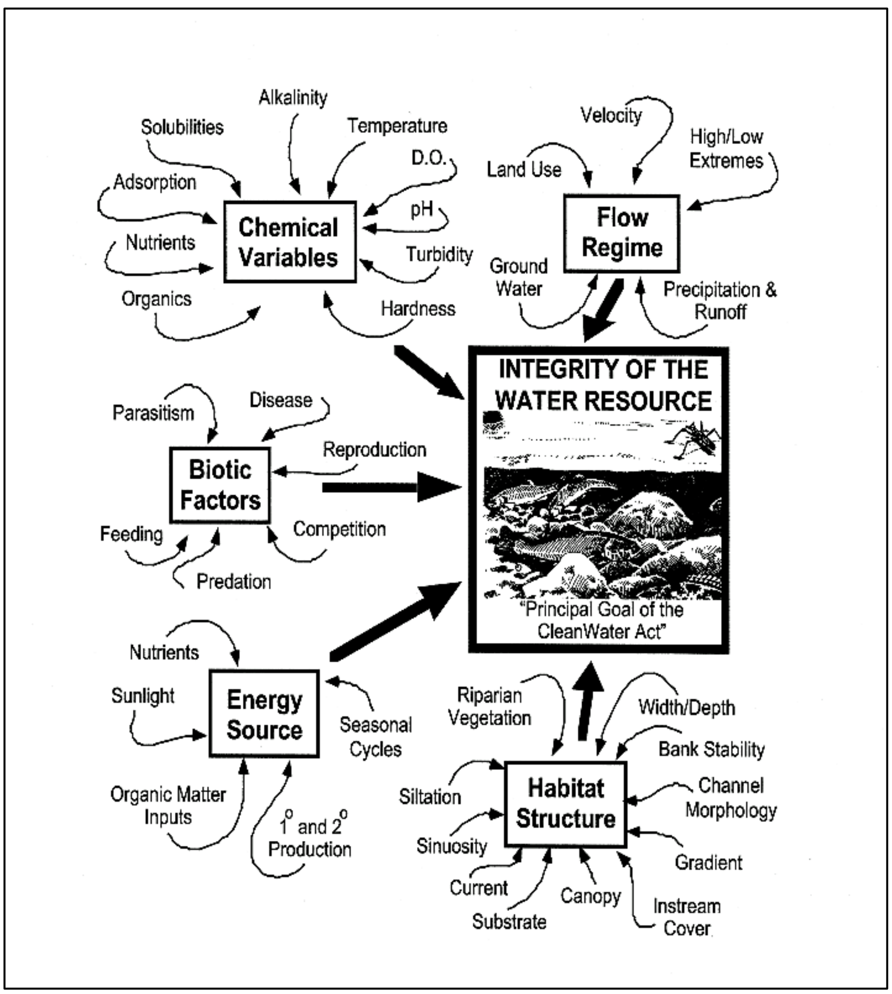

Figure 3. Conceptual basis of the Clean Water Act depicting the primary aspects of water resource integrity. (modified from Karr et al. 1986).

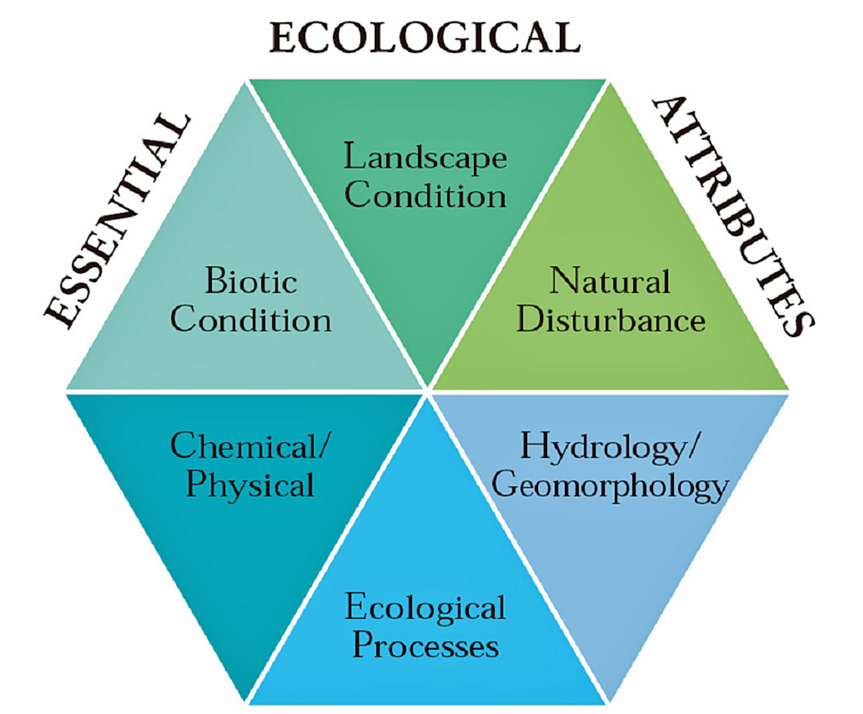

Figure 4. Attribute categories of the US EPA Science Advisory Board's assessment framework which was used as an organizing framework for the Watershed Assessment (US EPA 2002).

Park Description

Physical Setting

Point Reyes National Seashore is located in west Marin County California, approximately 40 miles northwest of San Francisco (Figures 1 and 5). The jurisdictional boundary of PORE encompasses 71,046 ac (28,751 ha) of beaches, coastal cliffs and headlands, marine terraces, coastal uplands and forests. 25,370 ac (10,267 ha) are congressionally designated wilderness and the only marine wilderness on the Pacific Coast south of Alaska. PORE manages 19,265 ac (7,796 ha) of the North District of GOGA lands adjacent to PORE and north of Bolinas-Fairfax Road. This area includes 22,000 ac (8,903 ha) of estuarine and marine waters including most of the waters of Tomales Bay (south of the mouth of Walker Creek). The marine boundary of PORE is adjacent to two national marine sanctuaries (Gulf of the Farallones and Cordell Bank), and includes four California State Areas of Special Biological Significance (ASBS) and the Estero de Limantour Marine Reserve. The California Marine Life Protection Act Program recently designated additional state Marine Protected Areas within the boundary of PORE (see Stressors chapter and http://www.dfg.ca.gov/mlpa/nccmpas_list.asp).

Golden Gate National Recreation Area is one of the largest urban national parks in the world (Figures 1, 6 and 7). GOGA comprises approximately 75,000 ac (30,351 ha) of coastal lands with approximately 550 ac (223 ha) in Muir Woods. The lands which are discontinuous and stretch in a long, narrow band along or near the coast, were predominately military areas and emplacements before the parks' creation. To the north and south of the Golden Gate, park lands are numerous and located in Marin County (north of the Golden Gate), San Francisco and San Mateo counties (south of the Golden Gate) as well as within San Francisco Bay itself. GOGA shares management of some marine waters with the Gulf of the Farallones and Monterey Bay National Marine Sanctuaries. The marine-estuarine boundary of GOGA generally extends 0.25 mi (0.4 km) offshore south until Fort Funston.

North of the Golden Gate, GOGA-managed lands include: Stinson Beach, Muir Woods, Muir Beach, the Marin Headlands, Point Bonita and Fort Baker. Located within the City and County of San Francisco are Alcatraz Island, Fort Point NHS, Fort Miley, Fort Funston, Cliff House/Sutro Properties, Fort Mason and Ocean Beach. GOGA shares management responsibilities of the Presidio with the Presidio Trust. The southern lands (San Mateo County) were added to the GOGA boundary beginning in 1980 with Sweeney Ridge (est. 1,500 ac [607 ha]), Milagra Ridge (240 ac [97 ha]), and the San Francisco Watershed lands (est. 20,000 ac [8,094 ha]; Figure 7). The San Francisco Watershed lands are located within the GOGA authorized boundary but managed by the County of San Francisco and public access is restricted. In 1992, Phleger Estate, an estimated 1,000 ac (404 ha), was acquired. The 105-ac (42 ha) Mori Point (located near Pacifica) was acquired in 2002 and more recently, the GOGA boundaries have been enlarged to include San Pedro Point and Rancho Corral de Tierra in San Mateo County.

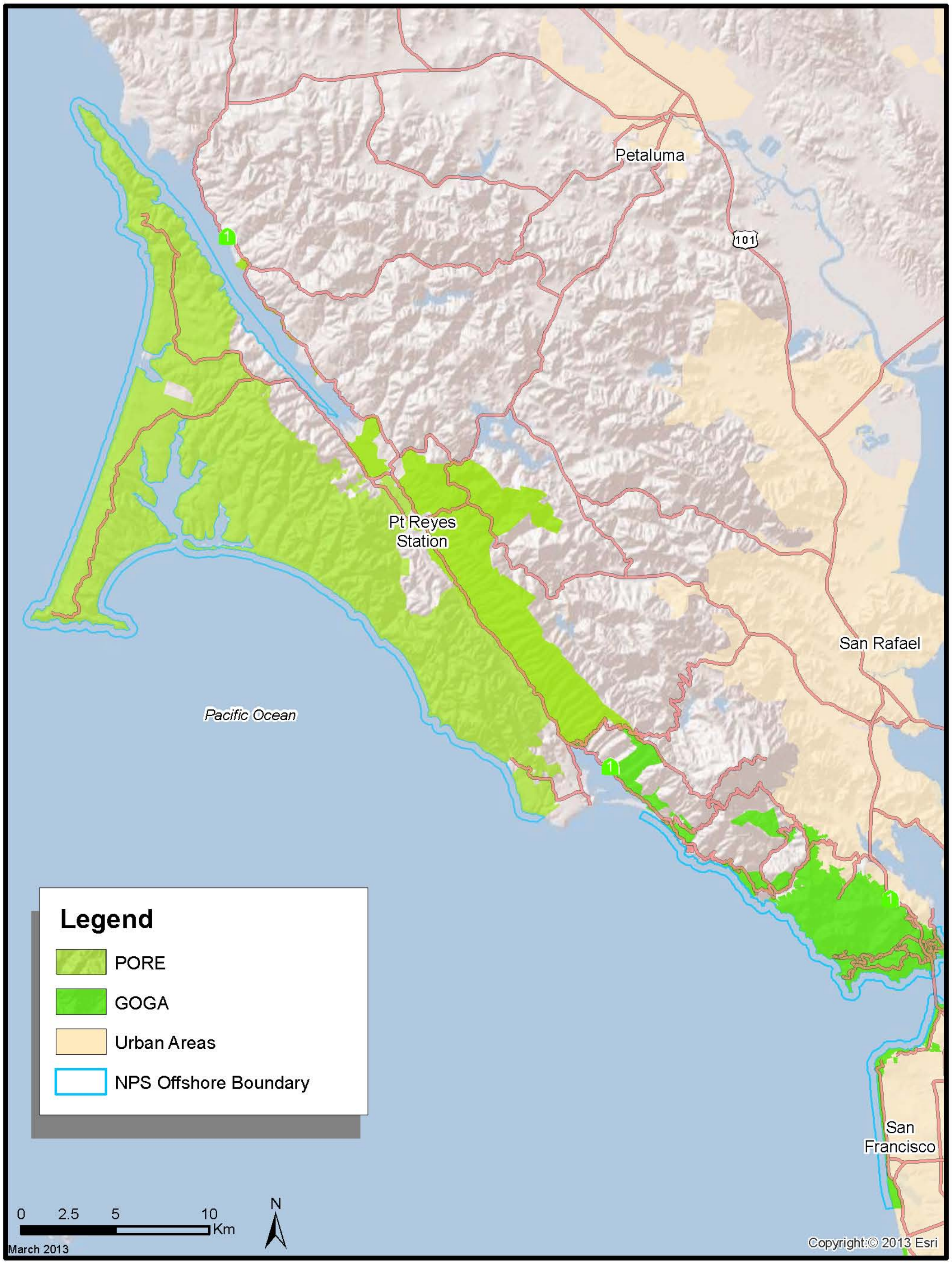

Figure 5. Lands managed by Point Reyes National Seashore (PORE) including the northernmost lands of Golden Gate National Recreation Area (GOGA).

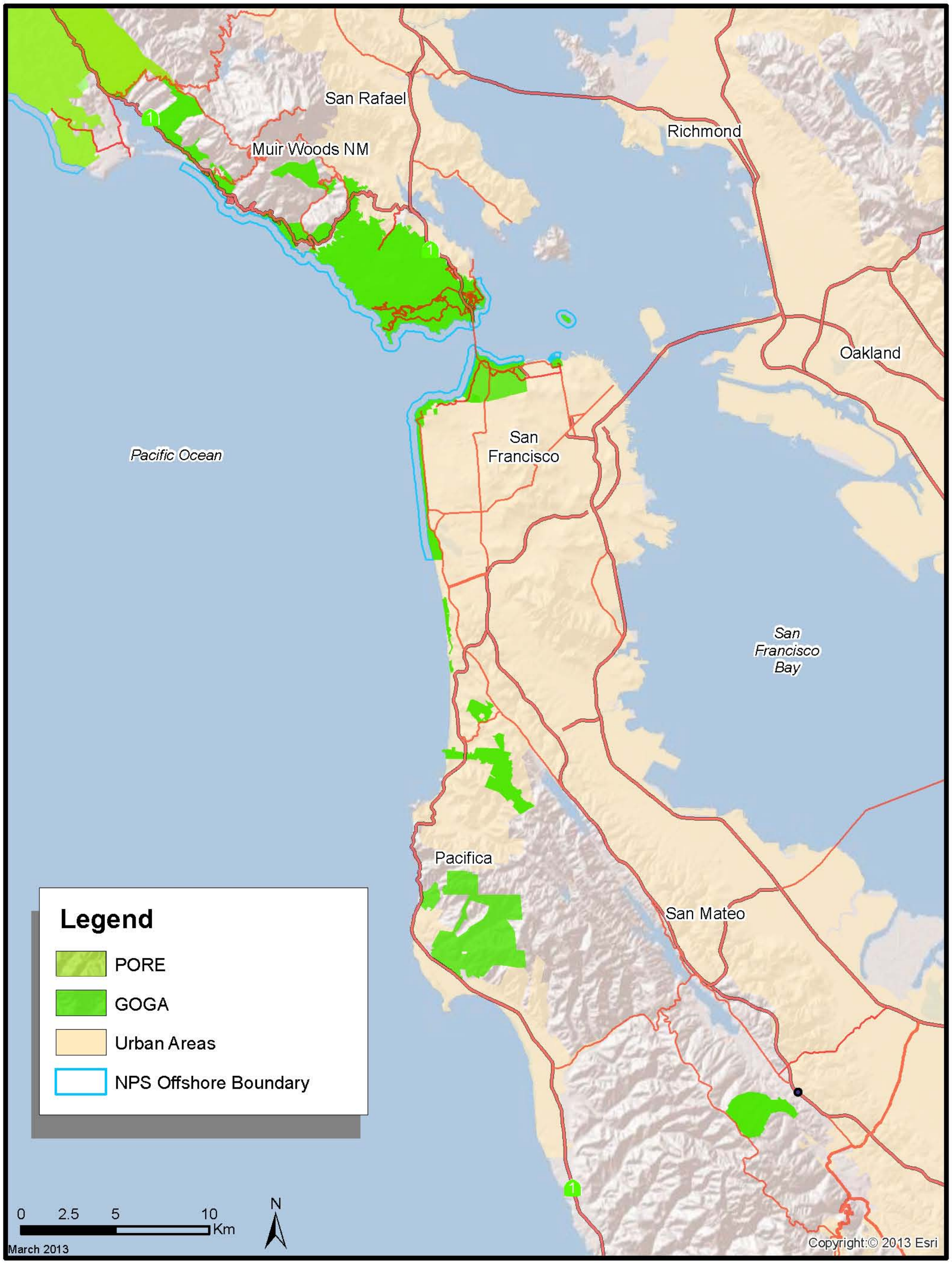

Figure 6. National Park Service lands managed by Golden Gate National Recreation Area (GOGA) and the Presidio Trust. PORE = Point Reyes National Seashore.

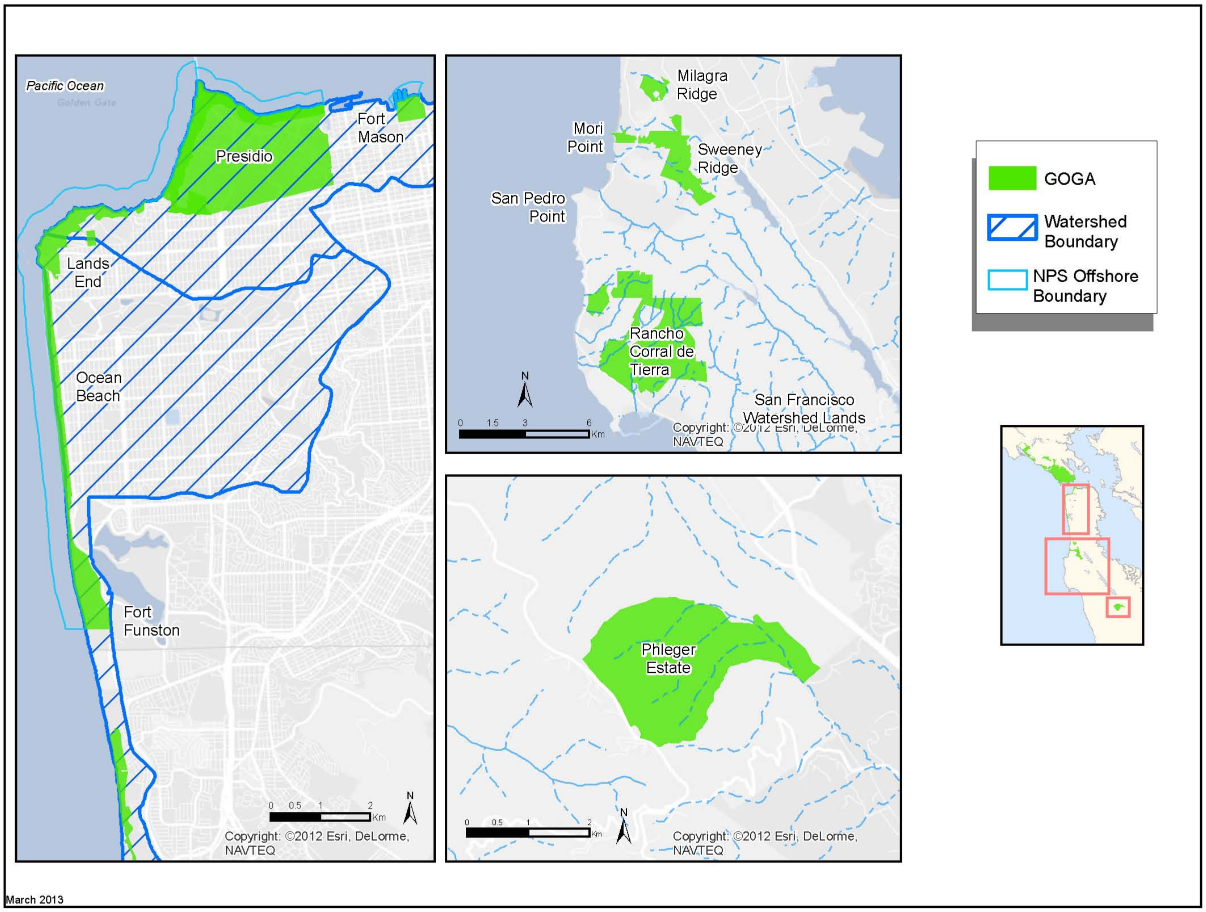

Figure 7. Land holdings of the Golden Gate National Recreation Area (GOGA) south of the Golden Gate Bridge, in the San Francisco Bay Region with watershed boundaries. Watershed boundaries are smaller than the watersheds used in the analysis (NPS GOGA Fire Management Plan 2005).

Terrestrial Resources

Due to its rich resources, the central coast of California has attracted human settlement since prehistoric times. Native American populations in California were possibly the highest pre-Columbian density north of Mexico (Pritzker 2000). Before Europeans came to California, Native American Miwok, the Ohlone, inhabited the southern sections of the PORE and GOGA park land for over 5,000 years. For centuries, they existed as hunter gatherers, depending on the land to provide food and materials to build shelters and to make tools and baskets. They used fire to promote the growth of seed-bearing annual plants, to prevent shrub encroachment on grasslands, and to keep the landscape open for deer and other animals. The Spanish in the late 1700s and later Mexican settlement introduced year-long cattle and sheep grazing, burning and cultivation that led to the extirpation of many native animal species and the spread of non-native plants. For example, in the Presidio, Spanish inhabitants cleared much of the vegetation including trees and coastal scrub, using wood for buildings and fires.

Natural habitats were altered with the influx of people. In the 1840s, after gold was discovered in the Sierra foothills, significant numbers of "settlers" arrived in California. San Francisco became a bustling city. The new wave of settlement brought more land conversion and exotic species, including trees, such as eucalyptus, acacia and Monterey cypress and pine. Large ranchos were subdivided into smaller ranches and the change in ownership and management altered the pattern and types of disturbance across the landscape as fences went up, fertile marine terraces were tilled and forests were logged on a large scale (Stanger 1967, Hynding 1982, Fairley 1987). Trees were planted in dune areas such as the Presidio and quickly dominated the landscape, blocking the prevailing winds from sweeping across the dune habitat. The newly created forests extended into established native plant communities and created microclimates, trapping moisture from the fog and providing increased shade. These new microclimates further encouraged the growth of exotic plant species. The rapid, extensive conversion of the landscape to non-native annual vegetation was so complete that the original extent and species composition of most native perennial grasslands are largely unknown (Burcham 1957, Holland and Keil 1995).

Mexican land grantees established ranchos in California during the early 1800s, including the Point Reyes peninsula. The Franciscan missionaries set the stage for the explosion of the beef and dairy industry in west Marin with the introduction of cattle in 1817. They established the San Rafael Asistencia, near San Francisco Bay, as an annex to Mission Dolores in San Francisco, serving as a recuperative center for ailing coastal Miwok and Ohlone natives. Secularization of the missions following Mexican independence from Spain led to land grant subdivision and the expansion of cattle ranching on the peninsula. As land was sold to the new immigrants, the title to the land usually became ensnared in litigation[4]. Through a complex scenario, the San Francisco law firm of Shafter, Shafter, Park and Heydenfeldt, obtained title to over 50,000 ac (20,234 ha) on the peninsula, encompassing the coastal plain and most of Inverness Ridge. By the 1860s, the Point Reyes peninsula was divided into more than 30 tenant dairy ranches (Figure 8). Initially, the Shafters signed new leases with existing dairy ranches; eventually the system of management "corresponded to the feudal system of England," according to the San Rafael Independent in 1939[5]. The dairy industry at Point Reyes provided food for many early settlers and gave immigrants a livelihood in California. The uses brought with them certain impacts such as the introduction of fecal matter to streams and trampling of riparian vegetation. Streams were dammed to create farm ponds, causing the destruction of stream habitat that created impediments to fish migration. As this system became increasingly difficult to manage effectively and the Central Valley became the primary cattle producer, the coastal cattle industry became less lucrative, (Burcham 1957, Toogood 1980), but many of the burning and grazing practices lasted until the 1960s. Grazing and farming in the San Mateo lands of southern GOGA started later (circa 1930s) and was generally less intense than in PORE and northern GOGA lands.

Many modern day roads began as trails during the ranching period. Trails were developed for wagon traffic and wove their way through the area, connecting the various ranches and later dairies (Livingston 1994). Roads were extensive during the late 1800s (Figure 9). Ranch roads often caused hydrologic impacts. A ranch road that traversed a valley in the Rodeo Lagoon watershed in GOGA intercepted uniform surface flow of water causing gullying and conversion of wetlands to scrub habitat (Cooper and Wolf 2008).

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[4] Text adapted from National Park service website: http://www.nps.gov/PRNS/history_ranch.htm (accessed 2006).

[5] For more information, refer to Ranching on the Point Reyes Peninsula: A History of the Dairy and Beef Ranches within Point Reyes National Seashore, 1834-1992. By D. S. Livingston, National Park Service, 1993, revised 1994.

Figure 8. Pierce Point Ranch, at the tip of Tomales Point, in Point Reyes National Seashore (http://www.flickr.com/photos/lawatt/1815485/ [public]).

Logging, focused primarily on redwoods, began in earnest in 1849. In the Bolinas area alone, 13–15 million board feet of timber were removed in 10 years (Munro-Fraser 1880). On the Phleger property in the south of GOGA, the Whipple Mill operated from 1852 to 1855 until the entire property was logged. After redwood was removed, loggers focused on cordwood (oak, bishop pine, madrone, etc.). In some areas of Mount Tamalpais (southern Marin County) after the trees were cut, workers skimmed the soil for clay to make bricks (Fairley 1987). These practices resulted not only in the loss of vegetation but in significant erosion. Logging operations diminished on GOGA lands during the 1850s as operations moved north to the larger forests. Among the legacies of this period are dense second-growth forests and high levels of siltation in areas such as Bolinas Lagoon (Fairley 1987). Logging on lands in the Olema Valley and Inverness Ridge, continued even into the 1960s with the operation of the Sweetwater Mill (now Five Brooks Stables and Mill Pond) and logging of the Righetti Ranch near Bolinas. Scars associated with logging practices are best illustrated along Inverness Ridge, near Fir Top, where remains of dense logging roads are visible from Stewart Trail.

From the early 1900s on, activities such as land clearing, timbering, cultivation, cropping, road building, commercial development markedly affected the parks. Aside from introducing exotic vegetation, the military presence at the Presidio and other installments in Marin and San Mateo counties left its mark on the landscape. Large areas were cleared for buildings and military waste including toxic chemicals were left on the land. Urbanization of the area took an extreme toll as much of the areas surrounding southern GOGA were developed. By 1990, explosive growth had filled in the central flats of the San Francisco Bay area and agriculture had moved beyond the suburbs. Problems from development continue today. These activities are discussed in more depth in the Stressors chapter.

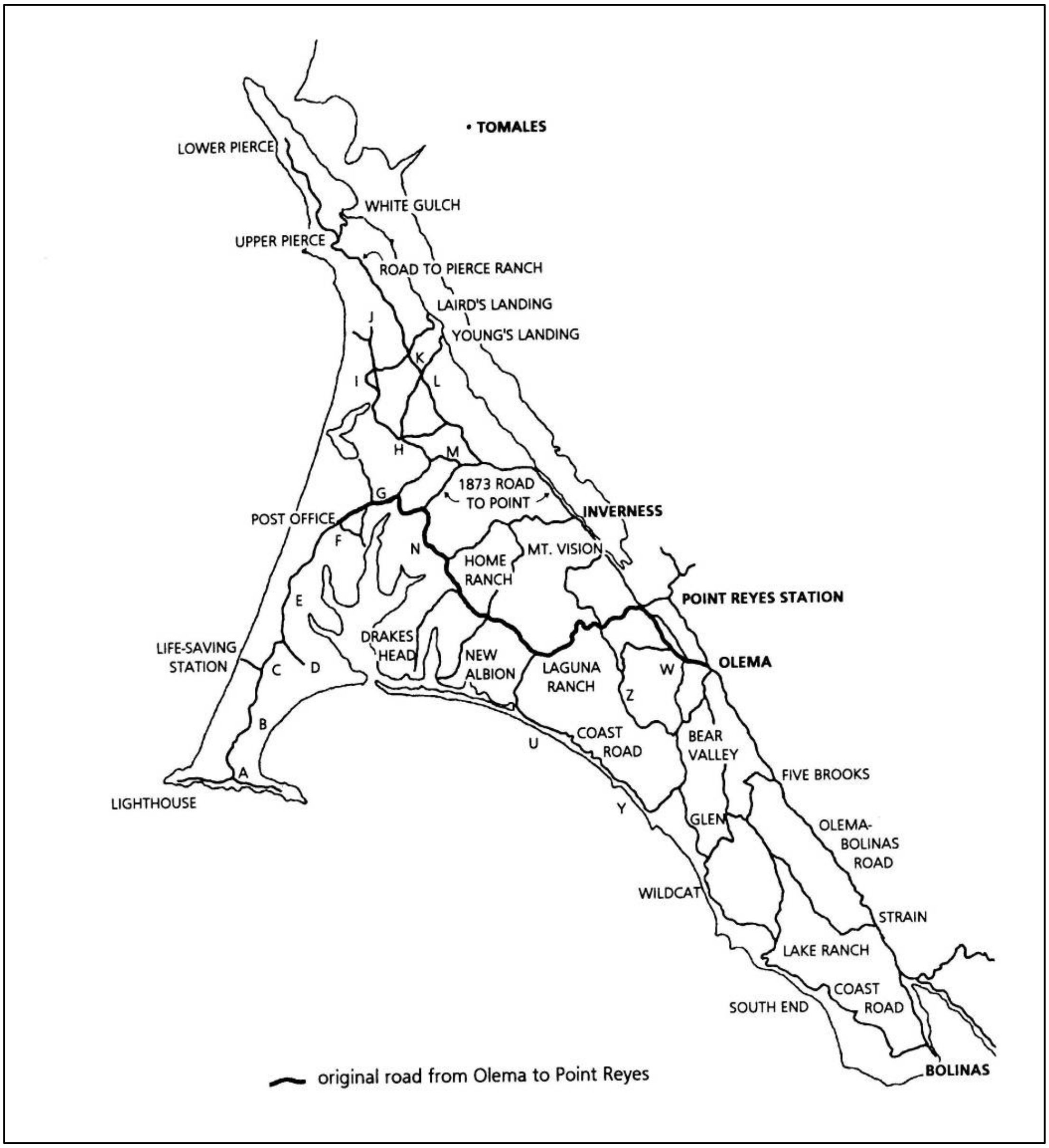

Figure 9. Map of major historic roads, ranches (A-Z), and features on the Point Reyes Peninsula, 1850s–1900 (Livingston 1994).

Nearshore Resources

The central coast is a rich area with a high diversity and abundance of fish. The Miwok and Ohlone used the nearshore resources, but their impacts were likely minimal due to their primitive fishing practices and relatively sparse populations. Skinner (1962) provides a comprehensive overview of the recreational and commercial harvesting of fish and wildlife resources in the San Francisco Bay region such as herring from the 1800s to the 1950s. After World War II, fleet expansion and improved technology caused a significant increase in fishing efficiency and an increase in the level of fishing pressure on many nearshore fisheries. By the late 1970s, declining trends in fish catch per unit effort for many species convinced the California Department of Fish and Game (CDFG) and the Pacific Fishery Management Council (PFMC) that there was a need to limit entry to fisheries. In California, the first "limited entry program" was established in 1977 for the abalone fishery and for salmon in 1980 (Leet et al. 2001). By 1983, this limited entry program became a salmon vessel permit system. While these and other limited entry programs capped the number of fishermen or vessels allowed on the California coast and created more orderly fisheries, they generally had little effect on overall fishing capacity. High-value fisheries that occur in nearshore areas along the park coastlines such as Pacific herring, sea urchin and Dungeness crab fisheries are now highly restricted. Currently, commercial fishing is prohibited. Recreational fishing in the parks is subject to CDFG and park regulations through annual updates to the park compendiums by the respective superintendents; fishing is allowed on park beaches in PORE and GOGA and freshwater lakes and ponds in PORE, but prohibited in most streams and lagoons (Muldoon 2012, Dean 2012).

Commercial oyster farming first began in Tomales Bay in 1875 and was well established by the late 1930s when oyster growing was abandoned in San Francisco Bay because of pollution. Japanese oysters were introduced to Tomales Bay in 1928. Four years later they were planted in Drakes Estero. The water in Tomales Bay and Drakes Estero is too cold for natural oyster spawning other than those native to the area. Farmers buy seed oysters and grow them using methods that vary depending on the desired end product. In the past, regulation on import of oyster seed was lax, putting Tomales Bay and Drakes Estero at risk of introduction of non-native species associated with oyster import. See the Stressors chapter for more information on current fishery and aquaculture impacts.

Human Population Projections

Bay Area population increases are expected to escalate in the next 20 years. It is estimated that by the year 2020, the San Francisco Bay Area will be home to more than 8 million people, a 16% increase over the 2000 population census (Association of Bay Area Governments 2000). This increase will be largely due to increases in births and life expectancy rather than migration. Much of the expected increase is in the western and northern counties, which are likely to influence park resources. Despite these projections, recent estimates indicate that the population is showing a slight downturn, a 0.5% decline, from 2000 to 2003 in Marin County and a 1.4% decline in San Mateo County. See Stressors chapter for additional information.

Land Use and Land Cover

Land use and land cover types (vegetation) of PORE and GOGA were mapped and incorporated into the parks' geographic information systems (GIS) using photo interpretation of 1990s aerial photography (Schirokauer et al. 2003). This mapping effort used the National Vegetation Classification System, with groupings based on structure and environmental factors such as elevation and hydrologic regime, resulting in over 80 vegetation alliances. For this report, the alliances were grouped into land cover types as follows: Beaches/Mudflats, Coastal Dunes, Unvegetated Shorelines (Dunes in Figures 10 and 11), Coastal Scrub/Chaparral, Grasslands, Pasture, Herbaceous Wetlands, Riparian Forest/Shrubland, Bishop Pine, Hardwood Forest, Douglas-Fir/ Coast Redwood, Built-up/Developed Urban disturbance and Disturbed. The land cover types correspond most closely to the "vegetation management community" of the vegetation map classification hierarchy (Schirokauer et al. 2003). It should be noted that Beaches and Mudflats, Herbaceous Wetland and Riparian Forest/Shrubland communities track closely with mapped wetland resources.

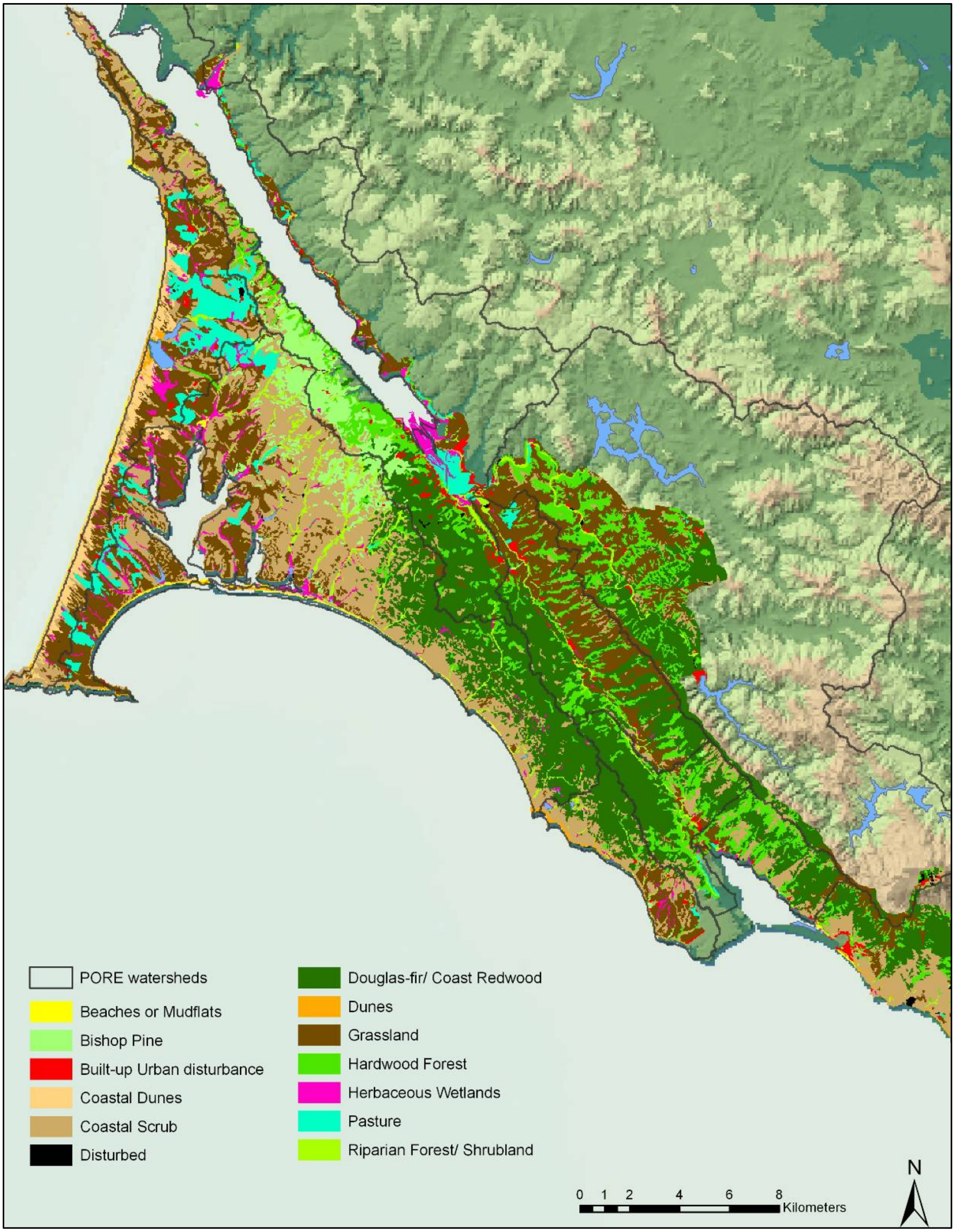

Figure 10. Land cover types for the Point Reyes National Seashore (PORE) and Point Reyes National Seashore-managed Golden Gate National Recreation Area lands. Note that this area has minimal urbanized boundaries.

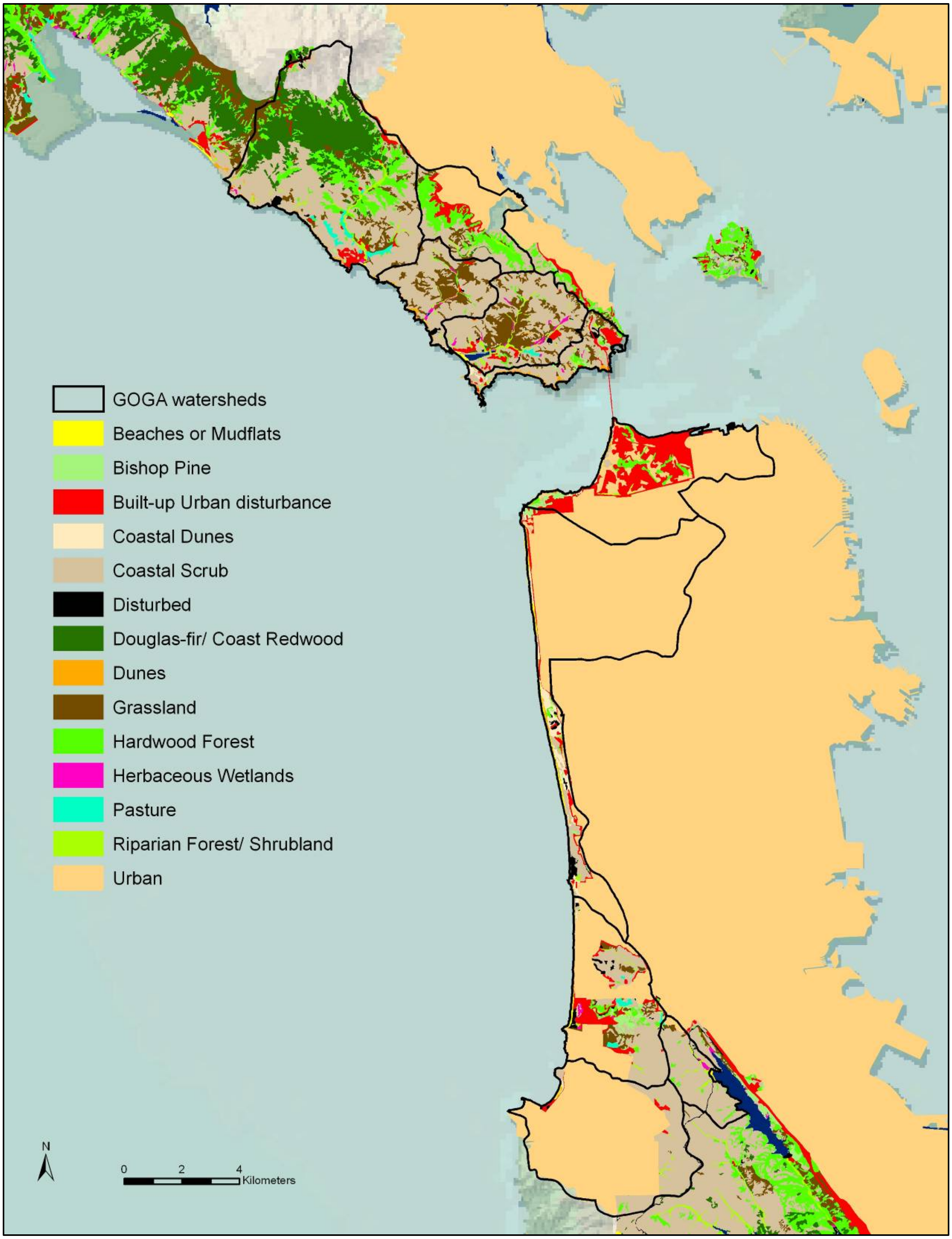

Figure 11. Land cover types for the Golden Gate National Recreation Area (GOGA) lands. Note the significant areas of urbanization bordering the park (tan-colored).

PORE and Northern GOGA

PORE and northern GOGA managed by PORE have little urban disturbance and is dominated by coastal scrub and forests throughout the upland areas of the park system (Figure 10). 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. 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 10 shows the distribution of land cover types by watershed. The Habitats chapter presents a series of tables which depicts the calculated land cover extent for various land cover types for each watershed.

GOGA

GOGA parklands are a patchwork of open space and culturally significant features interspersed with other public lands and urban development. Adjacent land use in the north is a mix of private residential and agricultural lands, publicly held watershed and parks and open space. Apart from the 91 miles (146 km) of shoreline (including islands), approximately 38 mi (61 km) of GOGA boundary adjoin residential communities in the three counties (NPS 2005, Curdts 2011). In south Marin County, adjacent lands include the unincorporated communities of Marin City, Muir Beach, Stinson Beach, Tamalpais Valley and Homestead Valley and the incorporated towns of Mill Valley and Sausalito. GOGA parklands are predominantly historic forest (non-native) within the Presidio in San Francisco City and County and adjoin urban areas. San Mateo parkland is mostly located in the northern part of the county adjacent to the city of Pacifica; though parcels at Mori Point and San Pedro drain isolated areas along the southern portion of the county to the open coast (Figure 11). In the north, a significant portion of vegetation is coastal scrub and forests, while in the south, much of the land is built-up (i.e., Presidio) or a thin strand along the coast. 'Urban' areas outside of the parks in Figure 11 indicate a coarse categorization of lands outside the park; 'Built-up Urban Disturbance' (also known as Developed) areas within the parks were part of a finer scale mapping effort. The Habitats chapter presents a series of tables which depicts the calculated land cover extent for various land cover types for each watershed.

Geology and Topography

The 191-mi (307-km) shoreline of PORE and GOGA is shaped by geologic activity and erosion. The actively eroding cliffs along the coastline comprise a variety of marine sedimentary deposits exposed by local uplift (Schoenherr 1992). Much of PORE and GOGA are located on the boundary between the North American and Pacific Plates. This transform fault plate boundary (the plates are sliding past each other) forms the best known geologic feature of California, the San Andreas Fault Zone. Intensive investigation and monitoring along the fault show a rate of movement of about 1 inch (in) (25 mm) a year along the San Andreas and its subsidiary faults, the Hayward and Calaveras (Figure 12; Grove and Niemi 2005, Titus et al. 2005). The San Andreas Fault is infamous for producing the large earthquakes that periodically rock California and is responsible for the youthful and beautifully rugged terrain. The San Andreas Fault Zone is a relatively new geologic feature in the San Francisco Bay area, originating to the south 28 million years ago, but extending through the Bay Area 6–10 million years ago (Page and Wahrhaftig 1989).

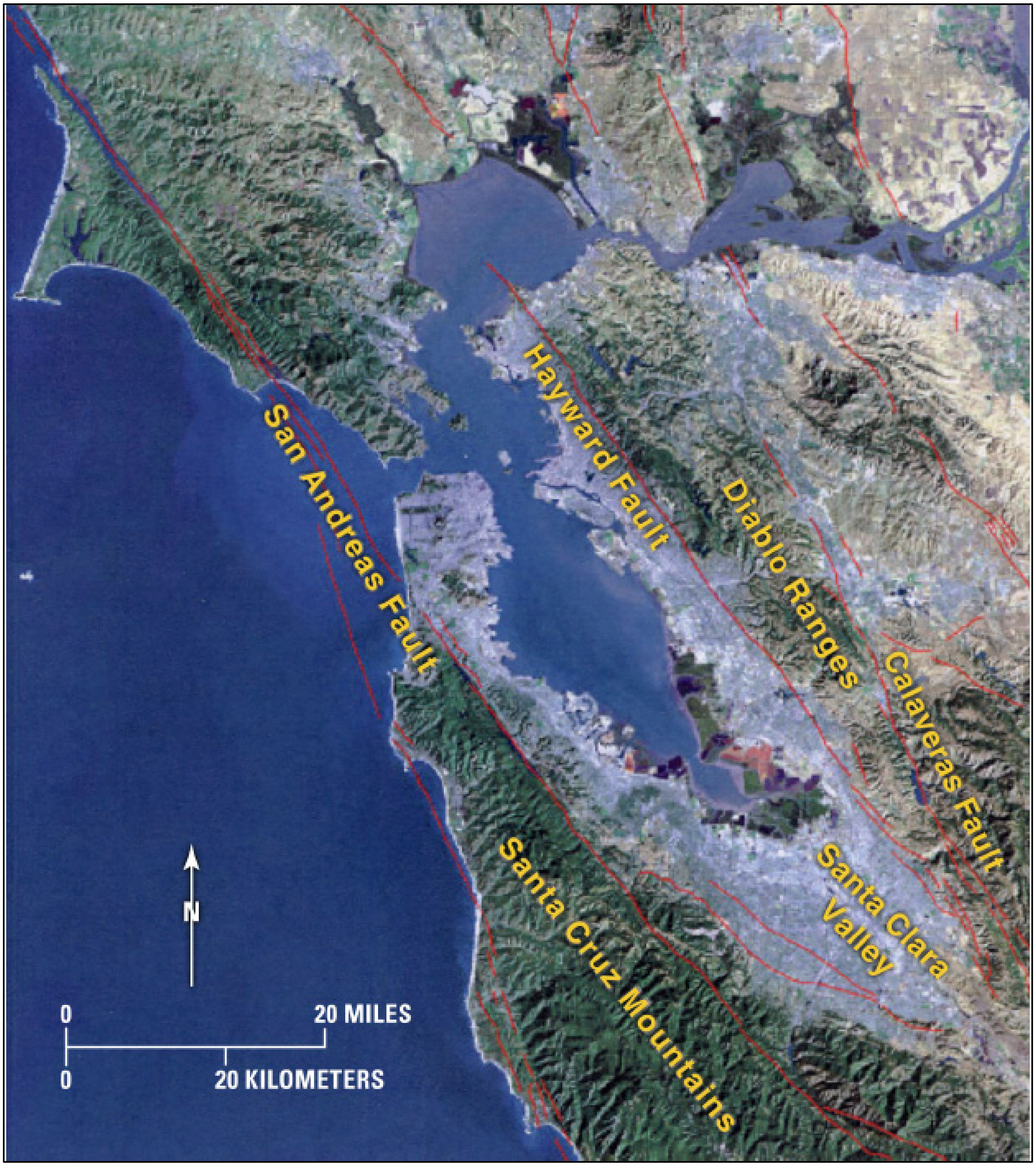

Figure 12. San Andreas Fault zone, a relatively new geologic feature in the San Francisco Bay area (modified from Google Earth images).

The Olema Valley, extending from Bolinas Lagoon to Tomales Bay, illustrates the San Andreas Fault Zone. The valley ranges in width from 1,500–7,000 ft (457–2,133 m) and includes a variety of fault-associated topographic features including linear ridges and drainage patterns, parallel stream systems, offset rows of trees and fences and a series of sag ponds. The surface rupture caused by the 1906 earthquake extended from Bolinas Lagoon to Tomales Bay, with lateral displacement ranging from 14–20 ft (4.3–6.1 m) in the Olema Valley (Gilbert 1908).

Bedrock east of the fault (generally east of Highway 1) is the Franciscan Complex that makes up much of California's Coast Range. The Franciscan Complex is highly unstable and is known for slope instability, thin soil and high runoff rates. Due to different rock types, the geomorphology, hydrology, weather, soils and plant communities east of the fault differ in many ways from that of the peninsula.

West of the fault, salinian granite underlies nearly the entire Point Reyes peninsula and is exposed in the areas of Inverness Ridge, Tomales Point and the Point Reyes Headlands. The granite is overlain by Miocene marine sedimentary deposits including the Purisima Formation and Monterey Shale (Clark and Brabb 1997). Coastal wave-cut benches and flooded valleys are the result of sea level fluctuations during the Pleistocene and Quaternary tectonic uplift (Scherer and Grove 2003). Features include well-developed Pleistocene marine terraces, Holocene alluvium in the larger active drainages, and Holocene tidal sediments in the larger embayment, such as Drakes Estero and the Estero de Limantour. Active dune fields and stabilized dunes are present along segments of the coastline and are especially well-developed at Kehoe Beach, along Point Reyes Beach and along Limantour Spit (Galloway 1977, Clark and Brabb 1997).

Climate and Oceanography

The coastal areas of central and southern California have a Mediterranean climate: temperate wet winters contrast with dry summers. Annual temperatures do not vary much along the coast, from high 50s ^{o}F (10^{o}C) in the winter and low 60s ^{o}F (16^{o}C) in the summer. The warmest months are September and October, which are in the mid-high 60s. The average annual rainfall in central California ranges from 15–55 in (38–140 cm), with almost all rain occurring between November and April (Figure 13). PORE and the northern areas of GOGA receive an average of 38 in (97 cm) of rain annually, higher than much of the San Francisco Bay area due to the somewhat more elevated terrain along the coast. Winter storms typically yield from 1–3 in (2.5–7.6 cm) of rain over a few days and are separated by mild, clear weather. Summer rains are rare and grasslands dry up during summer drought conditions which can last up to seven months.

Areas along the Marin and San Mateo counties coastlines are usually subjected to cool marine air, due to the influence of the California Current, a wide, slow-moving current that carries water southward from the cold northern Pacific. Spring and summer seasons along the coast are dominated by moderate to strong winds blowing out of the northwest. These winds cause the surface water to be blown offshore and it is replaced by cold bottom water that wells up to replace it, a phenomenon called upwelling (Figure 38). During the summer, the marine air is cooled as it passes over the offshore upwelling region and forms a fog layer along the coast. As the inland areas warm, the warm air from the valleys raises creating low pressure that pulls the fog in through the Golden Gate and the bays of Point Reyes. Fog drip is an important, but unquantified, contributor to precipitation in many coastal areas; estimates indicate it can contribute the equivalent of 10 in (25 cm) of precipitation per year in forested areas within the region (Schoenherr 1992).

In the fall, the northwest winds die down and the ocean is particularly calm. During this season, the coast typically experiences its warmest daytime temperatures. In the winter, proximity to the ocean keeps the coastal regions relatively warm; however, winter storms often create short-term, colder conditions.

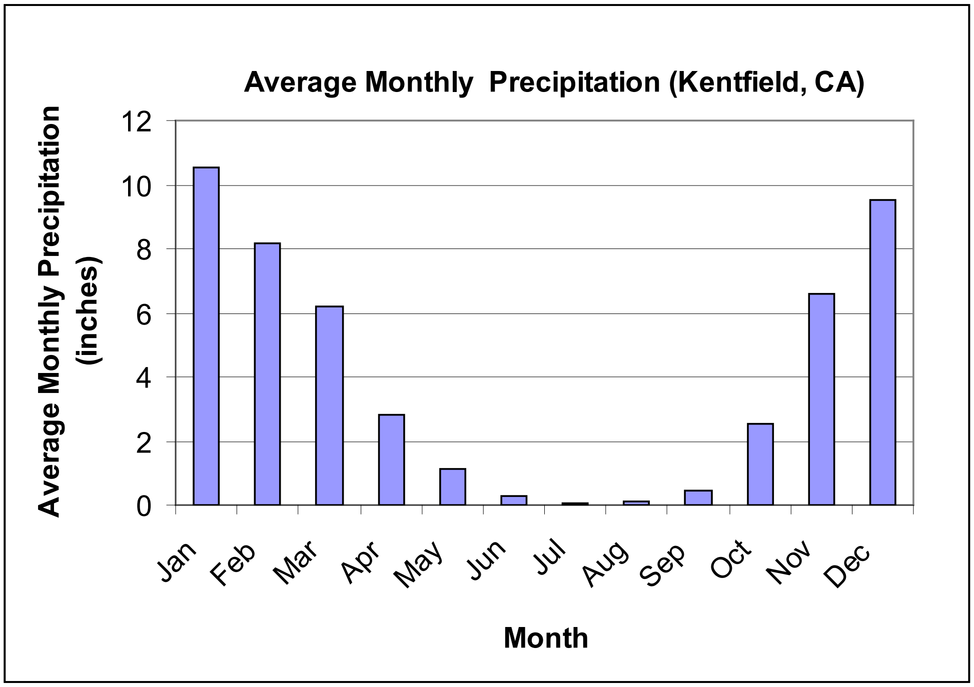

Figure 13. Seasonal precipitation at Kentfield, Marin County, California (Western Region Climate Center 2006).

Because of the strong coastal influence, coastal mountains and valleys create microclimates that vary according to their unique features. Mountains that parallel to the coast produce rain shadows and drier interior valleys. The complex terrain creates sufficient friction to slow the airflow and ocean-derived winds are lower inland.

Bathymetry

Seafloor topography, or bathymetry, affects hydrodynamics, water temperatures and underwater ecosystems. A 10-m (33-ft) interval bathymetric map shows the topography along the parks' shoreline (Figure 14). More detailed bathymetric maps were created for PORE and GOGA by the NPS Water Resources Division (Endris et al. 2009, Greene et al. 2009, 2011). The underwater area from the shoreline to the 400-m (0.25 mi) park boundaries varies from 0–20 m (0-66 ft) depth and within 5 km (3 mi) the depth varies from 0–60 m (0–197 ft). Not surprisingly, the areas with the more gentle downward slopes are outside the mouths of major estuaries including Tomales Bay, Drakes Estero, Bolinas Lagoon and San Francisco Bay (Figure 14). Outside the Golden Gate Bridge, the shallows are likely influenced by sediments from riverine sources forming deposits. Shallow areas outside the mouths of Drakes Estero and Bolinas Lagoon are strongly influenced by littoral process, while shallows near the mouth of Tomales Bay are influenced by runoff as well as the San Andreas Fault Zone. From San Francisco Bay, the 10-m (33-ft) contour extends nearly 8 km (5 mi) from the mouth of the bay.

Currents and their Effects on Primary Production and Estuarine Dynamics

The cold water California Current and comparatively warm water Davidson Current are major forces shaping the ecosystems in and around the study region and are components of the California Current System, which extends up to 1,000 km (621 mi) offshore from Oregon to Baja

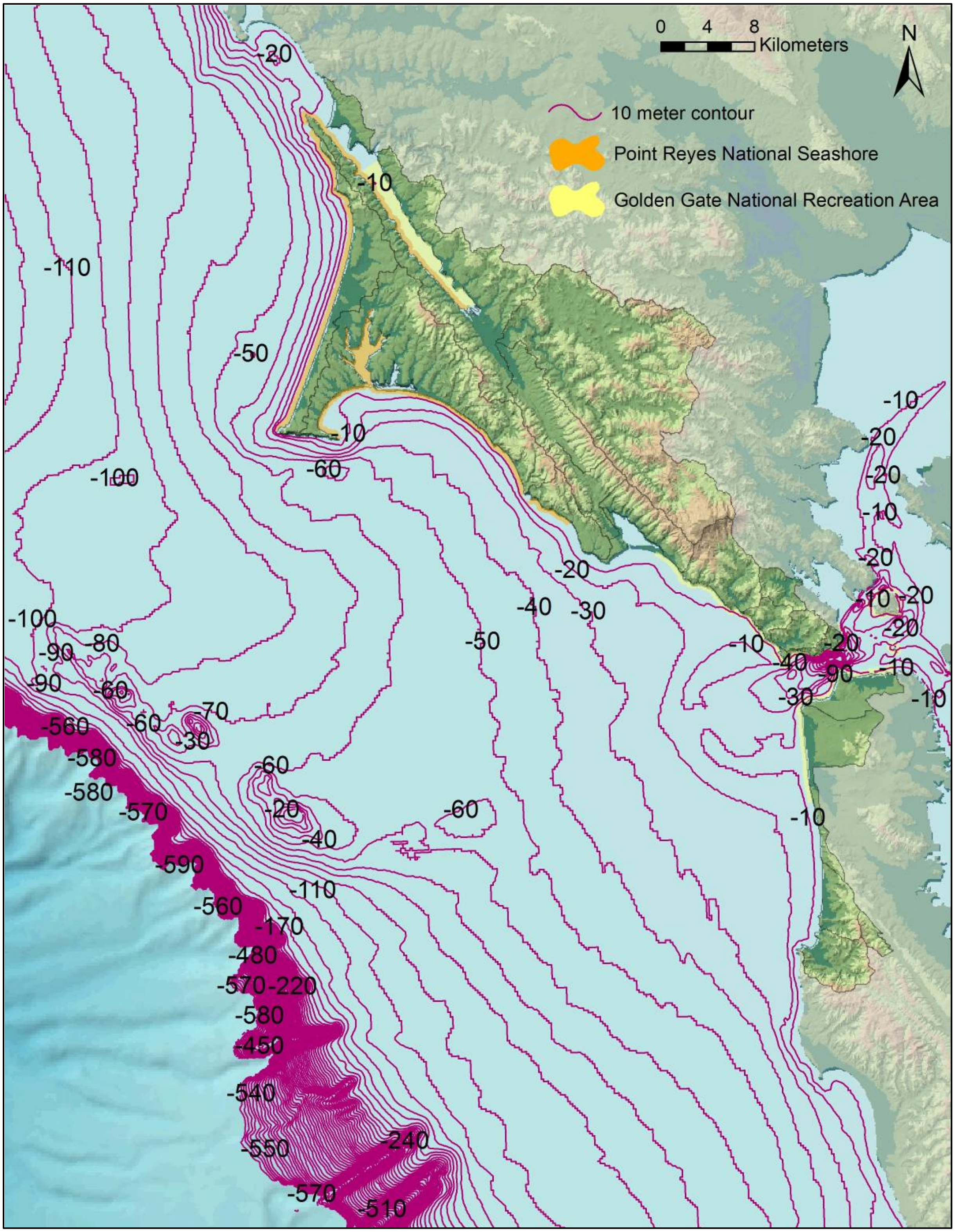

Figure 14. The 10-m (33 ft) bathymetric contours of the continental shelf off the coast of Point Reyes National Seashore and Golden Gate National Recreation Area (NPS and NOAA GIS data).

California and comprises a southward meandering surface current, a poleward undercurrent and surface countercurrents. The system has high biological productivity, diverse regional characteristics and intricate eddy motions that puzzled oceanographers for decades (Miller et al. 1999). A poleward undercurrent flows continuously from 33°N–51°N at a core depth of 200–275 m (656–902 ft), mean location of 20–25 km (12–16 mi) off the shelf break and mean velocity of 0.10 m/s (0.33 ft/s) with speeds up to 0.15 m/s (0.49 ft/s) (Pierce et al. 2000). A surface countercurrent (Davidson Current) flows northward during the winter, is associated with seasonal wind changes and is the surface expression of the undercurrent. The currents, along with winds and topography, control upwelling and downwelling and consequently the amount of productivity along the coast (Airame et al. 2003). Variation in these processes occurs temporally and spatially, making local regional assessment using a static geographic approach difficult. Coastal seawater composition varies significantly over an annual cycle, largely because of the varying strength of coastal upwelling processes.

Spatial differences in nearshore currents are influenced by large scale events such as El Niño and the Pacific Decadal Oscillation and more locally by the geometry of the open coast, bathymetry and season. The interaction between these factors is complex, but in general the system depicts two prominent circulation regimes, that vary with season.

Spring and summer along the coast are dominated by moderate to strong northwesterly winds during the upwelling period. The most important effect of upwelling is the varying delivery of nutrient-rich bottom water to the photic zone. This phenomenon along with abundant sunshine, allows the phytoplankton to bloom. The strong winds are punctuated by short periods of relaxation when plankton bloom in the warm, nutrient rich waters. The Central California Coast is one of the most productive ecosystems in the world due to the substantial eastern Pacific upwelling area (Gaines and Airame 2002). The most intensive upwelling occurs during the spring-summer, but can extend into October. Locally, upwelling events can be accompanied by significant nutrient levels on the order of 30 µg/L (ppb) nitrate with sudden nutrient drawdown and growth of phytoplankton, in 1–2 days (Wilkerson et al. 2000). The spatial variation induced by these oceanographic processes can be seen in Figure 15. Notice the large peak in chlorophyll at the tip of Point Reyes. The chlorophyll maximum corresponds well with abundance and diversity "hot spots." A time lapse look at these oceanographic processes offshore illustrates the variability at large scales using Sea-viewing Wide Field-of-View Sensor (SeaWiFS) standard OC4v4 chlorophyll data (Figure 16) and for a time lapse gif loop see: http://spg.ucsd.edu/Satellite_Projects/SeaWIFS_MLAC_Processing/Readme_SeaWiFS_MLAC_processing.htm. The phenomena are not well studied and it is hoped that new research will yield additional information on nearshore circulation patterns and nutrient dynamics.

In the fall, the northwest winds die down and the ocean is particularly calm (the relaxation period). There is little upwelling and the surface waters warm. Winter is the third season from November to March/April when a series of major storms track across the Pacific from the west and southwest. The winds accompanying the storms weaken the California Current, allowing the poleward flowing undercurrent (Davidson Current) to surface inshore of the California Current. The Davidson Current flows from south to north bringing warm southern water and downwelling to the coast. During El Niño years, coastal upwelling declines in the spring and summer and the Davidson Current is especially strong. During El Niño years, warm water pelagic species, like sea turtles and marlin, are sometimes seen well beyond their normal range.

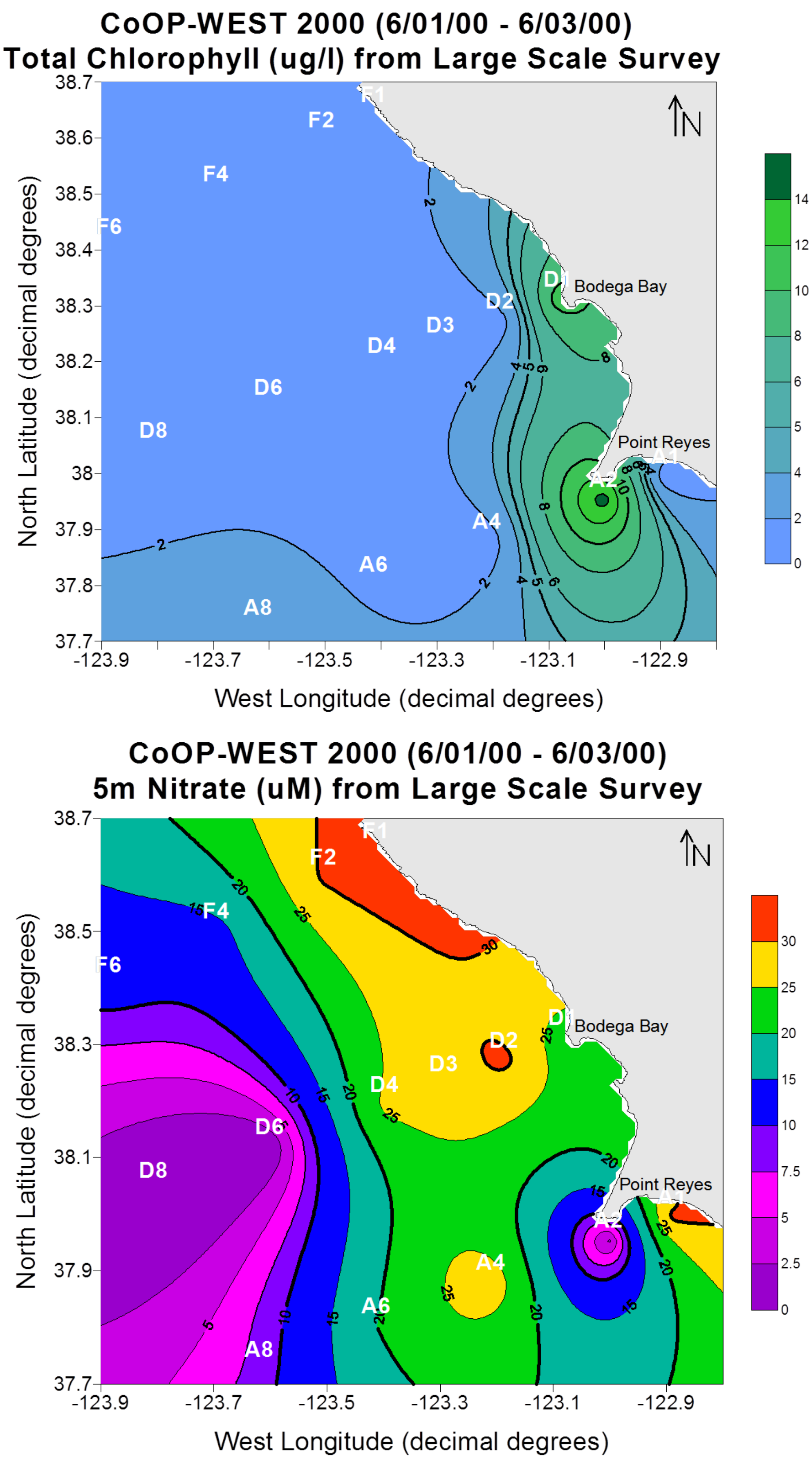

Figure 15. Central California coast near-surface chlorophyll (top) and nitrate (bottom) levels in early June 2000 (adapted from Wilkerson et al. 2000).

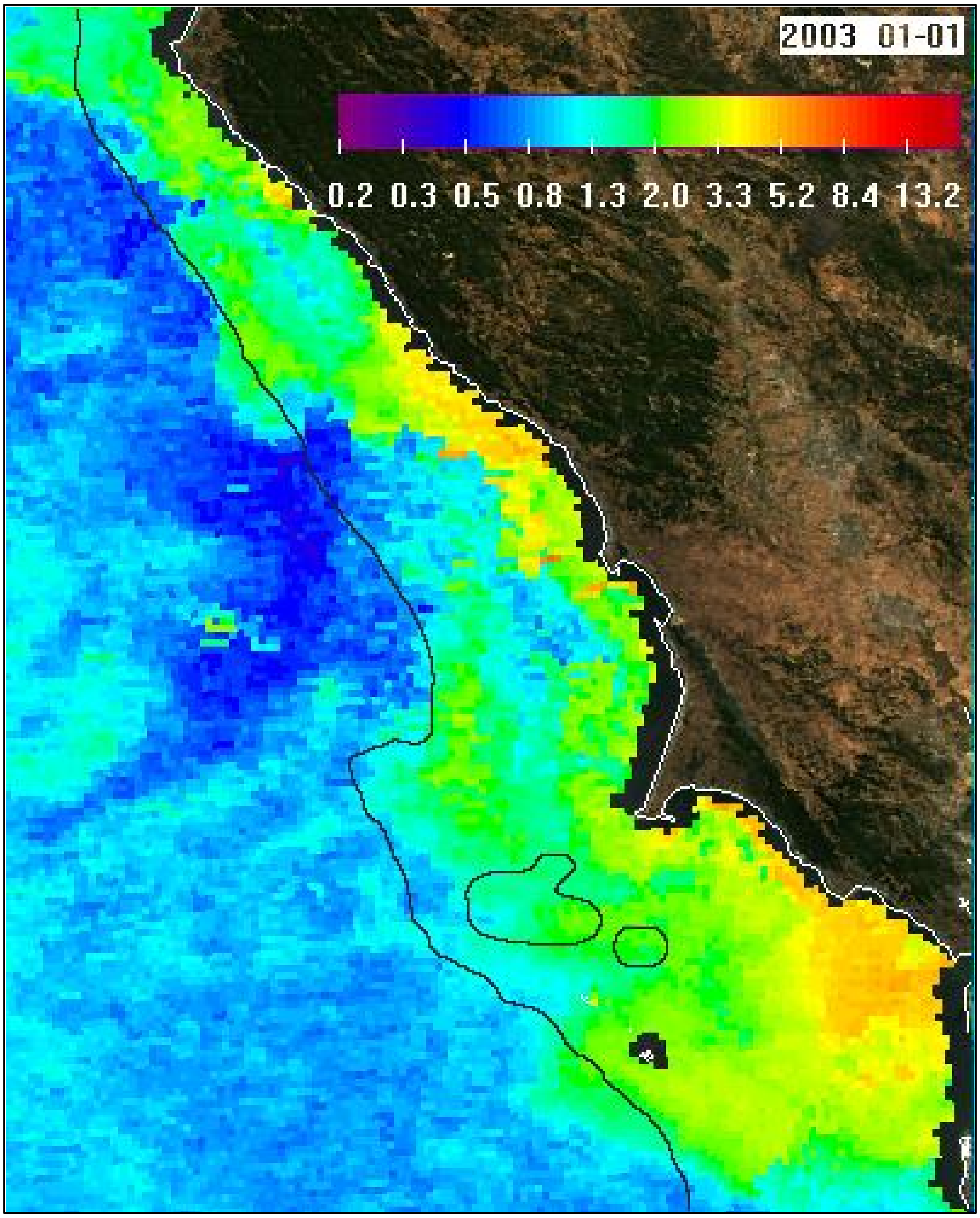

Figure 16. Chlorophyll concentration (mg/m^3) off Point Reyes peninsula and southern Marin Co. during a period of lower productivity in the winter of 2003 (adapted from Kahru 2005).

San Francisco Bay is the largest estuary in the region (and in California) and its outflow affects the surrounding open ocean differently depending on the season. During upwelling, the bay's stratified plume flows south to Pacifica; during the winter, the bay water flows north as far as Bodega Bay. This seasonal effect of San Francisco Bay means that areas such as Drakes Bay (PORE) experience wide variations in their current regimes. During the winter Drakes Bay is bathed in warmer water from San Francisco Bay and in the summer colder water from the upwelling regime. West of Drakes Bay, the Point Reyes Headlands act as a natural barrier so San Francisco Bay water does not influence the Abbots/Kehoe coastlines as significantly as the southern Bolinas and Drakes Bays.

Estuaries are influenced by water exchange with the coastal ocean; the degree of exchange varies with the volume of freshwater inflow, the physical geometry of the estuary and tidal exchange. Nutrient input from the ocean is minimal to San Francisco Bay, which has large riverine outputs, a narrow opening and a tidal exchange ratio less than 50% (Smith and Hollibaugh 1998). Much of Bay is heavily influenced by runoff from the Sacramento and San Joaquin River systems (Monroe et al. 1992). Tomales Bay with its unique linear shape and its narrow mouth also places constraints on tidal exchange with the ocean. Salinities in the southern end of Tomales Bay are highly variable, ranging from nearly fresh after heavy winter runoff to slightly hypersaline in summer, whereas regular tidal mixing at the north end of the bay maintains salinities consistent with the coastal waters (Hollibaugh et al. 1988, Kelly and Tappen 1998). Water in the northern 6 km (3.7 mi) bay exchanges with coastal water on each tidal cycle; water in the southern 14 km (8.7 mi) bay resides for about 120 days. In the summer, inorganic phosphorus builds up in the water column and dissolved inorganic nitrogen largely disappears. The phosphorus buildup reflects release of phosphorus during the oxidation of organic matter, while nitrogen disappearance is the net effect of denitrification.

Despite the minimal tidal influences in estuaries such as Tomales Bay, there are likely important indirect effects of coastal upwelling on the nutrient dynamics of these bays. By stimulating primary production in coastal waters, upwelling elevates the concentration of particulate organic matter in coastal waters which is delivered to the bays by tides and particle settling (Smith and Hollibaugh 1998). The influence of coastal processes on larval transport to San Francisco Bay is well known, as many of the population dynamics of migratory species cannot be explained by local processes alone (Smith and Hollibaugh 1998.).

Drakes Estero and Estero de Limantour are highly influenced by hydraulics and flow paths. Relative to most estuaries, the contributing watershed is small, resulting in an estuarine system dominated by ocean influence. The main body of Drakes Estero has regular tidal exchange, while the arms of the Drakes Estero and Estero de Limantour have longer residence time.

Bolinas Lagoon is a 1,000+ ac (405+ ha) estuary between Stinson Beach and Bolinas, a portion of which is part of GOGA. A substantial amount of research has been conducted on lagoon function and evolution over the past 20 years as the community and agencies consider restoration needs and alternatives. The lagoon is driven by daily tidal patterns and the local community is concerned about the probability and effects of inlet closure associated with sedimentation and loss of tidal prism. Studies indicate that while historic sedimentation from the watershed had a significant effect on lagoon function, the major source of sand and fine sediment is littoral sand transport and coastal bluff erosion (Phillip Williams and Associates 2006).

Hydrology

Surface Water Resources

The freshwater resources within the parks include a wide array of freshwater perennial and seasonal resources including a significant number of streams, wetlands, natural lakes, human-made impoundments, seeps and sag ponds. In addition to freshwater resources, there are numerous brackish lagoons and wetlands grading to saltwater. Marine areas are included within the park as the legislative boundary extends one-quarter mile offshore into the Pacific Ocean. All military forts have surrounding waters within their boundary. These resources and associated flora and fauna are featured in the Habitats chapter.

With the exception of a single spring dominated stream, PORE and GOGA stream flows are typical of California's Mediterranean climate, with large variations between wet and dry seasons. Seasonal flow patterns in the creeks are typified by low flows in the summer and fall, low-to-moderate winter base flows and sharp, short-duration winter storm peaks. Storms typically occur between mid-October and mid-April, with peak flows occurring often between December and February (Fong et al. 2011). Flow patterns for NPS watersheds in Marin County based on measurements in PORE from 1997 to 2001 and in GOGA from pre-1990 to 2001 are similar since the parks are adjacent and have very small, coastal watersheds with similar land uses (Cooprider 2004). For PORE, mean flows are highest in February, followed by January and March. The lowest mean flows occur in July. For GOGA, mean flows are highest in January and February and lowest in June through September.

PORE and Northern GOGA

From Tomales Bay in the north to Bolinas Lagoon in the south, there are two major watersheds within PORE plus several small coastal watersheds. Major creeks include Lagunitas and Pine Gulch creeks, which are located in the eastern part of the park (Figure 17). Lagunitas Creek flows through GOGA, but is managed by PORE. Lagunitas Creek and its tributaries, including Olema Creek and Bear Valley Creek, flow to Tomales Bay. Drainages in the southeastern portion of the park, including Pine Gulch, flow to Bolinas Lagoon. All other drainages flow into the Pacific Ocean (directly or via Drakes Estero). There are USGS and NPS gaging stations located on Olema, Lagunitas and Walker Creeks with daily discharge records (Fong et al. 2011).

GOGA

GOGA encompasses many small, coastal watersheds. Five major watersheds are located within the parks' legislative boundaries and include (from north to south): Redwood Creek, Tennessee Creek (a.k.a. Elk Creek), Rodeo Creek, Lobos Creek in the Presidio, the San Francisco Watershed Lands and West Union Creek in San Mateo County (NPS 1999). Lobos Creek is unique amongst because it flows year-round due to several springs (Philip Williams Associates 1995). Lagunitas and Olema creeks are located within park areas managed by PORE (to the north and bordering GOGA) and are discussed under PORE.

Hydrologic Units

The California Watershed Map (CALWATER) is standard watershed boundaries that meet standard criteria. The hierarchical watershed designations are six levels of increasing specificity: Hydrologic Region, Hydrologic Unit, Hydrologic Area, Hydrologic Sub-Area, Super Planning Watershed and Planning Watershed. We used a modification of the Super Planning Watersheds, which are approximately 78 mi^2 or 50,000 ac (20,234 ha) from the CALWATER coverage version 2.2.1, with input from park personnel (Figures 17 and 18). There are ongoing efforts to create crosswalks between the CALWATER system and other federal watershed classification systems, including that of USGS and National Resources Conservation Service (NRCS).

Major creeks define many of the watersheds selected for this analysis; the small size of many coastal drainages means that some watersheds are composed of several smaller drainages (i.e., Abbotts-Kehoe Pacific Drainages in PORE and the North Shore in GOGA). Seven watersheds in PORE, plus Bolinas Drainages in GOGA (Figure 17) and seven in GOGA (Figure 18) were evaluated. For the some PORE and GOGA watersheds, only a portion of the watershed is owned by NPS (Table 3).

Figure 17. Watershed units used in the coastal watershed assessment analysis for Point Reyes National Seashore (NPS 2005 and CALWATER data).

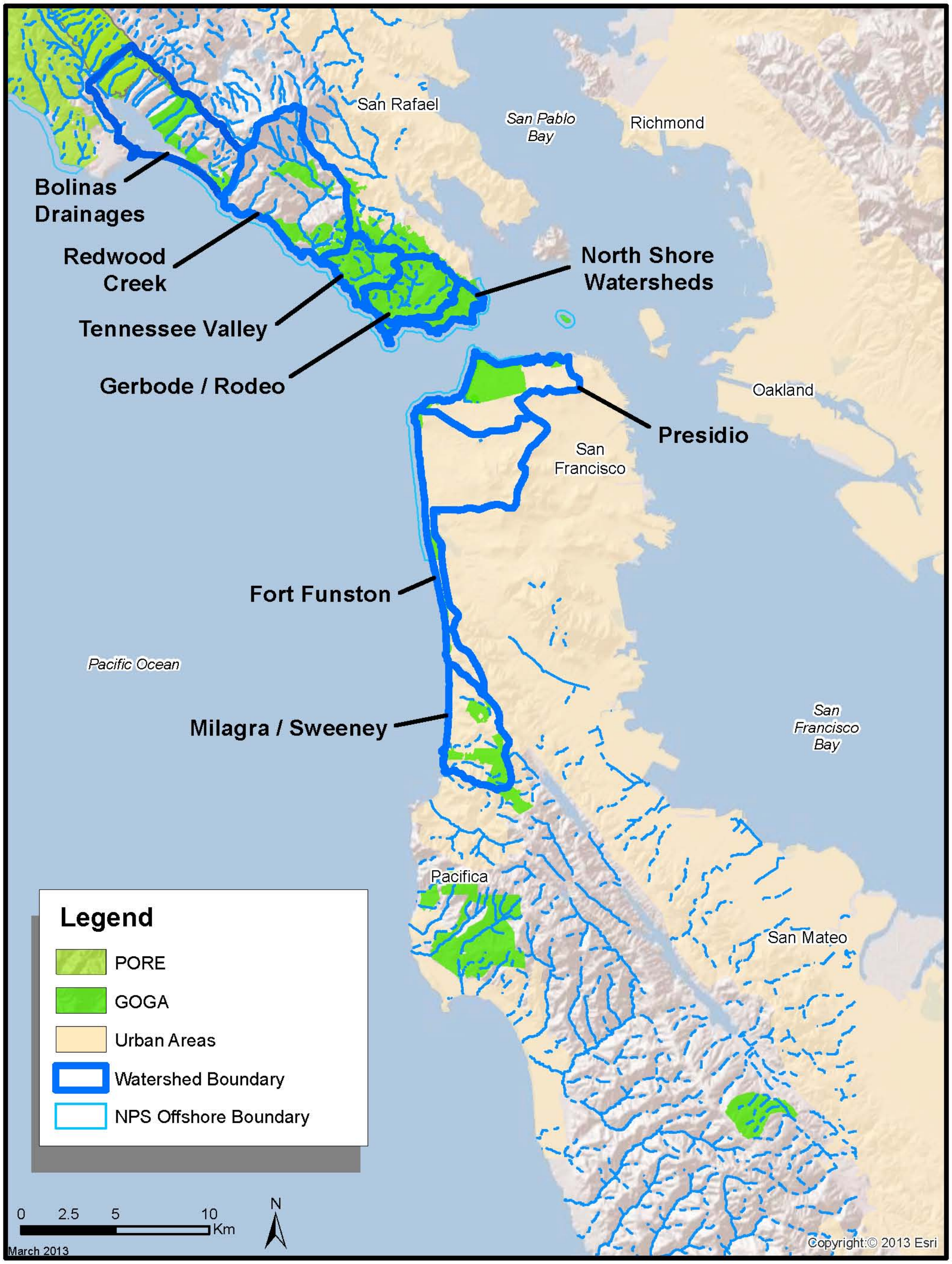

Figure 18. Watershed units used in the coastal watershed assessment analysis for Golden Gate National Recreation Area (NPS 2005 and CALWATER data).

Table 3. Watershed unit names used in Point Reyes National Seashore (PORE) and Golden Gate National Recreation Area (GOGA).

Park	Watershed Unit Names	Offshore distance
PORE	Tomales Bay	Entire Bay (excluding eastern waters north of Walker Ck.)
	Olema Creek	N.A.
	Abbotts-Kehoe-Pacific Drainages	Entire estuarine and quarter-mile ocean
	Drakes Bay and Esteros	Entire estuarine and quarter-mile ocean
	Double Point/Duxbury	Quarter-mile ocean
	Pine Gulch Creek	Not applicable
	Lagunitas Creek	Not applicable
GOGA	Bolinas Drainages	Variable estuarine distance
	Redwood Creek	Entire estuarine and quarter-mile ocean
	Tennessee Valley	Entire estuarine and quarter-mile ocean
	Gerbode/Rodeo	Entire estuarine and quarter-mile ocean
	North Shore watersheds	Quarter-mile estuarine and ocean
	Presidio	Quarter-mile estuarine and ocean
	Fort Funston	Quarter-mile ocean south to Fort Funston proper
	Milagra/Sweeney	Not applicable

There are no state designated groundwater basins in the project area, with the exception of the northern NPS lands in eastern Tomales Bay. In PORE, local seeps and springs were developed to supply water to campgrounds or ranches. Water for the developed areas comes from the North Marin Water District (NMWD) or local groundwater wells. In southern GOGA, the sustained summer base flows in Lobos Creek (drinking water supply for the Presidio) come from the groundwater basin south of the Presidio in the urban areas of San Francisco and Golden Gate Park (Philip Williams Associates 1995).

Water Supply

Most drinking water for urban areas of the San Francisco peninsula comes from outside the region (i.e., Hetch Hetchy Reservoir in Yosemite National Park). Locally, surface water provides the majority of water supply, including Lagunitas Creek (Marin Municipal Water District [MMWD]), Lobos Creek (Presidio Trust), Stinson Gulch and Easkoot Creek (Stinson Beach County Water District) and Arroyo Hondo Creek (Bolinas Community Public Utilities District [BCPUD]. In many cases, “groundwater” supply wells are located within the riparian areas of important streams (Redwood Creek – Muir Beach Community Services District [MBCSD]; Lagunitas Creek – NMWD). The NPS and other entities have demonstrated that the withdrawals directly affect surface flow and aquatic habitat (e.g., Redwood Creek [State Water Board 2001]) or are influenced by surface water conditions (e.g., salinity within NMWD wells).

Extensive monitoring and assessment have been conducted for the MBCSD well, including final negotiated water rights with GOGA. Extensive studies related to salinity intrusion NMWD wells have been conducted and are summarized in the Giacomini Wetland Restoration Project Environmental Impact Statement/Environmental Impact Report (EIS/EIR; NPS 2007). The need for improved understanding of the interactions between surface and open alluvial groundwater systems has focused attention on groundwater monitoring as part of restoration projects.

Stressors

To characterize and ameliorate problems associated with coastal watershed condition, it is essential to describe the stressors responsible for degraded conditions. Stressors are physical, chemical, or biological perturbations that are either (a) foreign to the system or (b) natural to the system, but applied at an excessive (or deficient) level (Barrett et al. 1976). By their definition, stressors disrupt habitat integrity through reduction and changes in habitat extent, water quantity alteration, water quality degradation and negative impacts on flora and fauna. Some of these stressors are of a general nature, such as population growth and climate change which in turn lead to multiple pressures causing widespread impacts. Some stressors are ongoing and others are the result of past land use practices. As is true of most stressor lists and conceptual frameworks, the stressors and their associated impacts are often highly correlated and difficult to differentiate. The cumulative impact of multiple stressors is observed on park landscapes. Each of the stressors and their impacts is described below and rated for watersheds for GOGA (Table 1) and PORE (Table 2). The watersheds were rated by a small team of park researchers for each park system: H = high problem, M=medium problem, L=low problem, P= potential problem and NA= not applicable. Legacy issues were largely placed in a disturbed lands category.

Climate Change and Sea Level Rise

Climate change is a response to a variety of stressors; however, it is such an overarching effect critical to our understanding of future coastal conditions, that we include it in this list of stressors. In 2006, the SFAN Inventory & Monitoring Program rated this as the most important issue across the parks (Adams et al. 2006). The "greenhouse effect" refers to the warming of the Earth's atmosphere due to the interaction of solar radiation with accumulated greenhouse gases (e.g., carbon dioxide, methane, hydro-fluorocarbons, nitrous oxide, sulfur hexane fluoride, per-fluorocarbons and water vapor) in the atmosphere. This warming effect has been enhanced over the past century by increased contributions of these gases, particularly carbon dioxide, from anthropogenic sources (NAST 2001). Potential consequences of this enhancement are rising temperatures, changes in the initiation and duration of the growing season, increased drought occurrences, increased storm/flooding severity and frequency, increased biological invasions, shifting species ranges and decreased predictability of weather patterns, all of which directly affect ecosystems (Parry et al. 2007, Moser et al. 2009, Largier et al. 2010). The San Francisco Bay Area is predicted to have increased rainfall and more intense and more frequent El Niño-Southern Oscillation (ENSO) events (Largier et al. 2010).

Surface ocean temperatures have increased in the North Pacific, offshore of the north-central California continental shelf (Largier et al. 2010). This increase in surface ocean temperature has significant effects on water column structure, sea level rise and ocean circulation patterns. While sea temperature also appears to have increased in nearshore locations like shallow bays and estuaries, waters over the north-central California continental shelf have cooled over the last 30 years (by as much as 1°C [1.8^{o}F] in some locations) due to stronger and/or more persistent upwelling winds during spring, summer and fall (Garcia-Reyes and Largier 2010). Changing temperatures will influence fish physiology, and fish could respond to these changes by shifting their distributional range to preferred temperatures (Largier et al. 2010). The most recent report by the Intergovernmental Panel on Climate Change (Parry et al. 2007), reports that a general northward range expansion has occurred in some terrestrial species (Parmesan and Yohe 2003) and range shifts have also been observed in ocean species such as gray whale calving and bottlenose dolphins (Largier et al. 2010).

Oceans are also predicted to increase in acidity; although, the degree of change is speculative at this point. Baseline levels of acidity do not exist for most parks or coastal areas. Ocean acidity is important because when the ocean becomes more acidic, the shells of many invertebrates, such as pteropods and krill, do not form fully. Consequently, the foundation of the oceanic upwelling food web and the habitats of the nearshore of the parks could be significantly altered by climate change (see also Largier et al. 2010).

Global average sea level rose at an average rate of 0.07 in/yr (0.18 cm) from 1961 to 2003 and at an accelerated average rate of about 0.12 in/yr (0.30 cm) 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 in (1,400 cm) over the next 100 years, with possible impacts on shoreline erosion, saltwater intrusion and changes in wetland water regimes (Pacific Institute 2009). In the San Francisco Bay Area, 140 years of tide-gauge data 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, which have predominantly erosible soils (Largier et al. 2010).

The possible effects of sea level rise on PORE and GOGA are being assessed through predictive models by various research institutions, including the USGS in cooperation with the NPS Geologic Resources Division and PRBO (http://farallones.noaa.gov/manage/climate/ocof.html). The Coastal Vulnerability Index developed by USGS reflects the relative potential of physical changes to the PORE and GOGA coastline due to future sea-level rise and incorporates six variables into the index (Figures 19 and 20).

PRBO has predicted major habitat loss at sites in some areas of San Francisco Bay as sea levels rise, even assuming a conservative global warming scenario such as 2°C (3.6°F) increase within the next century (Galbraith et al. 2002). Along the PORE and GOGA coastlines, some urban areas, coastal beaches, tidal flats and small rocky islands and outcrops could be affected. In natural habitats, structural changes could impact habitat use and result in ecological impacts, i.e., offshore rocks supporting bird nesting colonies and seal breeding sites, leading to a reduction in reproductive success.

Human Population Growth

With a population of 7 million people, the metropolitan centers of San Francisco, Oakland and San Jose are predicted to have a total population of 8 million by 2020 (Association of Bay Area Governments 2000). Population growth rates in Marin, San Francisco and San Mateo counties are either in line with or somewhat lower than the statewide average; however, population levels are expected to increase, resulting in land use change and pressures on the park resources (Table 4). For the parks, this includes pressures from adjacent development, as well as activities inside parks, such as trampling of sensitive plant communities, compaction of soils, creation of social trails and excessive impact on caves, wetlands and other sensitive ecosystems. Increasing human populations lead to sources of light and noise pollution, altering terrestrial and marine wildlife behavior and affecting feeding, migratory and reproductive cycles (Bondelo 1976, Avise and Crawford 1981, Brown 1990). Excessive noise levels also negatively affect visitor experiences. Human encroachment on park boundaries can also disrupt scenic overlooks that extend beyond

Figure 19. Relative coastal vulnerability for Golden Gate National Recreation Area. The colored shoreline is the relative coastal vulnerability index determined from the six variables. The “very high” vulnerability shoreline is found along sandy beaches where wave heights are highest and coastal slope is low. The “low” vulnerability shoreline is found along rocky cliffs where wave heights are lower and coastal slope is steep (Pendleton et al. 2005a).

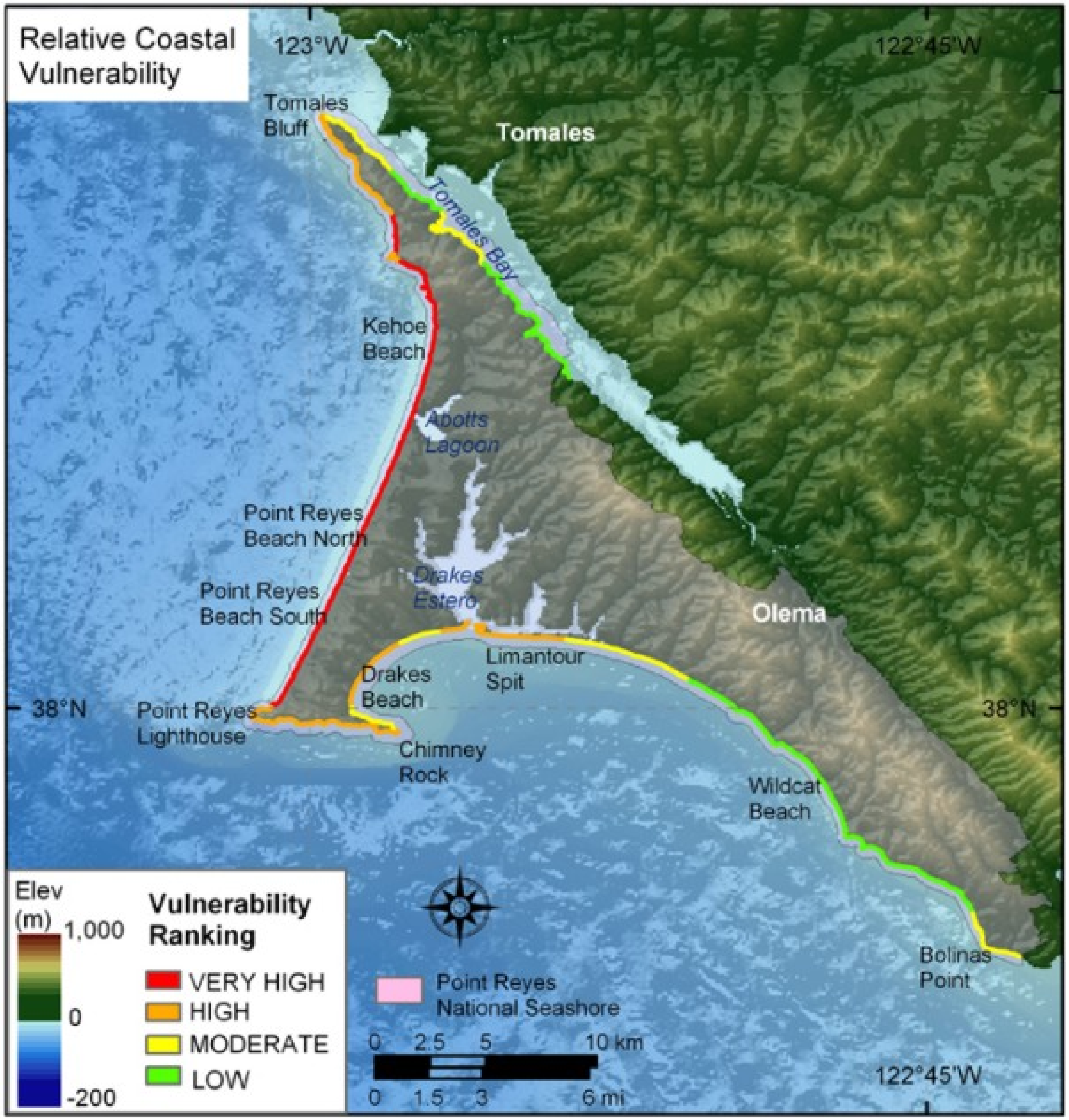

Figure 20. Relative coastal vulnerability for Point Reyes National Seashore. The colored shoreline is the relative coastal vulnerability index determined from the six variables. The "very high" vulnerability shoreline is found along sandy beaches where wave heights are highest and coastal slope is low. The "low" vulnerability shoreline is found along rocky cliffs where wave heights are lower and coastal slope is steep (Pendleton et al. 2005b).

Table 4. Population and population growth statistics by decade, 1960 to 2000.

San Mateo County	1960	1970	1980	1990	2000
Total	444,387	557,361	587,329	649,623	707,161
Change		112,974	29,968	62,294	57,538
Percent Change		25.4%	5.4%	10.6%	8.9%
San Francisco County					
Total	740,316	715,674	678,974	723,959	776,733
Change		-24,642	-36,700	44,985	52,774
Percent Change		-3.3%	-5.1%	6.6%	7.3%
Marin County					
Total	146,820	208,652	222,568	230,096	247,289
Change		61,832	13,916	7,528	17,193
Percent Change		42.1%	6.7%	3.4%	7.5%

park boundaries. Increasing numbers of people often increase the number of feral animals in the region, putting pressure on park wildlife and vegetation. Increasing vehicle traffic volume in and around the parks also leads to increased road mortality and the introduction of non-native species.

Air Quality Degradation

The primary factors controlling air quality include the locations of air pollutant sources and the amount and nature of the pollutants emitted from those sources. Meteorological processes and topography are also important factors: atmospheric conditions, such as wind speed, wind direction and air temperature gradients, interact with the physical features of the landscape to determine the movement and dispersal of air pollutants. Air quality degradation includes several sources of stress, including acid deposition, ozone, increases in the concentration and/or type of toxins and heavy metals, visibility/haze and nitrification (US EPA 1999) resulting in significant impacts to plant communities, species and species interactions, water quality and nutrient cycling. For instance, acid deposition can result in the leaching of nitrogen and calcium from ecosystems thereby affecting productivity, soil chemistry, water quality, biodiversity and resistance/tolerance of biota to other stresses (Adriano and Havas 1990). Increased deposition of heavy metals, especially mercury, may result in bioaccumulation and bio-concentration with potential toxic effects. Elevated levels of carbon dioxide and ozone can affect the competitive ability, distribution and survival of biota and reduce native biodiversity (Stiling et al. 2002).

As NPS Units, air quality attainment standards for PORE and GOGA are established through the Clean Air Act. PORE is designated as a Class I (highest protection) area, while GOGA and Muir Woods National Monument (MUWO) are designated as Class II areas. PORE and GOGA are located within the San Francisco Bay Area Air Basin (SFBAAB). For these parks and especially GOGA, air quality is an important issue due to their proximity to highly urbanized areas. The air pollutants of greatest concern in the Bay Area air basin are ozone, carbon monoxide and inhalable particulate matter (particulate matter <10 µm [3.9 x 10^{-4} in] in diameter, or PM10. Their characteristics are summarized in Table 5. The effects of nitrous oxides on nutrient dynamics have not been well studied in the San Francisco Basin. More detailed analyses of these issues are summarized in the PORE and GOGA Fire Management Plan EIS documents (NPS 2004a, 2005).

Table 5. Overview of air pollutants of greatest concern in the San Francisco Bay Air Basin (NPS 2005).

Pollutant	Sources	Health and Other Concerns
Ozone	Formed by a photochemical reaction in the atmosphere; ozone precursors, including reactive organic gasses and oxides of nitrogen (NO_x), react in the atmosphere in the presence of sunlight to form ozone. Ozone precursors are emitted by mobile sources such as vehicles, and by stationary combustion equipment	A severe eye, nose and throat irritant; increases susceptibility to respiratory infections. An oxidant; can cause substantial damage to synthetic rubber, textiles and other materials Produces leaf discoloration and cell damage in plants
PM10	Results from many kinds of dust-and fume-producing activities, such as demolition, construction, and vehicular traffic; entrained road dust from motor vehicles accounts for approximately two-thirds of the regional PM10 inventory in the project area	Health concerns focus on particles small enough to be drawn into the lungs when inhaled (PM10) Can increase the risk of chronic respiratory disease with extended exposure
CO	Motor vehicles are the primary source of CO emissions in most areas. In the urbanized portions of the San Francisco Bay Area, high CO levels primarily develop during the winter near congested intersections, when periods of light winds combine with the formation of ground-level temperature inversions from evening through early morning. Motor vehicles exhibit increased CO emission rates at low air temperatures.	Combines readily with hemoglobin and thus reduces the amount of oxygen transported in the bloodstream. Effects on humans range from slight headaches to nausea to death.

PORE/GOGA Greenhouse Gas Emissions Estimates

PORE and GOGA are participating in the NPS Climate Friendly Parks program, joining a network of parks nationwide that are putting climate friendly behavior at the forefront of sustainability planning. Becoming a climate friendly park includes conducting an emissions inventory, setting an emissions reduction goal, beginning the adaptation scenario planning process, developing a Climate Change Action Plan and committing to educate park staff, visitors and community members about climate change.

The greenhouse gas emissions inventory was completed using the Climate Leadership in Parks tool developed cooperatively by NPS and the US EPA. The tool converts emissions of various greenhouse gases into a common “Metric Tons of Carbon Dioxide Equivalent” (MTCE) unit, which is a basis for comparison between gases and simplifies reduction tracking. The inventory includes emissions resulting from the combustion of fossil fuels (from mobile and stationary sources, as well as purchased electricity), transportation (visitor vehicles and park fleet) and waste (decomposition of municipal solid waste sent to landfills and wastewater treatment).

PORE completed an emissions inventory in 2005 (US EPA and NPS 2009). PORE emissions totaled 7,663 MTCE in 2005, of which 78% resulted from sources other than energy, transportation and waste. The sources of the vast preponderance of PORE greenhouse gas emissions, 5,971 MTCE, are from dairy wastes (or manure) in the form of methane gas. Secondary in importance is the emission of 25,506 lbs (11,569 kg) of carbon monoxide, 1,727 lbs (783 kg) of nitrous oxide, 35 lbs (16 kg) of particulate matter (PM10 and PM2.5), from transportation sources, comprising 18.9% of the park’s greenhouse gas emissions.

In 2006, GOGA greenhouse gas emissions totaled 10,319 MTCE (US EPA and NPS 2008). The majority of these emissions are attributed to visitors. GOGA receives approximately 13 million visitors per year, generating an estimated 73 million vehicle miles (117 million km) travelled. Vehicle miles traveled to GOGA accounts for 88% of the park's emissions. The largest source of GOGA's emissions is transportation – 9,613 MTCE.

PORE has committed to lowering greenhouse gas emissions by 15% below 2005 levels by 2012 through implementing emission mitigation actions (US EPA and NPS 2009). GOGA has set a goal of operating the park in a carbon neutral manner by 2016 by implementing emission mitigation actions and carbon offset strategies (US EPA and NPS 2008).

GOGA has developed, and PORE is in the process of developing, a Climate Action Plan for actions the parks will take to meet their stated goals in emission reductions. Continued support of the program by PORE and GOGA may involve reducing vehicle miles traveled, improving vehicle efficiency and using alternative fuels can significantly reduce the emissions. PORE will investigate, among other strategies, use of technology to reduce methane, currently the predominant greenhouse gas produced at PORE (US EPA and NPS 2009). New infrastructure projects will incorporate design solutions for use of new technologies to resolve energy needs. The parks have performed and will perform emission inventories to monitor progress.

Development/Land Use Change

Development including industrial, residential and rural development generally results in the construction of roads, buildings and parking lots, wetland conversion, or conversion of adjacent agricultural land from grazing to vineyards. These activities result in habitat loss and fragmentation, declines in habitat extent, changes in habitat distribution and quality and increased pollutant loads, invasive species and disease and pathogen incidence (Wilcove et al. 1986). Habitat fragmentation can also create barriers preventing the normal distribution or dispersal of species, isolating them on islands of parklands.

Indirectly, the parks continue to be impacted by urban and residential development, due to increasing visitor use and development directly along their urban borders. Areas in the north are less populated; however, there are fairly large population centers such as Sausalito and Mill Valley and in the south, Bolinas (Stinson Beach), is probably the largest rural residential "gateway" community to GOGA and southern PORE. South of the Bay from the Presidio to Mori Point, park lands are surrounded by highly developed areas. These developments have large areas of impervious surfaces and consequent storm water surges.

Development within parklands is fairly minimal; particularly in areas north of the Golden Gate. Much of the existing infrastructure within the park landscape predates the creation of the parks; yet, the problems from these impacts continue. For example in PORE, the development staved off in the Limantour Beach area by the establishment of the park in 1962, has left remnant structures and a vast array of roads that are slowly being dismantled. In the Presidio, which was a highly developed military complex before being transferred to GOGA, existing complexes are being restructured and in some cases removed. Though there is a general understanding of many of these issues, the type and quantity of development should be identified and monitored more quantitatively in and around the park (NPS 2002).

Park infrastructure, such as the parking lots, roads and facilities, that support park activities impact natural resources. Many installations are located in fairly benign areas and do not impact natural aquatic resources; others are located in sensitive areas. For example, all facilities in Stinson Beach, GOGA are located on an historic willow floodplain, which was filled by the late 1950s. Similarly, the parking lot of the Ken Patrick Visitor Center (PORE) is located on a former coastal lagoon/marsh complex on Drake's Bay. On a broader scale, management activities such as installation of coastal barriers, fire suppression, grazing, invasive species control, removal of vegetation and reclamation of nearshore areas can alter ecosystem structure and function.

Agricultural Uses
Agricultural development includes a variety of activities that continue in the park because of founding legislation and the importance of protecting cultural resources. Most existing operations occur in the northern portions of the parks, in PORE and northern GOGA, and include pastoral operations (grazing), cultivation and dairies.

Grazing
Much like fire, cattle grazing changes the pattern and extent of vegetation cover types in the park system. Grasslands probably accounted for significantly more than 25% of the watershed prior to Spanish settlement and certainly more after Spanish grazing (Van Kirk 2000). With no way to document the extent of indigenous burning, natural wildfires, or native herbivory, historic grassland estimates are largely based on speculation. However, if Spanish livestock grazing was as heavy and extensive as indicated by early accounts, it would have resulted in a higher proportion of grasslands coupled with significant watershed degradation. American settlement of Marin County began in the late 1840s and for decades, livestock numbers far exceeded the human population (Van Kirk 2000). The rate of impacts appear to have declined as recent photos (i.e., 2000) compared to those from 1965–1970 indicate that prairies are diminishing in size as natural Douglas fir forests advance onto the grasslands (NPS 2002).

In PORE and managed GOGA lands, agricultural operations occur on nearly 30 percent of park lands (Figures 21 and 22). In areas of their concentration, grazing cattle occur on grassland and wet meadow habitats and are a source of sediment, nutrients and pathogens in many portions of the park (CRWQCB 2005). Range Management Guidelines have been prepared to guide management in these areas. PORE is currently in the process of developing Ranch Unit Plans and is monitoring projects that have been completed in the last few years[6].

Cattle grazing is no longer allowed on GOGA-managed lands in GOGA (NPS 1999), such as Rodeo, Gerbode and Tennessee valleys, but the effects of historic grazing practices are evident and pervasive, including gully erosion, soil compaction, nutrient enrichment, altered hydrology, increased vegetation cover of non-native pest plant species, and non-native pasture species that have naturalized from plantings and are now expanding into adjacent areas. Several areas administered by GOGA are currently grazed by horses; however, due to staffing limitations, management of these areas is sporadic and no impact monitoring has been conducted. Also, roads left over from the ranching era continue to be sources of sediment in some areas.

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[6] J. DiGregorio, National Park Service, Range Management Specialist, pers. comm., 26 August 2009.

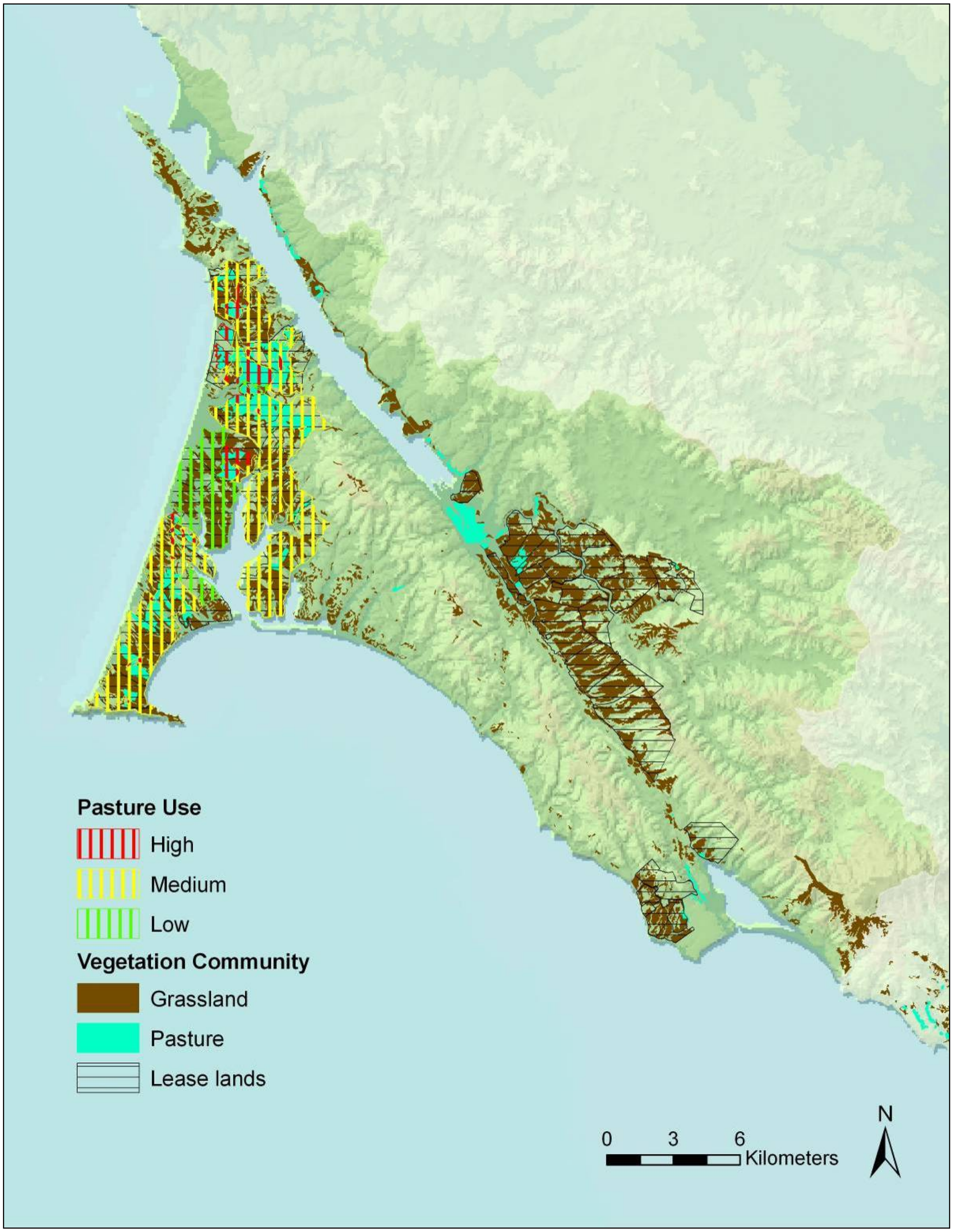


Figure 21. Lands managed by Point Reyes National Seashore illustrates areas that are leased for various purposes in 2006, including grazing and areas rated as pasture lands with high, medium or low usage. The areas labeled as pasture and grassland identified in the 1994 NPS vegetation map are illustrated for comparison.

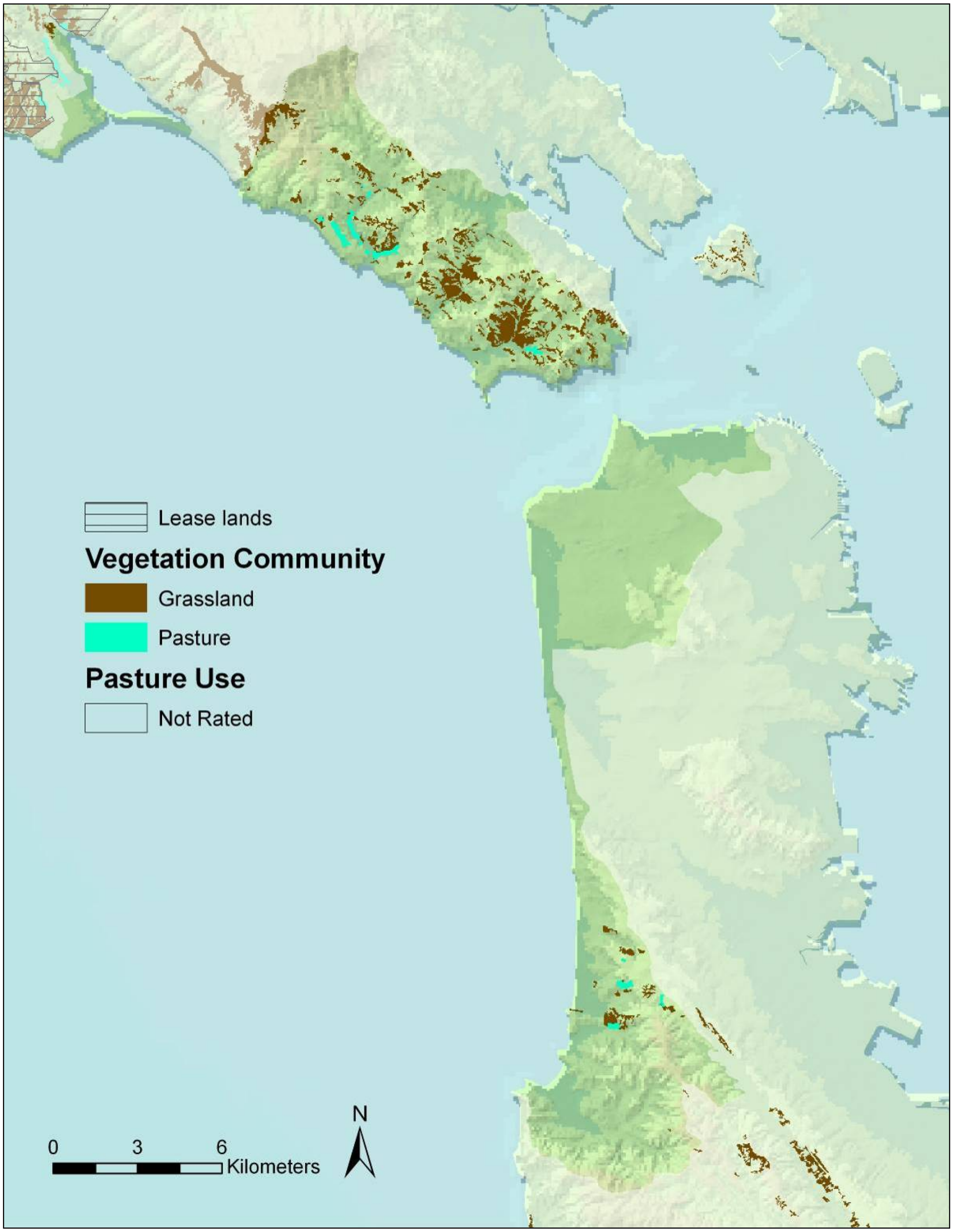


Figure 22. Pasture and grassland in Golden Gate National Recreation Area from the 1994 vegetation map are locations of potential impacts from historic grazing activities.

Dairy Ranching
According to Livingston (1995), a regionally significant dairy industry began developing by 1857 and over the next several decades, Swiss and Portuguese dairymen settled on Marin County ranches. Where extensive herds of Spanish cattle once roamed, milk cows took their place. Traditional dairy operations concentrate cows in discreet areas and result in more concentrated impacts (i.e., high pollutant levels) on fewer acres.

Currently there are six operating dairies in PORE-managed lands. Extremely high fecal coliform concentrations have been documented in streams adjacent to existing dairy operations (Ketcham 2001 and see Water Quality chapter). Manure spreading areas are correlated with the increased presence of invasive and noxious weed species. Dairies and ranching are associated with other impacts to wetland and riparian process.

Dairy improvement projects are underway in Kehoe Creek and Abbotts Lagoon Watersheds and monitoring programs are conducted to detect responses. Also, in the Tomales Bay watershed, a dairy management practices study conducted through the UC Cooperative Extension has been underway since 1999. Annual seeding and mulching treatments of high animal use areas have been a useful tool for improving water quality through reduced pollutant delivery downstream (Lennox et al. 2007). Areas that are seeded and mulched by late October to middle November show positive responses, but efficacy is affected by the location, type of livestock operation, landscape features, animal rotations and fall precipitation (Lennox et al. 2007). A systems approach for identifying water quality problems is allowing producers to prioritize and implement on-farm treatment efforts to improve water quality to yield (Lewis et al. 2005).

Some ranching practices provide mutual benefits to the operator and special status species. For example, conversion of small seeps and springs to stock ponds by ranchers created additional critical breeding habitat for the California red-legged frog. Numerous frog populations are now found in man-made stock ponds, which are maintained as ranch facilities.

Cultivation
Agricultural statistics for Marin County in 1856 indicate that about 3,000 acres (1,214 ha) (<1%) of the county was cultivated for grains and potatoes (State of California 1857). By 1867, over 33,000 acres (13,355 ha) were in cultivation in Marin County and more than half those acres were in wheat, barley or oats (State of California 1870). Grains, wood and dairy products were shipped from the port of Bolinas to San Francisco in the late 1860s. The 1883 statistics indicate a significant drop in cultivated grains as a dairy industry grew in Marin County (State of California 1885). Evidence of cultivation can be seen on bluffs near Limantour in the wilderness.

Silage operations exist on approximately 950 acres (384 ha) in PORE. Southern GOGA does not include any farmland though new acquisitions include southern park holdings that are near actively farmed areas in San Mateo County. GOGA has acquired former agricultural lands with the help of a non-profit landowner, the Peninsula Open Space Trust, near Montara in San Mateo County.

Aquaculture
Bivalve mariculture, a significant form of aquaculture in PORE, could affect the biological, physical and chemical characteristics of the coastal environment (Ulanowicz and Tuttle 1992,

Kaiser et al. 1998, Mazzouni et al. 1998, Mirto et al. 2000, La Rosa et al. 2002, NAS 2009). Site-specific studies of potential effects, whether harmful or beneficial, are lacking (Kelly et al. 1996, NAS 2009, Becker et al.2011). Whether native or non-native, shellfish could be affected negatively by changes in climate such as increases in ocean acidity (Gazeau et al. 2007), but the effects may be species-specific (Largier et al. 2010).

Oyster farming occurs commercially in Tomales Bay and Drake's Estero. Tables 6 and 7 include the commercial shellfish and wet storage operators in both water bodies (CRWQCB 2005).

Table 6. Tomales Bay commercial shellfish and wet storage operators (CRWQCB 2005).

Company	Acres	Products
Marin Oyster Company	30	Pacific oysters
Charles Friend Oyster Company	87	Pacific oysters
Cove Mussel Company	10	Pacific oysters, blue mussels
Hog Island Oyster Company, Inc.	133	Pacific oysters, Manila clams, blue mussels
Point Reyes Oyster Company	92	Pacific oysters, European oysters, Kumomoto oysters
Tomales Bay Shellfish Farms, Inc.	156	Pacific oysters, bay mussels, Manila clams, European flat oysters

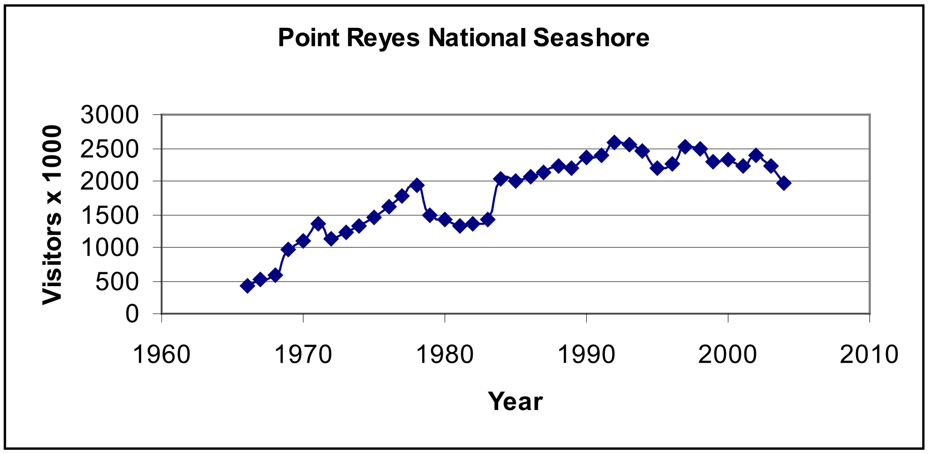
Table 7. Drake's Estero commercial shellfish operators (CDHS 2004).

Company	Acres	Products
Drake's Bay Oyster Company (formerly Johnson's Oyster Company)	1050	Pacific oysters, Manila clams

Recreation and Visitor Use

The broad variety of recreational uses and high visitation rates, especially in GOGA, create significant effects on natural resources. Roughly 15 million people visit GOGA and 2 million visit PORE each year (Figure 23). Hikers, mountain bikers, horse riders, dog walkers, kayakers, environmental education groups and aircraft (hang gliders, ultralights and helicopters) directly and indirectly affect wildlife, vegetation and soils. There is evidence of impacts of equestrian facilities (i.e., high pathogen levels), especially in GOGA, where stable operations have existed for many years. Recreation activities (i.e., hikers, kayaks, boaters, dog walkers) have the potential to negatively impact seabird and seal colonies and snowy plover wintering and nesting areas (Lafferty 2001, Truchinski et al. 2008). Harbor seals (*Phoca vitulina*) are most sensitive during their pupping season from March 1 through June 30. An NPS Inventory and Monitoring program records disturbance rates at seven harbor seal colony sites.

The effects of such high visitation rates on natural resources can be partially addressed by improved visitor management: increasing formal and informal education (ranger-led walks, volunteer docent programs, stewardship programs and interpretive signs), controlling activities through regulations, increasing enforcement patrols and closing social trails. For example, PORE and GOGA north of Bolinas Lagoon is closed to personal watercraft (protected areas include



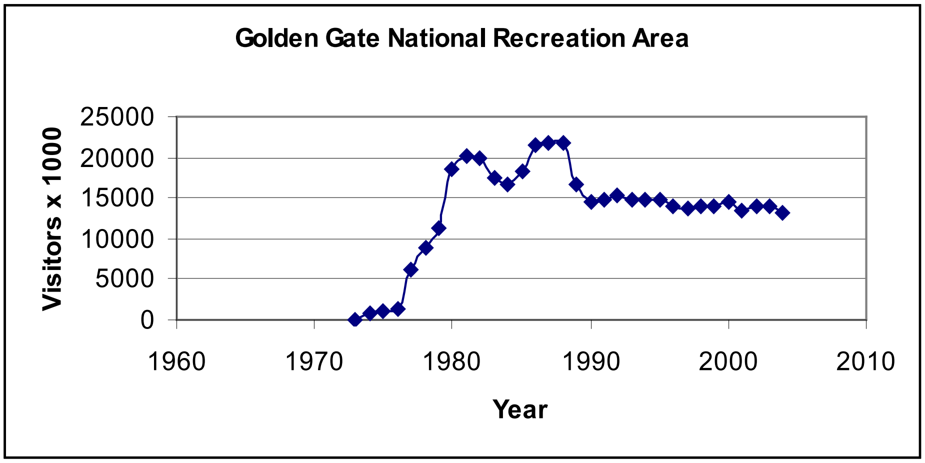


Figure 23. Visitor use of the Golden Gate National Recreation Area is over six times the average for the Point Reyes National Seashore from 2000 to 2004. Visitor use has been fairly stable for both parks since the early 1990s (NPS 2008).

Bolinas Lagoon, Drake's Estero and Tomales Bay). Special closures have been identified under the California Marine Life Protection Act (MLPA) planning process for the north central coast (see http://www.dfg.ca.gov/mlpa/northcoast.asp and Fishing and Harvesting in Stressors chapter) that restrict all activities near (300–1,000 ft [91–305 m]) seabird colonies, including Point Reyes Headland, Double Point and Miller Rocks at PORE. Marine Mammal Protection Act regulations prohibit harassment of marine mammals; general marine mammal viewing guidelines require that visitors remain 300 ft (91 m) away from whales, seals and sea lions. One of PORE's most important tools for native habitat protection and restoration is the stewardship of the land by local communities.

Resource Extraction

Resource extraction is a general category that includes dredging, sand mining, timber harvesting, harvesting of animals and herbaceous plants, recreational and commercial fishing, aquaculture and withdrawal of limited water resources. In PORE and GOGA, these issues concern all ecosystems: marine, terrestrial and freshwater. Historic harvests that brought populations down to a few individuals have resulted in genetic bottlenecks (NPS 2002). Poaching is also a problem for park biota within and adjacent to parks.

Dredging

Dredging alters the environment of the bay and ocean floor. If the dredged area does not refill with native material of the same grain size and composition, the change can be permanent (Chin et al. 2004). Whether the effects are short or long term, dredging operations affect benthic marine resources, which in turn can impact sub-tidal resources. Potential environmental impacts include disruption of communities, removal of habitats, a reduction in habitat diversity, destruction of spawning areas, suffocation and burial of organisms, gill abrasion by coarse particles, flocculation of algae, reduction of primary productivity and food finding abilities, increased turbidity and suspended solid levels, alteration of water velocity and current patterns, alteration of the sediment water interface, increased oxygen consumption and the release of bio-stimulants and toxic chemicals (Wakeman et al. 1975).

Two types of dredging occur within the west-central and adjacent areas of San Francisco Bay (hereafter "SF Bay"): 1) sand mining for construction aggregate and 2) maintenance and improvement dredging of harbors and navigation waterways (Chin et al. 2004). Often these activities are linked; the need for navigation providing construction aggregate. Maintenance dredging alleviates short-term problems, such as shoaling of harbors, waterways, or channels, but carries with it the problem of dredge material disposal. About 6 million yds^3 (4.6 million m^3) of sediment are dredged from SF Bay each year (Goldbeck 1999). Much of the past dredging activity was in the central part of SF Bay, where the major shipping lanes diverge after passing through the Golden Gate. To provide adequate water depth for the increasing draft of ships, emergent or shallow bedrock knobs were repeatedly blasted. Millions of cubic yards of sand and gravel have been permanently removed from bay-floor shoals since 1915. The process continues today; active sand-mining leases allow private contractors to extract sand and gravel from submerged state lands on a permit basis (Figure 24). At present no fewer than 10 sand mining lease sites exist in west- central SF Bay that are regulated by the California State Lands Commission, including leases near Alcatraz Island and the Presidio near park boundaries.

The San Francisco Bay is also a place to dispose of material excavated from waterways. Dredging materials are currently dumped 300 yds (274 m) off Alcatraz Island, throughout the Golden Gate shipping channel and at the San Francisco Bar. Disposal of dredge materials at the Alcatraz Disposal Site and other in-bay sites occurred for many years (Figure 25); however, by the mid-1980s, the Alcatraz mound had grown to the extent that it had become a navigational hazard, indicating that dredged material dumped there was not dispersing. The disposal site covered an area of about 0.25 mi^2 (0.64 km^2), larger than the exposed landmass of Alcatraz Island (Figure 25). Water depths over the site in 1997 ranged from 33–36 ft (10–11 m) at the shallowest to about 65–82 ft (20–25 m). Fishermen and environmentalists protested that the mud dumped at Alcatraz was harmful to marine life, and they blockaded the dumpsite in 1989 (Goldbeck 1999). These actions led to a moratorium on dredging and eventually to the creation of the Long Term Management Strategy (LTMS) program in 1991.

The LTMS program, led by a consortium of agencies (San Francisco Bay Conservation and Development Commission, San Francisco Bay Regional Water Quality Control Board [RWQCB] and the State Water Resources Control Board), has alleviated conflicts that had developed in the SF Bay by getting all interested parties to work together for solutions. Using the results of USGS studies, the US EPA designated the San Francisco Deep-Ocean Disposal Site in 1994, 55 mi (89 km) outside the Golden Gate in the Pacific Ocean (Karl et al. 2001). The LTMS

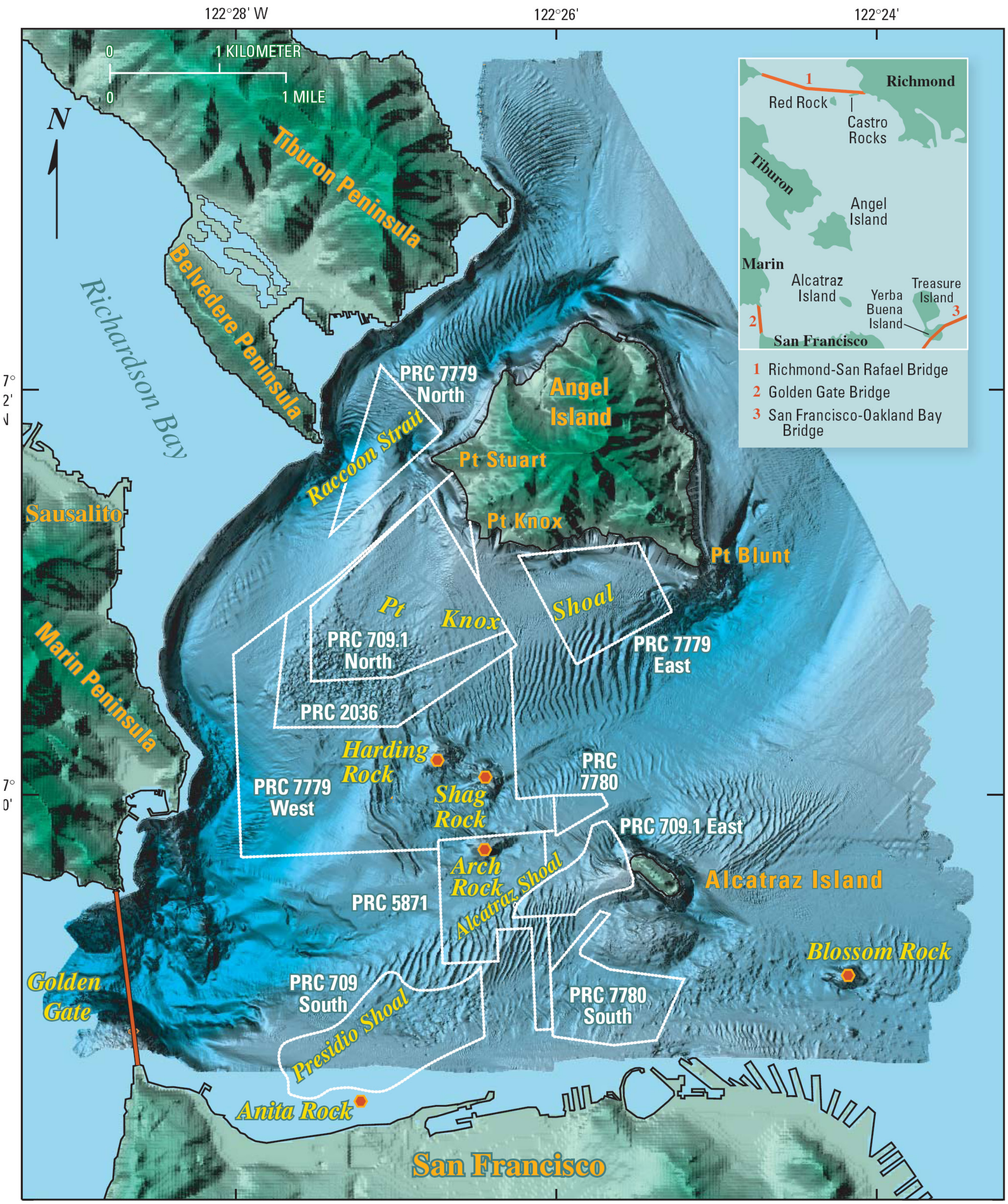


Figure 24. Approximate locations of lease areas for sand extraction in west-central San Francisco Bay as of June 1999, based on data from the California State Lands Commission Boundary Unit. Base map is composed of USGS shaded-relief images. Note the areas near Alcatraz Island and the Presidio Shoal (Chin et al. 2004).

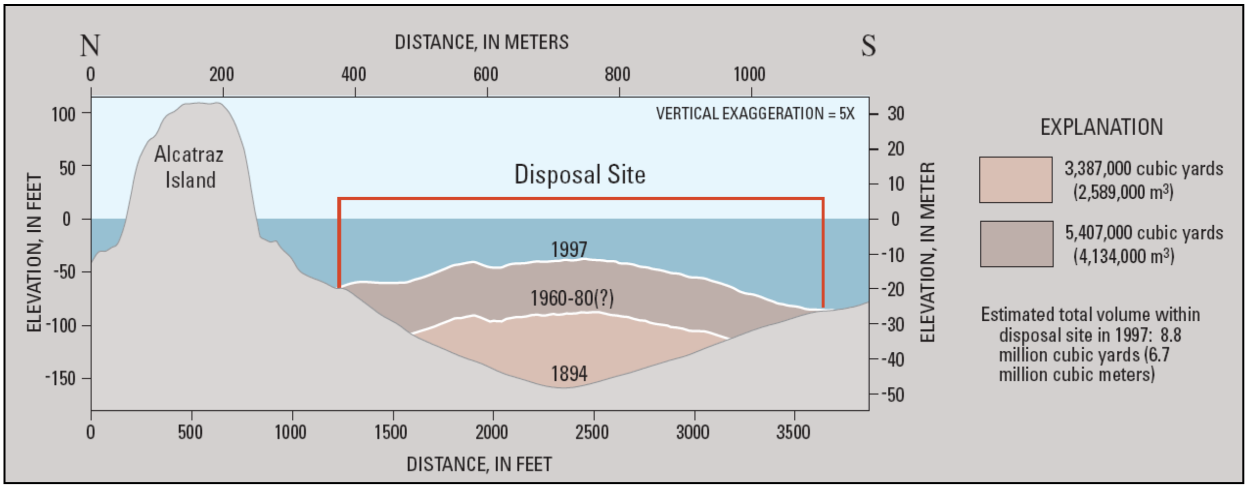


Figure 25. The evolution of the San Francisco Bay floor in the area of the Alcatraz Disposal Site. Oblique images show the topography of the bottom in 1894, during the period 1960–80 and in 1997. The 1997 image is derived from 1997 USGS multi-beam survey (95 kHz) of west-central San Francisco Bay. Images for earlier times constructed from available data. Cross section shows how dumping of dredged material in the Alcatraz Disposal Site transformed a bay-floor depression into a mound reaching within 33 ft (10 m) of the water surface (Chin et al. 1998).

strategy will use as much dredged material as possible for wetland restoration and other beneficial reuse projects, but about 20 percent of dredged material will continue to be disposed of at sites in the bay and the remainder will be taken to the deep-ocean disposal site. This strategy will be phased in over a decade (Goldbeck 1999).

An important related issue is whether dredged material is contaminated. In 1989, dichlorodiphenyldichloroethylene-contaminated sludge was dumped near Alcatraz (NPS 1999). The effects of dredging and sand mining near the Presidio and Ocean Beach areas requires additional study as effects are not known.

Mining, Oil Development and Oil Spills

Mineral and soil extraction can increase sedimentation of downstream water bodies or increase pollutant concentrations associated with extractive byproducts. Extracting water, river rock, sand and gravel can alter habitat by changing flow volume and patterns, reducing bank stability and changing sediment deposition patterns (Brooks 2003). Water table changes may also occur as a result of mining and well drilling, which can affect ground water-dependent habitats (Fetter 2000).

Though mining in the parks does not continue today, past practices have led to elevated levels of mercury in San Francisco Bay and Tomales Bay. Gold mining in the mid to late 1800s led to elevated levels of mercury from mining upstream in San Francisco Bay and failure of a former (Gambonini) mercury mine tailings pond near Walker Creek led to elevated levels in Walker Creek and Tomales Bay. These influences have led to the declaration of mercury impairment within San Francisco and Tomales Bay by the RWQCB (see Water Quality chapter).

Immediately offshore of PORE and GOGA is one of the most heavily used shipping corridors along the Pacific Coast. Regardless of cargo, the threat of accident, and loss of oil and other pollutants, to the coastal waters and shoreline is a constant concern. In addition to the obvious danger associated with high numbers of container and cargo ships passing through the Golden Gate Channel, park coastal resources are under constant threat of damage by grounding and subsequent breakup of smaller commercial or recreational vessels. PORE averages four shipwrecks per year, consisting of small to moderate oil or fuel spills, damage to intertidal habitat and cleanup of materials from the boat.

Oil spills are a threat to marine flora and fauna along the entire park coastline. The impacts include lethal effects such as hypothermia and suffocation in seabirds and marine mammals and sub-lethal effects such as disease and tumors in many species. Though polyaromatic hydrocarbon (PAH) concentrations in mussels and clams indicate low levels of contamination in coastal areas of the parks compared to San Francisco Bay, they did suggest higher exposure to petroleum during the winter season (Applied Marine Sciences 2002). Average concentrations of PAH analytes measured in the Regional Monitoring Program for Trace Substances (Hoenicke et al. 1996) and the PORE intertidal monitoring program were twice as high in San Francisco Bay as at the Point Reyes coastal sites (Applied Marine Sciences 2002). The higher springtime concentrations of PAHs along the Point Reyes coast were believed to be due to oil released from the SS *Jacob Luckenbach* (see below) or smaller fishing vessels. Significantly higher concentrations of PAHs in mussels at Bolinas sites may have come from the same source or a result of the proximity of Bolinas to San Francisco Bay (Applied Marine Sciences 2002). The pattern of PAH contamination suggests that bivalves might be better indicators of oiling than contamination levels in sediment that occurred several months before sampling.

Waterfowl, seabirds and shorebirds are particularly affected by oil spills (Wiens et al. 1996, Carter 2003). The GOGA General Management Plan indicated that coastal resources were affected by oil-related events in 1971, 1976, 1980, 1986 and 1989 (NPS 1999) and beaches at PORE were also oiled during those events. For more than a decade, the National Oceanic and Atmospheric Administration (NOAA) Beach Watch citizen scientist shoreline monitoring program has recorded and investigated four major oil-related events (FMSA 2003):

- The *Cape Mohican* in 1996 spilled 96,000 gals (36 x 10^4 L) of fuel oil into a dry dock in San Francisco Bay – 40,000 gals (15 x 10^4 L) escaped into San Francisco Bay and beyond into the Gulf of the Farallones National Marine Sanctuary (GFNMS). Approximately 4,000 birds and 247 billion Pacific herring (*Clupea pallasi*) eggs were lost. Over 120 mi (193 km) of coastal and bay shoreline was affected. Natural resource damages for all habitats and species was assessed at $3.6 million.
- The *Command* in September of 1998 spilled approximately 3,000 gals (11 x 10^3 L) of oil. Damages were assessed at $4.05 million for natural resource restoration of seabirds.
- The Point Reyes Tarball Event occurred in 1997–1998. Over 2,000 oiled birds were recovered from beaches along the GFNMS with a concentration on PORE beaches. Initially, the source of the tarballs was unknown, but subsequently oil was discovered leaking from the sunken vessel, the SS *Jacob Luckenbach*. As the WWII-era ship degraded in offshore waters, bunker oil was released during storm events. Through oil spill recovery funds, NOAA and the State of California removed the remaining bunker oil and stabilized the vessel in 2005.

- The *Cosco Busan* in November 2007 spilled 58,000 gals (220,000 L) of bunker oil fuel following a collision with the Bay Bridge. Extensive fouling of marine and coastal resources occurred within San Francisco Bay, as well as outside of the bay north to Drake's Beach.

These examples illustrate the frequency and magnitude of impacts. Past frequencies of oil spills are likely to continue due to the continual pressure to open nearby outer continental shelf leases for oil exploration and development, and due to the existence of refineries in the region. Seven oil refineries are located in the Bay Area, and oil accounts for 75 percent of the tonnage entering the bay. Small boat wrecks are numerous, but do not spill much oil. Nevertheless, wrecks can harm resources when they land on beaches where nesting snowy plovers occur. Resource losses also result from oil clean up procedures. Mechanical graders used to clean up oil removed the top 6 in (152 mm) of sand along with the oil where most sand dwelling species occur.

Logging

Historically, logging practices were an important force on the landscape and some areas are still feeling the impacts of a checkered history of logging. There are numerous accounts of large old growth redwoods once lining the canyons leading from Mount Tamalpais to the sea (Van Kirk 2000). The historic sediment record suggests the widespread presence of redwoods throughout the park system, prior to modern human habitation. Interpretation of sediment cores from Mountain Lake in the Presidio (Reidy 1994), a lake that formed approximately 2,000 years ago, suggests that redwood and pine pollen percentages remained stable across the Pre-European-Early Spanish period, but declined possibly due to heavy logging in the early 20th century (Russell 1983).

Extensive historic logging is usually blamed for initiating sedimentation in areas such as Bolinas (Van Kirk 2000) and Tomales Bays. However, Van Kirk (2000) indicated that impacts were minimal during early logging periods due to the primitive nature of early logging practices and the relatively small amount of trees removed. As technology advanced (bigger bulldozers), the potential for impacts expanded as well. There are certainly differential impacts from logging conducted in the late1800s versus logging conducted in the mid-1900s. In Marin County, logging was generally concentrated in the Pine Gulch, Olema and Papermill (now Lagunitas) Creeks. Small stands of old growth redwoods are preserved in Muir Woods; however, there are indications that these stands are much smaller than those that previously existed in other coastal valleys. The last era of logging within the Marin County lands includes the southern half of the Olema Valley-Inverness Ridge/Fir Top, with the operation of the Sweetwater Mill (now Five Brooks and Mill Ponds), as well as logging further to the south on the Righetti Property. Though logging is not allowed in the parks today, old logging roads and the lack of old growth redwoods, has changed the character of the landscape.

Fishing and Harvesting

"Nearshore" is defined in the California Nearshore Fishery Management Plan as the area from the high-tide line offshore to a depth of 120 ft (37 m) (CDFG 2002a). Nearshore fish species include highly-prized game fish and small fishes used for bait, food and industrial products. Invertebrates include crustaceans (crabs and shrimp), mollusks (abalones, clams, scallops and native oysters) and echinoderms (sea urchins). In general, the State manages marine waters within 3 mi (4.8 km) of the shore; the federal government has jurisdiction beyond this boundary. Park boundaries are 0.25 mi (0.4 km) offshore. The NPS state lease declares that "fishing, including the taking of mollusk or crustacean shall be permitted in accordance with regulations imposed by the State Department of Fish and Game. Any restrictions, or enclosures of fishing, shall be invoked only after consultation with and concurrence by the appropriate State agencies."

California contributes the most commercial landings of nearshore species at an estimated 93,954 metric tons (mt) (103,565 tons [t]), followed by Oregon (22,198 mt; 24,469 t) and Washington (14,637 mt; 16,134 t) (US EPA 2004). Commercial landings along the central coast are a dominant proportion of the catch of many nearshore species.

The most important fisheries on the parks' borders are Dungeness crab (*Metacarcinus magister*), groundfish (including several nearshore species), Pacific herring (commercial), Chinook salmon (*Oncorhynchus tshawytscha*; party boats), halibut species (recreation fishing at Tomales Bay), albacore (*Thunnus alalunga;* recreation at PORE) and squid species (commercial). A study of the fisheries within the borders of the north-central coast national marine sanctuaries between 1981 and 2003 found that these seven fisheries yielded an average of nearly 35 million lbs (15,876 mt) of landings worth over $31 million per year in constant 2003 dollars (Table 8; Scholz et al. 2005). Collectively, they accounted for 92% of landings and revenues at the study-area ports. From 1981 to 2003, the average price (dividing ex-vessel revenues by landings) was $0.93/lb ($2.05/kg) in the study region—almost twice the state average of $0.53/lb ($1.17/kg) (Scholz et al. 2005). More data on landings and the fisheries were assembled for the MLPA planning process for north-central California (http://www.dfg.ca.gov/mlpa/northcoast.asp).

Systematic tracking of recreational fishing is relatively recent. Though the Recreational Fisheries Information Network (RecFIN) database begins in 1980 (http://www.recfin.org), the California Recreational Fisheries Survey (CRFS) was instituted in January 2004 to provide catch and effort estimates for marine recreational finfish fisheries. Locations within the parks have site specific recreational catch data from this database. For example, Recfin catch data for Fort Point at the northern end of the San Francisco peninsula include the following species (and catch totals in parentheses): jacksmelt (407), northern anchovy (304), Pacific sardine (478), shiner perch (278), surfperch family (208) and walleye surfperch (256).

The CRFS a collaborative effort between the CDFG and the Pacific States Marine Fisheries Commission, and is funded by state and federal sources. The goal of the CRFS is to make accessible marine recreational fishery-based data that are needed to sustainably manage California's marine recreational fishery resources (CDFG 2006). The CRFS meets the specific data needs for managing species with federal harvest guidelines or state allocations. The CRFS monthly estimates assist fishery managers in tracking progress toward harvest limits. Catch and effort are reported by six geographical districts to assess regional shifts in catch rates, average fish weights and fishing activities (CDFG 2006); however, the San Francisco region includes both the bay and the coastal areas around the parks so estimates reflect a much wider area than that influenced by park management. Catch and effort estimates are also reported by four modes of fishing (i.e., beaches and banks, man-made structures, commercial passenger fishing vessels and private or rental boats). For several major recreationally targeted species, notably nearshore rockfishes, surfperches, greenlings, lingcod, flatfishes, salmonids and sculpins, north-central California accounts for the majority of the statewide recreational catch.

Table 8. Relative economic importance Gulf of the Farallones and Cordell Bank National Marine Sanctuaries' waters for select study area fisheries, 1997 to 2003. Albacore is primarily an offshore species and rarely occurs in nearshore areas (Scholz et al. 2005).

Fishery	Average revenue ($) of sanctuary waters	Average revenue ($) as % of study area total revenue	Average revenue ($) as % of state total revenue
Albacore*	76,003	23%	1%
California halibut (hook-and-line)*	44,146	17%	10%
California halibut trawl**	233,317	27%	15%
Dungeness crab*	3,283,100	55%	17%
Groundfish			
Rockfish (hook-and-line)*	442,200	77%	17%
Flatfish (trawl)**	331,894	28%	6%
Rockfish (shelf trawl)**	150,203	66%	22%
Rockfish (slope trawl)**	61,095	42%	9%
Salmon*	1,929,946	46%	24%
Squid*	59,763	21%	0%

* Percentage of study area revenue associated with each of the fishing grounds derived from local knowledge interviews.

** Derived from tows within sanctuary waters.

The commercial fisheries of north-central California have experienced numerous boom and bust cycles, which has led to vigorous debates over management priorities. There is evidence that high commercial harvest rates post-World War II significantly affected populations, such as Dungeness crabs and groundfish. Salmon, tuna and sardines, the main fisheries of the 20th century, underwent cyclical swings or collapse in the 1960s. During the 1970s and 1980s, financial and technical assistance from the U.S. government led to an increase in trawl fisheries for rockfishes and flatfishes in the north-central California fleet. At the same time, an increase in seafood exports to Asia led to an expansion of the sea urchin fishery, based in what are now GFNMS waters (Scholz et al. 2005). Statewide commercial landings peaked in 1981 at over 900 million lbs (408,237 mt) and declined to 370 million lbs (167,830 mt) by 1991. From 1981 to 2003, the overall declining trends in landings and revenues are mirrored in GFNMS and Cordell Bank National Marine Sanctuary (CBNMS). From a peak of 58 million lbs (26,309 mt) in 1982, when groundfish and herring fisheries dominated regional fisheries, landings declined to roughly 22 million lbs (9,979 mt) in 2003 (Figure 26; Scholz et al. 2005).

Stronger commercial fishing regulations were enacted by NMFS in the 1990s in response to evidence that economically important species (i.e., rockfish species, lingcod, Boccaccio) were in steep decline (Scholz et al. 2005). Rockfish are long-lived, late maturing and slow-growing species, which make them particularly vulnerable to overfishing (see Habitats chapter for more information.) Further restrictions were placed on commercial and recreational salmon fisheries by the PFMC in 2008 and 2009. The PFMC closed the commercial and recreational salmon fishery along the central California coast as a result of dramatic decreases in adult returns.

Commercial fishing is conducted with fewer vessels than a generation ago. The fishery is not diversified and may be vulnerable to fishery management changes affecting fisheries dependent on single source revenues. The majority of commercial fishing vessels, when judged by the

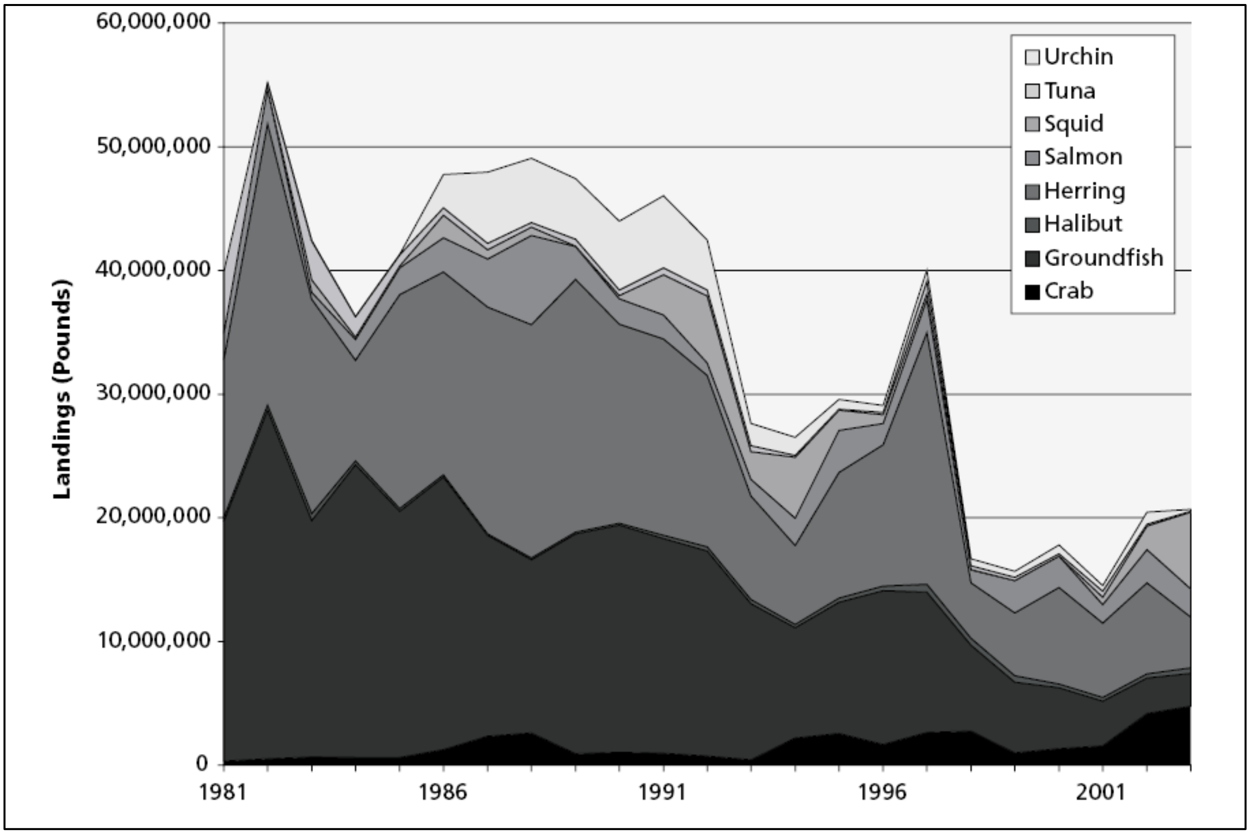


Figure 26. North-central California coast landings of select fisheries, 1981 to 2003 (Scholz et al. 2005).

species groups they are landing in area ports, appear to only participate in one fishery. The preponderance of single-fishery operations in the study area is partially a reflection of the time and cost associated with switching gear. According to fishermen surveyed, even over the course of a whole year one would not necessarily fish all the licenses held (Scholz et al. 2005).

Despite these boom and bust cycles, the impact of harvests on nearshore populations is poorly understood as population status is not well documented for a majority of nearshore species. Accurate, long-term predictions of potential yield and impacts will require a substantial increase in knowledge about biological interactions as well as knowledge about climate effects on the nearshore community (Leet et al. 2001, US EPA 2004). Because the composition of the nearshore fauna is very diverse and management authority is shared among many entities and fisheries statistics are summarized at scales larger than park boundaries, detailed information on the effects of fishery practices on species along the PORE and GOGA coastlines is difficult to ascertain. In addition to direct effects, bycatch is also an important issue.

The north central coast study, which includes PORE and GOGA, was the second of five statewide study regions to complete the Marine Life Protection Act (MLPA) planning process. Passed in 1999, the MLPA directed the state of California to redesign the system of marine protected areas to function as a network. The objective was to increase coherence and effectiveness of protecting marine life and habitats, marine ecosystems and marine natural heritage, and to improve recreational, educational and study opportunities provided by marine ecosystems (CDFG 2009).

In August 2009, after two years of stakeholder, science advisory team and blue ribbon task force meetings, the California Fish and Game Commission voted to adopt the Integrated Preferred Alternative for the MLPA north central coast region (CDFG 2009). The Integrated Preferred Alternative established 10 State Marine Reserves (SMR), 11 State Marine Conservation Areas (SMCA), three State Marine Recreational Management Areas and six special closures, in total covering approximately 153 mi^2 (396 km^2) (20.1%) of state waters in the north central coast study region. Approximately 11% (86 mi^2) (223 km^2) of the 153 mi^2 are designated as "no take" SMRs. The SMRs include Estero de Limantour SMR, Point Reyes SMR and Montara SMR (Figure 27). In the SMCAs, limited commercial and recreational taking of fish and shellfish is allowed. The SMCAs within NPS boundaries are Drake's Estero SMCA, Point Reyes SMCA, Duxbury Reef SMCA and Pillar Point SMCA (Figure 27). Three special closure areas were designated along the PORE coastline (Point Reyes Headlands, Double Point/Stormy Stack and Point Resistance) and one on the GOGA coastline (Egg Rock to Devil's Slide). Special closure areas restrict who can access these areas due to their sensitivity as pinniped pupping areas and seabird nesting colonies. There are no State Marine Recreational Management Areas within or adjacent to NPS lands. The adopted marine protected area designations and restrictions took effect on April 1, 2010.

Hydrologic and Geomorphic Alteration

Streams, lakes, wetlands and groundwater resources can be altered by a variety of factors such as water withdrawal (surface and groundwater), impoundments (dams and culverts), channelization and levees, channel hardening, expansion of impervious surfaces, loss of riparian buffers, and changes in runoff characteristics due to changes in plant community composition. Water transport and diversion also affect stream processes such as sediment deposition/erosion, accretive/avulsive meandering, flow regimes (bankfull/dominant discharge/peak flow) and long-shore sediment transport (Brooks 2003).

Water diversion: surface and groundwater

Water level fluctuations in ponds, wetlands, streams and lakes are directly linked to groundwater levels and hydrology, which influence vegetation dynamics. Altered water quantity can affect water quality, flooding events and water temperature profiles. Terrestrial and aquatic ecosystems are affected by these alterations which can lead to habitat degradation, non-native species invasions, riparian and wetland habitat loss, and decreased biodiversity (Gordon et al. 1992).

The watersheds of GOGA support and are impacted by important municipal water supplies in the area. Lagunitas Creek is used as part of the municipal water supply for Marin County. A series of dams operated by MMWD supply much of southern Marin, while well diversions at the downstream end of the watershed supply the NMWD – West Marin Service Area. Arroyo Hondo, one of the park's most remote watersheds is the sole water supply for the BCPUD. Many watersheds originating in PORE lands along Inverness Ridge are used as the Inverness Public Utilities District water supply. Redwood Creek water supports the Muir Beach Community and several state park residences along the creek. Elk Creek supplies three residences. Lobos Creek is used to supply the Presidio of San Francisco. The headwaters of Easkoot Creek are a source of potable water for Stinson Beach. San Francisco watersheds supply the domestic water for San Francisco and San Mateo Counties. Sources include: Crystal Springs Lakes, Pilarcitos Creek, Pilarcitos Lake and San Andreas Lake (NPS 1990). Each of these freshwater systems must meet drinking water objectives set by the State of California (Urban Watershed Project 2001).

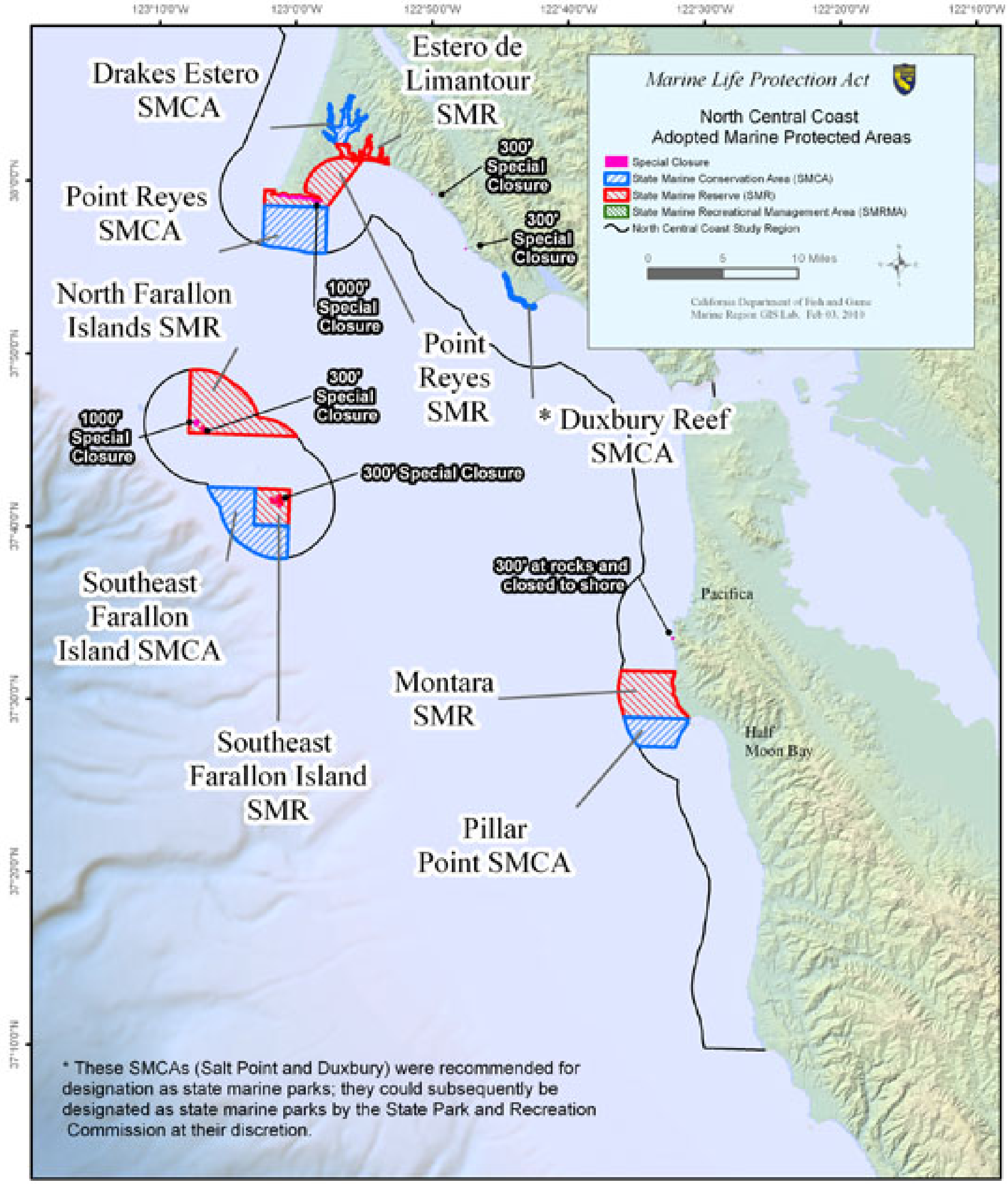


Figure 27. Adopted California Marine Life Protection Act designations (effective April 1, 2010) for the North Central Coast including Point Reyes National Seashore and Golden Gate National Recreation Area coastlines (CDFG 2009).

Dams and Stream Crossings[7]

Water flow impediments (e.g., culverts, dissipaters, dams) impact stream discharge and morphology and the passage of fish and other migratory species. The Lagunitas watershed is regulated with a large dam, Kent Reservoir on the mainstem, and Nicasio Reservoir on Nicasio Creek. These structures are operated for water supply only, with no flood control or fish passage arrangements. There are numerous legacy earthen dams at PORE, many posing problems for the natural function of streams and fish migration. Ten of them are on the NPS dam inventory due to the risk their failure poses to humans: Home Ranch, Kehoe Ranch, Niman-Schell, Hagmaier Pond, Mill Pond, Lower Muddy Hollow, Lower Turney, Upper Estero, Lower Estero and Mount Vision Pond. The Bureau of Reclamation (BOR) evaluated the condition of the 10 listed dams under its Safety Evaluation of Existing Dams (SEED) program (BOR 2000). Kehoe and Home Ranch dams were rated as being in poor condition, while Home Ranch poses a significant downstream hazard due to its proximity to recreational areas. The Water Resource Stewardship Report also concluded that "2 of the dams considered to be in seriously deficient condition (Mount Vision Pond Dam and Lower Muddy Hollow Dam) should have prompt attention to correct the observed deficiencies" as a priority (Pagano et al. 2006). In 2008, PORE completed removal and restoration of natural estuarine and shoreline processes at Lower Muddy Hollow Dam and Limantour Beach Pond Dam. In 2009, the Lower Turney Dam was removed.

Many of the dams at Point Reyes are located in designated Wilderness (Figure 28) and considered non-conforming structures. However, dams in some areas are habitat opportunities for California red-legged frogs, so it is important to assess the impacts of their removal on frogs (Collins 2007). A number of the dams at Point Reyes lie within existing ranch boundaries and maintenance and upkeep of these are the responsibility of ranchers.

Stream crossings are human-made structures used primarily for transportation purposes which cross over or through a stream channel, such as: paved and unpaved roads, railroad tracks, biking or hiking trails, or low-water fords. Stream crossings include culverts and bridges. Culverts vary in the degree of their impact on stream morphology and special status species. Culverts that are undersized or constructed improperly are in danger of failing causing localized erosion, downcutting and passage problems. Degraded infrastructure can cause larger-scale impacts to hydrologic and geomorphic processes and watershed functions. These processes include flooding, surface water interaction with the groundwater table, horizontal movement or meandering of the creek channel, impediments to connectivity of the stream with the floodplain, and the movement of boulders, gravel, fine sediment, etc. (NPS 2004b).

Culverts often create temporal, partial or complete barriers for anadromous salmonids on their spawning migrations (Robison et al. 1999). Typical passage problems created by culverts include: excessive drop at outlet (too high of entry leap required); excessive velocities within culvert; lack of depth within culvert; excessive velocity and/or turbulence at culvert inlet; and debris accumulation at culvert inlet and/or within culvert.

Following the 1996 and 1997 federal listing of coho salmon as threatened in northern California, six counties (Sonoma, Marin, Napa, San Mateo, Alameda and Santa Cruz) formed the FishNet 4C Group to examine various land-use activities conducted or permitted under county

[7]Text adapted from Water Resource Stewardship Report (Pagano et al. 2006).

Figure 28. The Bureau of Reclamation evaluated the condition of the 10 dams listed under its Safety Evaluation of Existing Dams program. Color codes: dark green=congressionally-designated wilderness, light green=Tomales Bay State Park, dark blue=congressionally-designated or potential marine wilderness, tan=park lands, and white=other lands) (Bureau of Reclamation 2000).

jurisdiction that could impact coho salmon habitat. An inventory and fish passage evaluation of county-maintained stream crossings within Marin County was conducted between May 2002 and June 2003 and in San Mateo County between September 2003 and July 2004. The inventory was focused primarily on county-maintained crossings within anadromous stream reaches within Marin County watersheds known to historically and/or currently support runs of coho salmon and/or steelhead trout. However, a number of city and state-maintained crossings were also evaluated. The Stream Crossing Inventory and Fish Passage Evaluation Reports identified and prioritized culvert locations to fix which would result in unimpeded passage for all species (and life stages) of salmonids (Ross Taylor and Associates 2003, 2004).

Additional inventories and studies are underway at GOGA, including a sediment budget study and a report of all sediment sources in the Redwood Creek watershed; erosion surveys continue throughout the Marin Headlands; and culvert mapping has occurred in Rodeo Valley. In 2007, PORE removed or replaced culverts with bridges at five other sites in the Drake's Estero watershed to improve geomorphic process and fish passage. A fish passage assessment project was analyzing all the culverts (approximately 10 sites) in the Bear Valley Creek watershed.

Erosion/Sedimentation

Anthropogenic coastal watershed erosion is a significant problem worldwide, leading to large expenditures to stabilize erosive cliffs, slopes and beaches along coastal rivers and oceans. Slopes in the coast range are inherently unstable due to a combination of faulting, erosive soil types and locally intense rainfall. Surface anthropogenic disturbances, such as trails and road cuts, vegetation clearing and alteration of surface water drainages, can trigger slope failures (NPS 2005). Rills and gullies originate at old roads and social trails especially in heavily used areas devoid of vegetation. Rills and gullies create a network of channels conveying greater volumes of sediment and water to stream channels, leading to flashier flows during rain events. Large gully networks range in character from persistently devegetated, rilled slopes to large individual channels up to 15 ft deep (4.6 m) and wide. Many of the gully systems continue to enlarge or are reactivated by uncorrected or renewed land disturbance. Other channels have stabilized but remain as persistent scars on the landscape. Some of the worst and most obvious problem areas are in grasslands (NPS 1999); however, downstream areas have and continue to be impacted on large scales.

There are many causes of the accelerated erosion problems that occur across the park landscape, including but not limited to:

- Many roads developed prior to park establishment or under different management regimes are no longer suitable for current uses. As noted above, their configuration results in inadequate drainage and increased sediment yields into creeks, which in turn degrades water quality. Water diversions and the concentration of runoff may initiate or accelerate slumping and landslides in sensitive areas. NPS transportation plans have identified priority road related erosion features and have developed prescriptions for reducing their impacts.
- Grazing increases erosion by decreasing the amount of vegetation available to capture water, and by compacting the soil, thus deterring infiltration. This compaction increases runoff, which carries topsoil and sediments into the creeks. Riparian degradation also

affects the hydrology of streams, enhancing flow during storms, which causes more flashy runoff patterns. The conversion of many areas to annual versus perennial bunch grasses may have reduced the capacity of the vegetation to hold soils during precipitation events.

- Areas of concentrated use enhance erosion events. Off-road vehicles (ORV), hang gliders, bicyclists, horses, dogs, hikers and other visitors have created denuded areas with compacted soil. Compaction also inhibits infiltration, increasing runoff and erosion. The trend of increasing trail use portends a long-term and potentially increasing threat.
- Global warming and associated sea level rise will exacerbate coastal erosion.

The RWQCB identified Lagunitas Creek and Tomales Bay as water quality limited by sediment under Section 303(d) of the Clean Water Act. The RWQCB anticipated initiating a sediment total maximum daily load (TMDL) program in the Lagunitas Creek watershed by 2010.

Coastal Landslides
The coastal urban regions of California, including areas in San Mateo (GOGA) are growing rapidly, putting increasing demands on coastal infrastructure and lifelines, such as highways, utilities and community services. These structures and services, as well as the general population that are located in the coastal zone, are at risk from coastal landslides, which are triggered by a variety of phenomena including long-term and seasonal changes in the water table as a result of changing land use, coastal erosion caused by natural response to changes in sea level and changes in sediment transport patterns caused by construction of dams, breakwaters and other coastal structures, and episodic disastrous earthquakes and storms. Coastal landslides can be significant contributors to longshore sediment load. Increases in the frequency of landslides can in some cases amplify nearshore sedimentation (USGS 2008).

The coastal bluffs making up the entire PORE shoreline are susceptible to coastal erosion and landslides. The southern areas of PORE, from Wildcat south to Bolinas are prone to extensive landslides. The lakes in the southern portion of the park are formed as a result of slides, with extensive landslide features extending up slope to the top of Inverness Ridge. There is also substantial slide evidence around the Point Reyes Headlands, which supports the historic lighthouse facility and unique wildlife habitat.

Sediment Limitation
While many coastal bluffs are eroding, this problem is exacerbated by the lack of sediment coming down California’s rivers. The upstream damming in the San Joaquin and Sacramento Rivers leading to San Francisco Bay has led to sediment limitation and presumably sediment starved beaches along the central coast. The lack of sediment may have led to accelerated erosion in some locations; however, the extent of the problem is not well studied. The California Geologic Survey is working on a Coastal Sediment Master Plan to examine the feasibility of linking sediment-starved beaches in the central and south parts of the state to projects in the north coast with excessive sediment (California Coastal Sediment Working Group 2009). Sediment limitation is a broad-based problem, so it was not rated in the stressor table.

Disturbed Lands
As we have noted, many detrimental land uses have been curtailed by current park legislation or management practices; however, legacy problems remain. We have collectively included these

legacy issues as “Disturbed Lands” and include in this category: abandoned roads and trails from historic logging or other past uses, existing infrastructure (i.e., buildings slated for removal or those remaining as cultural artifacts) and old mines or quarries.

Roads

All phases of road development—from construction and use by vehicles to maintenance—affect physical and chemical soil conditions, water flow and air and water quality. Roads affect habitats, increase wildlife mortality and are corridors for the dispersion of nonnative pests (Clevenger and Huijser 2009). There are currently over 100 mi (161 km) of roads and trails in PORE (Figure 29; NPS 2004a) and numerous roads in GOGA. Route 1 is maintained by the State of California. The major roads through PORE and northern GOGA are maintained by Marin County. Southern GOGA roads are maintained by the City of San Francisco, San Mateo County and State of California. More minor roads in PORE and GOGA are maintained by the NPS. Transportation access to PORE and northern GOGA is limited, in keeping with area’s open space/wilderness character; however, traffic and road deterioration is a significant issue. All primary access roads are two-lane corridors in the vicinity of PORE and become narrower as they enter the parks’ rural landscape. Most intersections are controlled by stop-signs or are uncontrolled. Ranch roads have been identified as a maintenance issue. PORE intends to evaluate ranch roads as part of the ranch unit planning process to identify primary and secondary ranch roads, leading to different periods of use and maintenance requirements.

Many of the roads developed prior to park establishment were either improperly aligned or were not designed to handle the traffic volume that accompany visitation. Major roads need seismic or safety upgrades. Modern day roads in PORE began as trails with the ranching industry, while many of the roads in the Marin Headlands (GOGA) were designed to support less intensive military uses. As visitor numbers increase, traffic puts significant stress on park roads leading to more impacts. The Marin Headlands – Fort Baker Transportation Management Plan was completed in 2009 with the goals of rehabilitating the roadway network and studying implementation of alternative transportation modes to make park lands more accessible to the general public. Alternative transportation has been an objective since the creation of the park in 1972, but almost 30 years later only limited transit access had been implemented and pedestrian and bicycle access are in need of significant improvements. Other major transportation improvements include construction of The Presidio Parkway, a world-class design to replace the existing roadway that, when constructed, will improve the seismic, structural and traffic safety of Doyle Drive (Highway 101). The project team has strived to create a roadway that reduces impacts to biological, cultural and natural resources; respects the project setting within a national park, the National Historic Landmark District and surrounding neighborhoods; meets community needs; and provides a safer roadway (http://www.presidioparkway.org).

Trails

A properly designed and constructed trail has low gradient, requires minimal earth movement and allows water to be carried off in sheets rather than in channels. This design is accomplished by sloping the trail surface in cross section outward and down-slope. Well-designed trails require a minimum of maintenance and cause little erosion. Many of the trail routes in PORE and northern GOGA; however, were not designed as trails but were aligned on old roads. Road-based trails, many of which were created with bulldozers, are often more damaging and difficult to maintain over time because technology allowed the road builders to ignore the constraints of

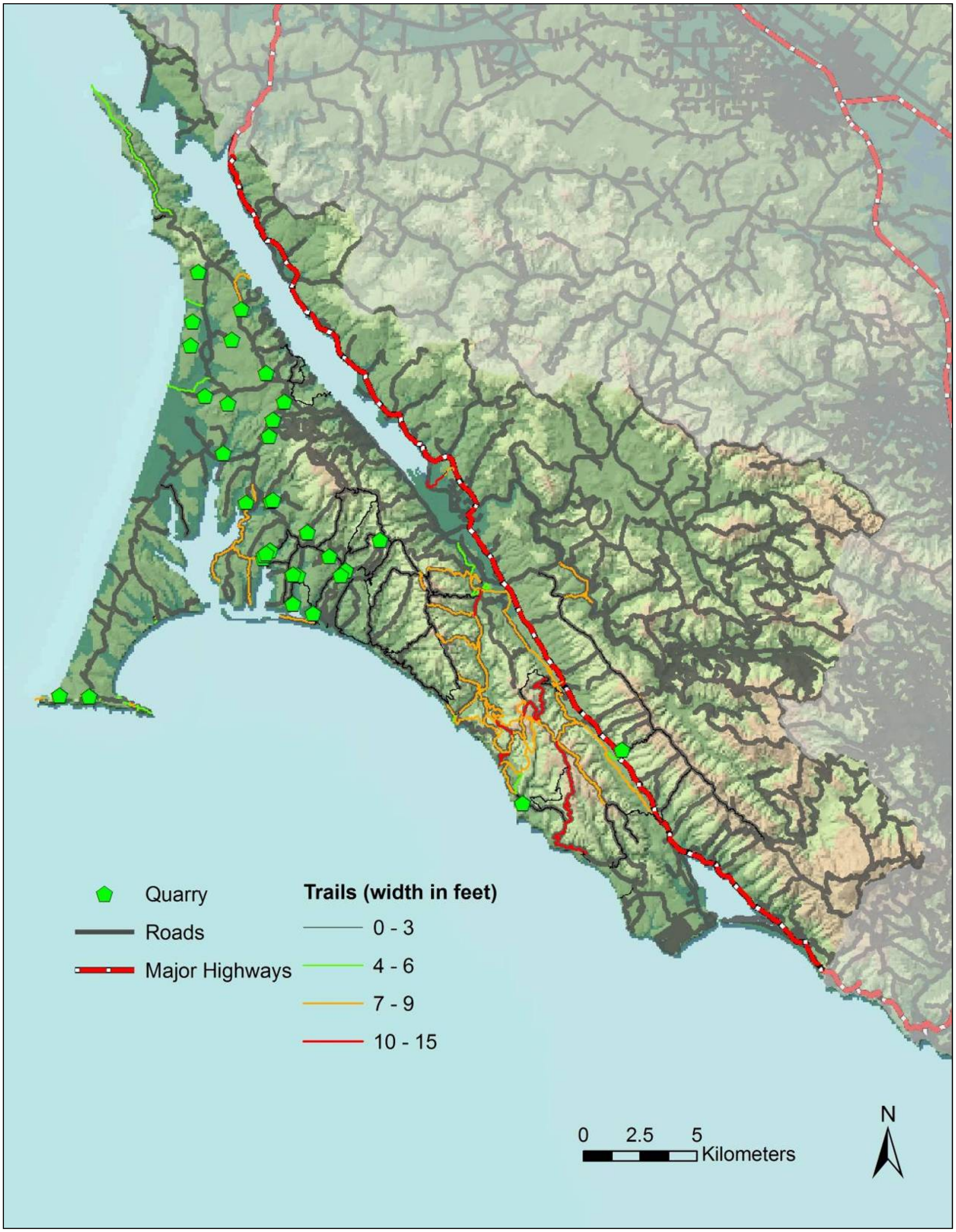


Figure 29. Quarries, roads, major highways and trails are shown for the Point Reyes National Seashore (Quarries and Trails from NPS PORE GIS Program; Roads and Major Highways from NOAA 2005).

topography and other natural features. Roads are typically built using inbound ditches and drainage structures such as culverts, water bars or dips (trails constructed by design are typically out-sloped allowing water to drain off as sheet flow). Trails which were originally designed as roads often have concentrated flow which is accelerated to the extent that it causes soil erosion. The ditches, culverts, water bars and dips require frequent maintenance and often fail.

There are a significant number of trails in both parks, especially in the more southerly coastal watersheds of PORE and most GOGA watersheds. PORE has 147 mi (237 km) of trails (Figure 29); GOGA has 125 mi (201 km) of trails and the Presidio has 15 mi (24 km) (Figure 30). Not all of these trails are problems; as the stressor rating tables indicate, trails are rated as a medium to high problem in nearly every watershed, especially in the highly developed/utilized GOGA watersheds: Presidio, Fort Funston and Mori Point. In 2003, PORE completed a Trail Inventory and Condition Assessment with Recommendations Report (NPS 2003). Of the 133 mi (214 km) of rated trails at PORE, the inventory found that nearly 70 mi (113 km) (52%) of the trails were in poor condition, 49 mi (79 km) (37%) were in fair condition and 15 mi (24 km) (11%) needed to be replaced.

Levees and Railroad
An extensive levee system was constructed along the eastern side of Tomales Bay as part of the Marin County railroad line construction (Livingston 1994). To convert salt marshes to pastures, levees were built at the southern end of Tomales Bay on the Giacomini property and on either side of Papermill Creek near Point Reyes Station (Evens 1993, Niemi and Hall 1996). The construction of levees for railroad or agricultural purposes increased sedimentation rates and resulted in a reduction of bay water volume and tidal exchange (NPS 2007). As areas were severed from their natural drainages, 550 acres of historic tidal marsh habitats were lost (NPS 2007).

Levees were also built to control movement of creeks (e.g., Home Ranch levee, Muddy Hollow levee) in the lower floodplain areas. However, consistent with PORE's policy of enabling natural function, the creeks have begun to reclaim historic channel paths. Creeks are reclaiming their former channels and floodplains, thereby providing important ecological habitat formerly lost from many areas.

Infrastructure
Park infrastructure contributes to stresses on natural systems and processes in the watersheds. Examples of infrastructure issues are particularly prevalent in GOGA which has inherited many military bases (i.e., Fort Baker, Fort Cronkhite and Presidio). PORE maintains infrastructure to support an annual visitation of 2.25 million people and provide offices, support structures and limited housing for the permanent and seasonal staff. PORE structures include:

- Over 100 public and administrative structures,
- 3 visitor centers,
- 2 environmental education centers,
- 30 restroom complexes,
- 4 backcountry campgrounds,

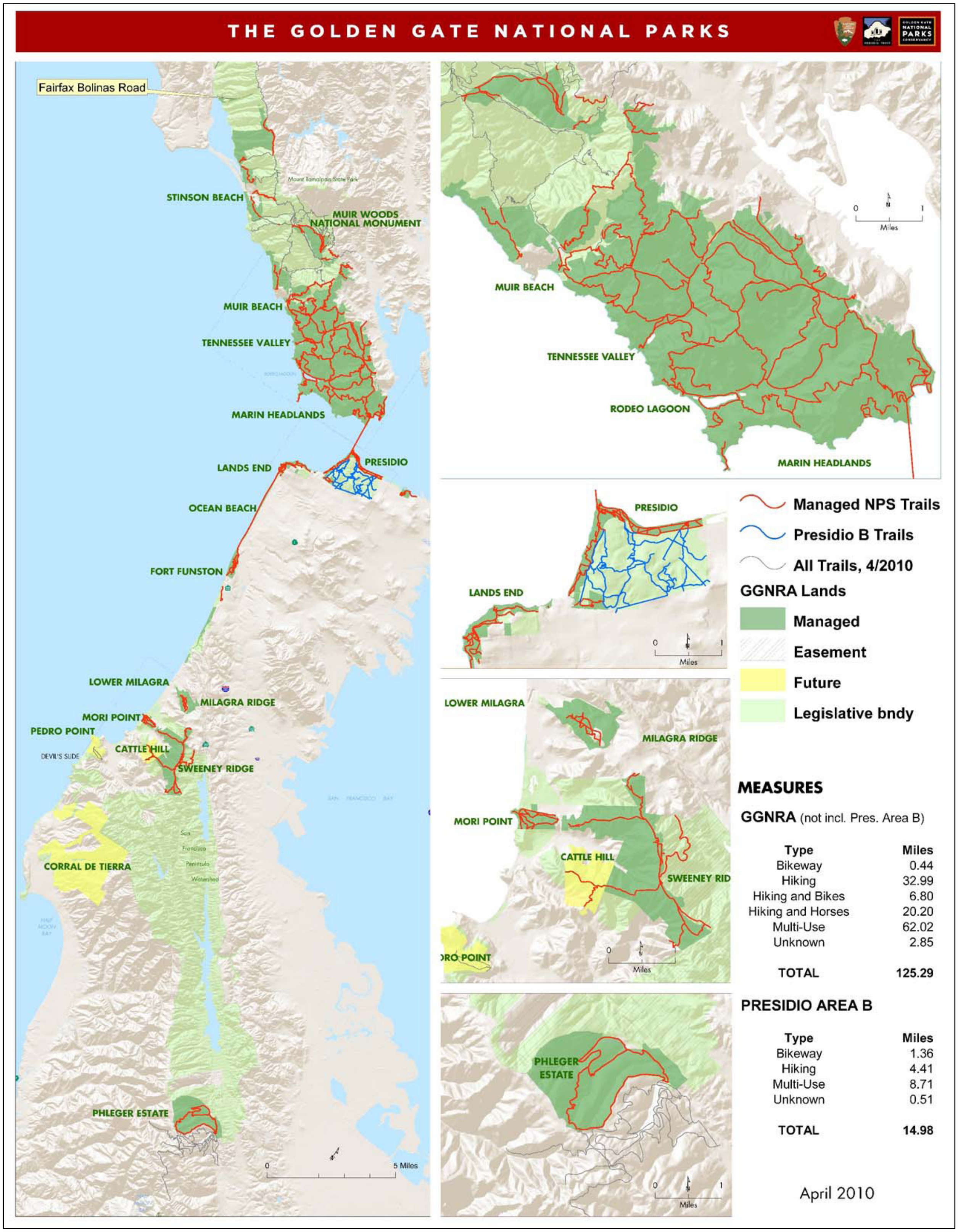


Figure 30. Trails in Golden Gate National Recreation Area (GGNRA) and The Presidio (Golden Gate National Recreation Area GIS Program 2010).

- 27 water systems and
- 55 sewage treatment facilities.

PORE also manages and protects cultural resources, including 374 historic structures. The structures range from simple timber-framed barns to the cast-iron Point Reyes Lighthouse to the concrete Mission Revival Marconi transmitting station. Historic structures are found throughout most of PORE (although there are none in the wilderness) and mark the built history of PORE. PORE has 124 recorded archaeological sites and 39 identified cultural landscapes which reflect the maritime, ranching, communications and military history of PORE. GOGA protects more than 1,250 historic structures, including numerous military facilities.

Quarries

No mining or gravel extraction on PORE or GOGA is permitted now; however, abandoned quarries exist throughout the parks. Historically gravel quarries (local borrow sites) were used regularly to maintain ranch roads. There are 35 quarry sites on PORE lands that range from 0.5–3 ac (0.20–1.21 ha) with an average less than 1 ac (0.40 ha) (Figure 29). There is an historic lime kiln site in Olema Valley and a copper mine on Copper Mine Gulch, a tributary to Pine Gulch Creek. PORE is in the process of inventorying its quarries. In GOGA, numerous quarries exist in Gerbode/Rodeo, Tennessee Valley, Milagra Sweeney and Mori Point watersheds; however, GIS point coverage for these entities is not yet available. A large portion of Mori Point was originally used as a quarry and the sand from the past dredging operation is still present.

Water Quality Pollution

Water quality stressors include point and non-point sources and those that originate within and outside of the park lands. External sources of pollution, such as atmospheric deposition (stream acidification) and upstream sources of industrial, urban and agricultural pollutants are particular threats to urban parks such as GOGA.

Internal sources of pollutants from recreational practices and land uses that were grandfathered in, with the creation of PORE and GOGA, continue to be problems. PORE and northern GOGA contain numerous ranches, dairies and pasture lands, which contribute to water quality degradation, due to excessive nutrient enrichment from feces and runoff. Horse stables are also the source of elevated nutrients and copper (Cooprider 2004). Septic leach fields have been identified as nutrient sources in some areas (i.e., Lagunitas Creek in PORE and Redwood Creek in GOGA). Research by Stanford University at Stinson Beach adjacent to GOGA found that nearshore waters had nutrient signals from adjacent community septic systems that led to increased primary productivity (de Sieyes et al. 2008). Elevated concentrations of nitrogen and phosphorus can cause dramatic shifts in vegetation and macroinvertebrate communities, paving the way for non-native species invasions and reduced biodiversity. Nitrogen-loading in shallow estuarine embayments can lead to shifts in the dominant primary producers (e.g., macroalgae may replace eelgrass), which can lead to declines in dissolved oxygen, altered benthic community structure, altered fish and decapods communities and higher trophic responses (Bricker et al. 1999).

Landfills and localized hazardous waste inherited by the parks are significant sources of pollutants in some areas, particularly in GOGA (Dames and Moore 1994, NPS 2008). The Presidio of San Francisco has undergone a thorough review of such areas in an attempt to mitigate them in the most effective and efficient manner. Radioactive and nonradioactive wastes dumped in the GFNMS are potential environmental hazards off the coast (Chan 1974). Between 1974 and 1970, at least 47,800 barrels of low-level radioactive waste was dumped in an area of the Gulf of the Farallones. In the 1990s, the USGS, GFNMS and U.S. Navy used side-scan sonar imagery to guide deep submersible vehicles (manned and unmanned) through a 9,688 ft^2 (900 m^2) area of the seafloor where barrels were known to be located (Karl 2001). Subsequent sediment analysis was done in 1998 in approximately 10% of the entire area covered by barrels. The results provided no evidence of significant regional-scale contamination due the barrels (Jones et al. 2001).

Most water quality sampling has focused on sites with known or suspected water quality impacts, including beaches (discussed more in the Water Quality chapter).

Invasive Species

The control of invasive species is one of the most significant land management issues facing national parks. Next to habitat destruction, non-native species are considered the most important threat to native populations in California (Leet et al. 2001) and are the most significant threat to biodiversity in the parks. Non-native invasive species can reduce or eliminate native populations of flora and fauna, alter natural disturbance regimes, and change ecosystem functions. The sustainability of threatened and endangered species and the loss of more common species are of special concern. Non-native invasive plants, animals and microorganisms also affect the structure and quality of habitat, alter species genetics and pollination dynamics, impact soil structure, biota and chemistry, and can significantly affect watershed hydrology including evapotranspiration rates, stream flow and erosion and sedimentation dynamics (Mack et al. 2000).

Freshwater Aquatic Invasive Species

Generally, more is known about terrestrial invasive species in the parks than aquatic species. Through scattered surveys, it appears that PORE has relatively few invasive fish species in its creeks; while lentic systems are more impacted due to a history of stocking ponds and reservoirs. The following are freshwater nonnative invasive species that have been recognized as a concern in local creeks primarily because they are predators on amphibians and native invertebrates: 1) mosquito fish (*Gambusia affiinis*); 2) signal crayfish (*Pacifastacus leniusculus*); 3) swamp crayfish (*Procambarus clarkii*); and 4) bullfrog (*Rana catesbeiana*; Fong 2000, NPS 2008). There are also native California fish that have been introduced to coastal streams and lakes outside of their native range. For example, Sacramento perch (*Archoplites interruptus*) tend to exist in the more freshwater portions of some lagoon systems (Saiki and Martin 2001).

Marine and Estuarine Invasive Species

Much of the existing information on estuarine invasive species comes from a review which identified over 234 non-indigenous plant and animal species in San Francisco Bay and ranked the Bay as one of the most invaded estuaries in the world (Cohen and Carlton 1995, 1998). Moreover, the rate at which aquatic invasive species are becoming established in San Francisco Bay has increased from an average of one every 55 weeks before 1960, to one every 14 weeks between 1961 and 1995 (Cohen and Carlton 1998).

In general, areas closest to San Francisco Bay are considered the most subject to invasions due to the movement of ships and the Bay itself as a source of invasives. The San Francisco Estuary Spartina Eradication Project has identified numerous impacts by invasive *Spartina* species to coastal estuarine ecosystems including impacts to endangered species, conversion of tidal mudflat to meadow, loss of shorebird foraging habitat, loss of critical channel habitat, and local extinction of native California cordgrass (San Francisco Estuary Spartina Eradication Project 2003). Seeds can travel long distances on the tides or with migrating birds and can be accidentally transported between estuaries on boats, boots, field equipment, or with aquaculture and restoration activities. Since 2001, San Francisco Estuary Spartina Eradication Project surveys have detected individual plants at Bolinas Lagoon, Tomales Bay and Drake's Estero (San Francisco Estuary Spartina Eradication Project 2008). In cooperation with parks, the project staff members have spearheaded efforts to remove and/or control *Spartina* infestations.

Invasive species, such as the European green crab, can decimate local populations of clams and other invertebrates and indirectly affect fish and shorebirds (Grosholz and Ruiz 1995).The European green crab was introduced to San Francisco Bay, California in 1989–1990. The invasive crab became abundant and spread throughout north, central and south San Francisco Bays and was subsequently found in Bolinas Lagoon, Drake's Estero and Tomales Bay (Cohen and Carlton 1995).

In Tomales Bay, a survey of 19 sites found that of 99 epifaunal taxa, 21 species (21%) were introduced and of 118 infaunal species, 9 species (8%) were introduced (Fairey et al. 2002). Introduced epifaunal species across the state ranged from a low of two species at Fort Bragg, to a high of 31 species from Port Hueneme, so the Tomales Bay samples fall in the middle range for the number of introduced epifaunal species. There was no discernable trend in the number of species introductions by latitude across the state; however, many "native" species exhibited significant range expansions within California, possibly as a result of recent intrastate vessel activity. A lower percentage of taxa were introduced in the infaunal samples when compared to the epifauna samples, indicating epifaunal communities may be more susceptible to introductions than infaunal communities (Fairey et al. 2002).

New coastal inventories and research studies are finding non-native species previously unknown to the coast (e.g., *Didemnum* sp., a colonial tunicate[8]) The Tomales Bay Biophysical Inventory (http://www.tomalesbaylife.org) is providing an important model for the inventory of marine invasive species. As of January 2006, six marine invasives were included in the inventory (Table 9). In Drake's Estero, marine invertebrate fouling communities of sessile organisms, particularly Didemnum sp., were present in oyster farming locations, but not in the non-oyster farming areas (Elliott-Fisk et al. 2005), and more recently was documented on eelgrass adjacent to oyster structures (Grosholz 2011).This suggests the importance of monitoring and regulating these operations for their potential as conduits for invasive species.

[8] B. Becker, National Park Service, Point Reyes National Seashore, CA, 2007.

Table 9. Invasive marine invertebrate and fish species identified in the Tomales Bay Biophysical Inventory (TBBI database query 2006).

Common Name	Latin Name
invasive colonial tunicate	*Didemnum* sp.
green crab	*Carcinus maenas*
leathery sea squirt	*Styela clava*
golden star tunicate	*Botryllus schlosseri*
sea grapes	*Molgula manhattensis*
yellowfin goby	*Acanthogobius flavimanus*

The discharge of ships' ballast waters from foreign ports is believed to be the single largest source of coastal, aquatic invasive species. A survey found that 53–88% of the aquatic invasive species introduced into San Francisco Bay in the 1990s originated in ballast water discharges, which prompted additional ballast water studies and new regulations to control ballast water sources (Cohen 2000). Recognizing the threat of new invasions and the absence of a mandatory national ballast water management program, the California State Legislature passed the "Ballast Water Management for Control of Nonindigenous Species Act" (California Assembly Bill 703) during the 1999 legislative session to regulate ballast water discharges.

Cohen and Carlton (1995) have identified other sources of marine invasive species that include transport in shipments of commercial fishing products via a packing algae, *Fucus* spp., used to pack live bait worms and live Atlantic lobsters; aquarium animals and biological supply houses; oyster farm transplants; and, spreading on the Pacific Coast of North America due to ocean currents.

Terrestrial Species Invasive Plants

Non-native, invasive plants thrive in PORE and GOGA, particularly in areas subject to intensive historic land use (grazing, military occupation) or adjacent to urbanized areas, which are a constant source of weed invasions. The spread of non-native plants is the most significant threat to the biodiversity of the parks (NPS 2002). Invasive Plant Species (terrestrial and aquatic) were rated as the second most important "vital sign" by the NPS SFAN in 2004 (Adams et al. 2006). Invasive plant species are an important issue, receiving significant attention and resource allocation. Of over 900 species of plants in PORE and GOGA, approximately one-third are non-native (Table 10). Of those, at least 60 are invasive enough to threaten the diversity of native plant communities in the parks.

Table 10. Summary of invasive plant species in Golden Gate National Recreation Area and Point Reyes National Seashore watersheds (Williams et al. 2009).

Park Name	Acres in Park	# of Natives	# of Exotics	# of Invasives	% Flora Exotic	% Flora Invasive
Northern GOGA	20,556	514	267	61	34.2%	10.6%
PORE	71,070	733	337	59	31.5%	7.4%
ALL GOGA	75,500	910	452	61	33.2%	6.3%

The spread of 28 of the most invasive, non-native species targeted for control in riparian areas (Table 11) has been curbed due to volunteer and staff removal efforts[9,10]. Research on some invasive plants within the parks has confirmed their ability to alter community composition and reduce the diversity of native plants (Alvarez and Cushman 1997), insects (Fisher et al. 1997) and small mammals[11]. Invasive, non-native species are also found within all nine Special Ecological Areas designated as the most biologically intact and diverse areas within GOGA. SFAN has developed a terrestrial invasive species protocol that is focused on early detection monitoring to locate new, isolated infestations before they become established in the parks (Williams et al. 2009).

Table 11. Invasive plant species known to affect riparian areas[11,12].

Common Name	Latin Name	Common Name	Latin Name
arundo	*Arundo donax*	helichrysum	*Helichrysum petiolare*
black acacia	*Acacia melanoxylon*	Himalayan blackberry	*Rubus armeniacus*
broad-leaved peppergrass	*Lepidium latifoluim*	Monterey cypress	*Cupressus macrocarp*
calla lilies	*Zantedeschia aethiopica*	Monterey pine	*Pinus radiata*
cape ivy	*Delairea odorata*	ox-eye daisy	*Leucanthemom vulgare*
capeweed	*Arctotheca calendula*	pampas grass	*Cortaderia jubata*
cordgrass	*Spartina alterniflora;* also *Spartina densiflora*	periwinkle	*Vinca major*
cottoneaster	*Cotoneaster* sp.	poison hemlock	*Conium maculatum*
English ivy	*Hedera helix*	Scotch broom	*Cytisus scoparius*
eucalyptus	*Eucalyptus globulus*	striated broom	*Cytisus striatus*
French broom	*Genista monspessulana*	tall fescue	*Festuca arundinacea*
giant rhubarb	*Gunnera manicata*	thoroughwort	*Ageratina adenophora*
gorse	*Ulex europaeus*	Veldt grass	*Ehrharta erecta*
Harding grass	*Phalaris aquatic,* also *Phalaris arundinacea*		

Disease

Disease is known to occur in all plant and wildlife populations and can significantly affect local demographics. The level of impact of diseases on PORE and GOGA aquatic species populations is largely unknown; however, certain disease agents have been identified. The Farallones Marine Sanctuary Association (FMSA) is studying the infection rate of spiny-headed worms (*Profilicollis* sp.), an acanthocephalan parasite that lives in crustaceans and insects as juveniles, and in the digestive tracts of vertebrates as adults (FMSA 2002). In 1995, the CDFG estimated that 1,000–4,000 surf scoters (*Melanitta perspicillata*) died due to an unusually high load of acanthocephalan parasites (FMSA 2002). Up to 94% of sea otter (*Enhydra lutris*) carcasses found around central California between 1997 and 2001 had parasites and the *Profilicollis* sp. parasite was a direct cause of death in 13–17% of the carcasses (Mayer et al. 2003).

Sudden Oak Death (SOD) syndrome is a major concern in coastal areas and could impact many oak woodland species and habitats (Rizzo and Garbelotto 2003). SOD has concentrated impacts on tanoak populations in the local area, and could impact natural stand density and diversity in

[9] K. Cooper, National Park Service, Point Reyes National Seashore, CA, pers. comm., 2006.
[10] R. Steers, National Park Service, SFAN I&M, Sausalito, CA, pers. comm., 2010.
[11] J. Howell, USGS, Golden Gate Field Station, Sausalito, pers. comm., 1997.

coastal Marin County. This syndrome is widespread in coastal California and is commonly found in tanoaks and in evergreen hardwood forests dominated by oaks, California bay (*Umbellularia californica*) and madrone (*Arbutus menziesii*). Currently, Marin County is heavily infested by SOD. A recent study of PORE vegetation by researchers from University of California at Berkeley (Moritz et al. 2008) sampled SOD at 48 locations within three major vegetation types and foliar samples were taken at 74 locations. Of these foliar sampling locations, 29 (39%) tested positive for the pathogen, *Phytophthora ramorum,* and the pathogen was found in all three major vegetation types sampled. From the proportions of the randomly located plots that tested positive for infection, the researchers inferred that as much as 63% of redwood-tanoak forests, 45% of California bay-coast live oak forests, and 24% of Douglas-fir forests at PORE may be infected with *P. ramorum*. In several plots, tanoak mortality was greater than 95% (Moritz et al. 2008).

Pine pitch canker has also been identified in bishop pine populations of PORE and in Monterey pines adjacent to Drake's Estero[12]. Pine pitch canker kills pine trees, adding to the fire fuel load in the parks, and increasing the potential for wildland fires (NPS 2004a).

Mosquito-borne Disease
Mosquitoes are vectors of many diseases, including the recent threat, West Nile and historically, malaria. An evaluation of mosquito populations of restored marshes and ongoing management is important for minimizing the levels of mosquito and other pest populations. Historic tidal marshes provide unsuitable mosquito breeding habitat, and wherever possible the Marin/Sonoma Mosquito & Vector Control District favors the return of reclaimed areas to a natural state. When diked areas without natural tidal regimes are flooded by heavy rains or levee breaks, mosquito populations flourish. *Anopheles freeborni* was the most important malaria vector in California while the disease was endemic. *Culex pipiens* (the "house mosquito") is the species most likely to transmit West Nile virus to humans in San Francisco and Marin counties, but at least 43 other mosquito species are known to carry the virus. *Culex tarsalis* (the "encephalitis mosquito") is likely to be another important local vector. In 2009, there were no cases of West Nile virus in humans reported in San Francisco, Marin or San Mateo counties. The Marin/Sonoma District maintains a database of every known breeding source for pest and vector mosquitoes. Their efforts focus on keeping the density of adult mosquitoes capable of transmitting the virus in populated areas below levels that could support an epidemic.

Harmful Algal Blooms
Under certain conditions, harmful algal blooms (HAB) occur when an oversupply of nutrients allow a large increase in phytoplankton. Some blooms produce poisoning syndromes in. Humans and other animals are exposed to HAB toxins from eating contaminated fish or shellfish, drinking contaminated water, or by contacting contaminated water.

Paralytic shellfish poisoning (PSP) is an acute, sometimes fatal form of food poisoning that is associated with the consumption of bivalve mollusks that have fed on the toxin-producing dinoflagellate, *Alexandrium catenella* (Langlois 2008). Eating shellfish that contain PSP toxins leads to an acute disturbance of the nervous system within a few minutes to a few hours. The CDPH Marine Biotoxin Monitoring Program conducts a year-round program to monitor coastal

[12] A. Forestel, National Park Service, Fire Ecologist, pers. comm., 2010

shellfish, issue annual statewide quarantines on sport-harvested mussels, and conduct public education activities to protect the public from marine biotoxins.

The source of the dinoflagellates that cause PSP is unknown, but regardless of the origins of the toxin-producing dinoflagellates, the general pattern is for HAB to be detected first along the open coast, occasionally followed by transport into bays and estuaries (Langlois 2008). The degree to which coastal phytoplankton blooms intrude into bays and estuaries is likely influenced in part by the orientation of the bay relative to coastal currents and by the extent of tidal mixing and transport that occurs inside the bay (Langlois 2008).

In the fall of 1991, domoic acid was identified along the California coast. Domoic acid is a neurotoxin of lower potency than the PSP toxins, but it can result in the condition called amnesic shellfish poisoning. Blooms of diatoms that produce Domoic acid occur at greater frequency and longer duration than most PSP events (Langlois 2008). Domoic acid has had dramatic impacts on marine mammal and seabird populations along the coast, raising the public's awareness of marine biotoxins. The CDPH coordinates a volunteer-based phytoplankton monitoring program for the early detection of toxigenic blooms. See CDPH Marine Biotoxin Monitoring Program website (http://www.cdph.ca.gov/healthinfo/environhealth/water/Pages/Shellfish.aspx, accessed 29 March 2012) and Water Quality chapter for more details.

Natural Disturbance

Earthquakes

Due to their location along the San Andreas Fault, the parks experience fairly frequent earthquakes. The probability of a major earthquake in the San Francisco Bay Area before 2036 is 63% (Figure 31) and for PORE and Northern GOGA that lie along the San Andreas Fault it is 21% prior to 2036 (Field et al. 2008). Earthquakes can accelerate soil erosion, cause massive slumping and landslides, and alter nearshore bathymetry. For example, as a result of the Loma Prieta earthquake in October 1989, the Lone Tree Slide closed Highway One between Muir Beach and Stinson Beach along the northern California coast. The road was reopened in June 1991, after over three quarters of a million cubic meters of soil and rock were removed from the slide face. The slide material was disposed into a large fill on the west side of Highway One. The seaward edge of the fill extended over 60 m (197 ft) into the ocean, burying intertidal communities (MLML 1995).

Fire

Fire changes vegetation, forest floor cover (e.g., ground vegetation, litter or duff) and structure, and soil properties, all of which can alter the movement of water over, or into, the soil. In the first years following a large fire, watershed storage capacity is reduced and net surface runoff is increased as a result of reduced soil cover, lack of soil cover and/or increased soil hydrophobicity (water repellency). These changes can result in channel extension, upland erosion and stream channel incision. Changes in hillslope processes result in increased discharges, soil erosion and higher sediment yield, affecting aquatic habitat conditions within the watershed. At PORE, a two-year, post-fire geomorphology study of the Muddy Hollow watershed found that fire effects (e.g., increased woody debris in steams, broader alluvial fan) and watershed response varies spatially along the stream and elevation gradient (Collins and Ketcham 2005).

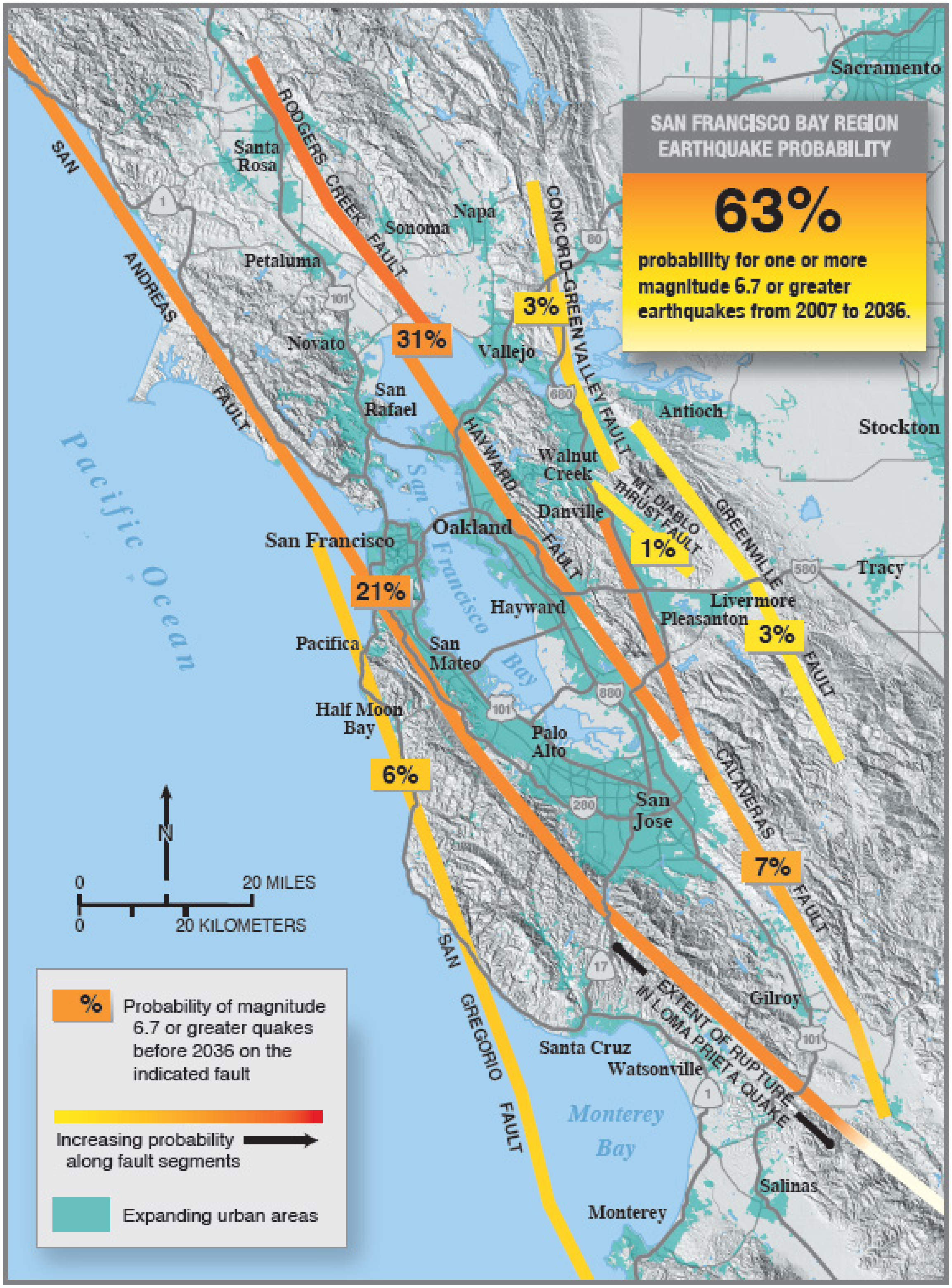


Figure 31. Probabilities (in boxes) of one or more major (magnitude ≥6.7) earthquakes on faults in the San Francisco Bay region from 2008 to 2036 (Field et al. 2008).

Total Suspended Solids (TSS) and nitrogen in park water resources could be exacerbated by fire management activities. The ash generated by fires is rich in nitrogen, a nutrient essential to biotic reproduction. Excess nitrogen in a water body can increase production of algae and aquatic plants. When this excessive biomass decays, it can deplete a water body of oxygen and lead to fish kills.

PORE and GOGA operate under Fire Management Plans (NPS 2004a, 2005) which include efforts within the parks and at the wildland urban interface to manage fuels mechanically and with controlled burns.

Habitats

Introduction

PORE and GOGA are 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). From the tip of Tomales Point to the southernmost areas of Sweeny Ridge and Phleger Estate, the parks support a diversity of habitats extending from the Pacific Ocean to the coastline, sea cliffs to sand dunes, mud flats to salt marshes, chaparral and coastal scrub to grasslands, redwood forests and oak woodlands (Figures 10, 11 and 32). The park lands span two of the largest estuaries on the West Coast, Tomales and San Francisco Bays, drowned river valleys from the Pleistocene. 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 use multiple habitats. Habitats and associated biota are described to explain the qualities that make each of these systems unique and worthy of protection and/or restoration. Specific watershed areas and issues are described in more detail in the Water Quality chapter. Because of the coastal resource focus of this report, the coastal aquatic and transitional habitats are discussed in more detail than upland terrestrial habitats. Numerous vertebrates, especially birds and mammals, occur throughout the parks in multiple habitats. The following habitat descriptions contain a summary of significant species that are associated with the habitat.

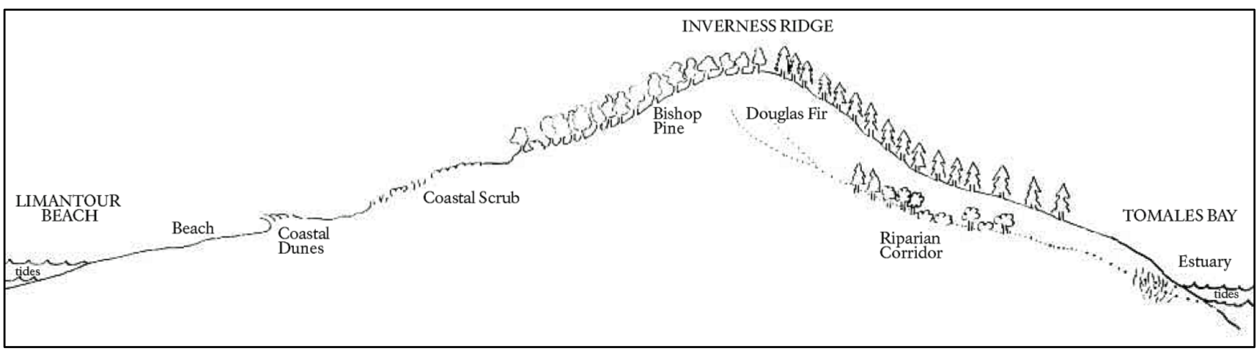


Figure 32. Point Reyes National Seashore habitats from estuaries and beaches to the ridge tops.

Nearshore Marine Habitats

The nearshore marine environment of PORE and GOGA extends from Tomales Bay in the north to Half Moon Bay in the south. The PORE shoreline includes 100 mi (161 km) of shoreline (including islands), including much of Tomales Bay and all of Drake's Estero and Abbott's Lagoon (Curdts 2011). The GOGA shoreline includes 91 mi (146 km) of shoreline (including islands), extending from Bolinas Lagoon in the north, into San Francisco Bay, and to a patchwork of lands near the coastline in the south near Pacifica (Curdts 2011). North of the Golden Gate, much of the coastline is mostly undeveloped coastline, but south of the Golden Gate, the shoreline is impacted by urban development with park managed areas forming narrow strips of protected land along the coastline.

Much of the coastline is protected by NPS and the national marine sanctuaries, as it abuts the federally protected, Gulf of the Farallones National Marine Sanctuary in the north (0.25 mi [0.40

km] offshore) and the Monterey Bay National Marine Sanctuary to the south (Figure 33). The Cordell Bank National Marine Sanctuary lies to the northwest of PORE. Point Reyes also has four California State Areas of Special Biological Significance (ASBS; CEPA 2009). ASBS is a state designation based on the presence of certain species or biological communities that because of their value or fragility deserve special protection consisting of preservation and maintenance of natural water quality conditions to the extent practicable (Water Resources Control Board and California Regional Water Quality Control Board Administrative Procedures, September 24, 1970, Section XI and Miscellaneous Rev. 7-9/1/72). The ASBS within or adjacent to NPS lands are: Bird Rock (at Tomales Point), Point Reyes Headlands, Double Point and Duxbury Reef. The Estero de Limantour is a State Estuarine Reserve. 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. In 2009, five marine protected areas were designated off the coast of PORE in the north central coast region, which increases the protection of near shore marine resources (see Stressors chapter).

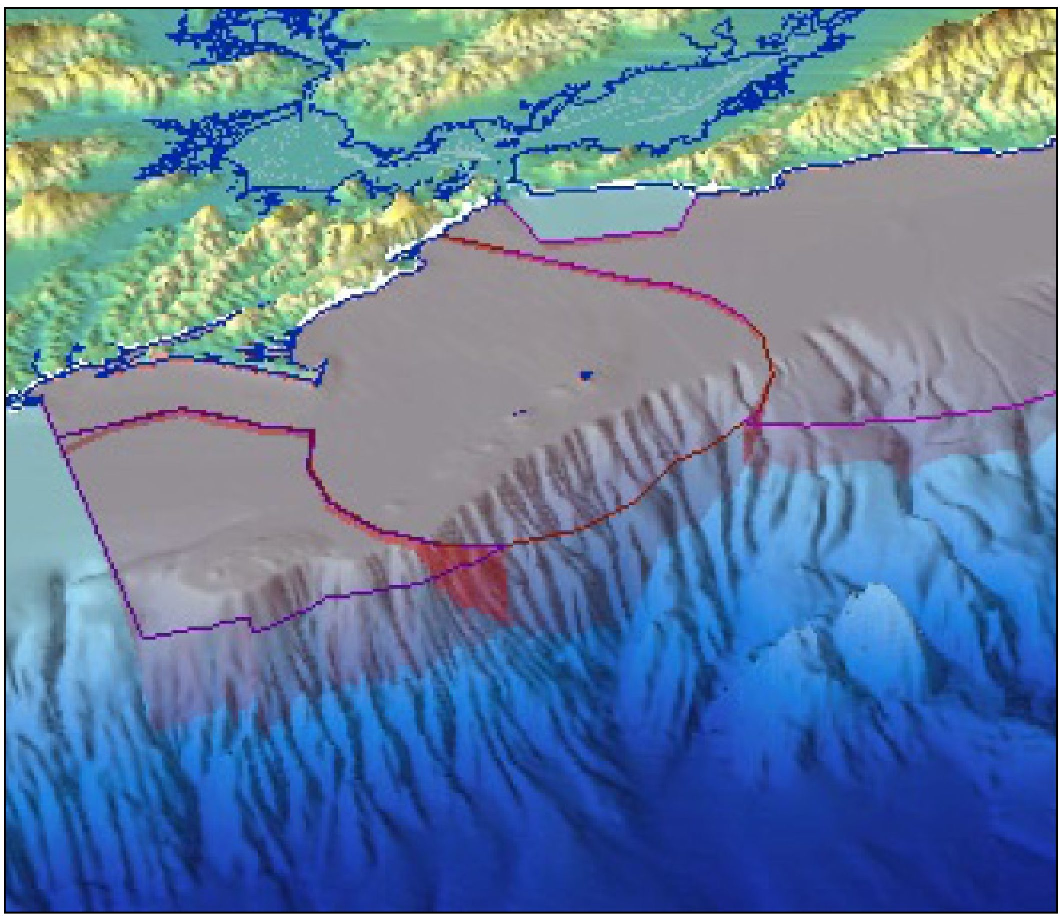


Figure 33. Three-dimensional image of bathymetric relief within and adjacent to the Point Reyes National Seashore and Golden Gate National Seashore. The sanctuaries adjacent to the park systems are outlined in red (adapted from NCCOS 2003).

The coastal ASBS and other affected areas are also termed Critical Coastal Areas (CCA) and receive “protection” under the state’s Non-Point Source Program. The CCA Program’s goal is to ensure that effective non-point source pollution management measures are implemented to protect or restore coastal water quality in CCAs. CCA identification supports the acquisition of grant funding by prioritizing protection efforts. Additional areas included as CCAs and bordering park areas include Tomales Bay, Lagunitas and Walker Creeks (California Coastal Commission 2009).

Nearshore marine habitats can be distinguished by their position relative to the shore, their physical exposure to waves along the shore, the substrate type and tidal exposure (Ricketts and Calvin 1968). Physical structure determines whether the area is considered open coast, protected outer coast and bay, or estuary. Each of these areas can be further divided by the substrate type and degree of tidal exposure. The open and protected outer coast, generally exhibits rocky or sandy substrates; whereas protected areas are usually soft bottomed, grading from subtidal to mudflats and tidal marshes (Figures 34 and 35). Notice the predominance of sandy habitats in some areas, mixed sand and gravel with wave cut rocky platforms in others and exposed rocky cliffs at promontories along PORE coastline (Figure 34). Salt marshes and tidal flats exist in the area's estuaries: Tomales Bay and Drake's Estero in Figure 34 and Bolinas and Rodeo-Gerbode watersheds in Figure 35. Notice the variability in natural habitat types north of the Golden Gate (including the Marin Headlands) and the predominance of sandy habitats on the west coast and manmade structures on the southern San Francisco peninsula.

The nearshore coastal environment is highly variable with a complex spatial distribution of marine resources due to diverse lithologies, active tectonic and geomorphic processes, topographic relief and dynamic nearshore currents. This physical diversity coupled with high productivity results in an equally diverse distribution of organisms. Bay/estuarine invertebrates and fish are described in Appendices 1 and 2. Nearshore marine invertebrates and fish are described in Appendices 3 and 4. In addition to a broad array of invertebrates and fish, these areas support diverse populations of seabird and shorebird species including the common murre (*Uria aalge)*, Brandt's cormorant *(Phalacrocorax penicillatus)* and rare species such as the ashy storm-petrel (*Oceanodroma homochroa)* and western snowy plover (*Charadrius alexandrinus nivosus*). A large number of whales, seals and other marine creatures also pass near the park's coastline; however, populations today are much smaller than they once were (Leet et al. 2001). Many mammal populations are rebounding from large scale historic declines. The influx of Russian sealers in the late 18th century and first half of the 19th century and Boston whalers in the latter 19th century decimated sea otter, fur seal, elephant seal and whale populations.

Conceptual Model

The simplified conceptual model (Figure 36) supports the discussion that follows. It depicts the natural drivers and anthropogenic stressors that influence habitat extent and quality and key species for the nearshore and bay/estuary habitats. Oceanic variation caused by changes in weather patterns and major currents provides the backdrop for nearshore physical and biological processes (see Park Description chapter). The Stressors chapter discusses the principle stressors affecting nearshore areas including oil spills, harvesting, aquaculture, water quality degradation (nutrients, storm water runoff, ocean disposal), sediments due to road slides and other forms of coastal erosion, dredging and structural features such as seawalls, jetties, harbors and seafloor cables (SIMON 2000).

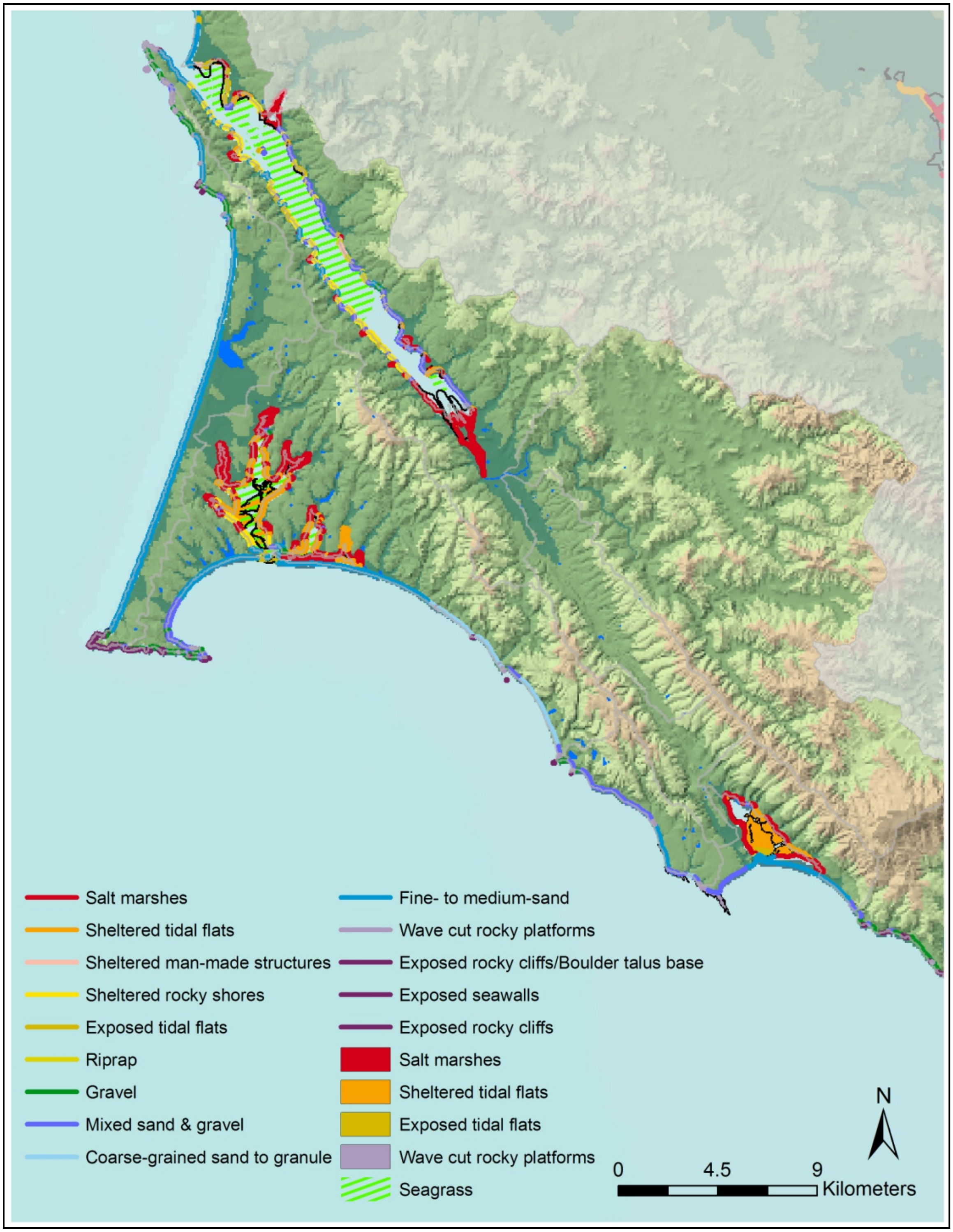


Figure 34. Coastal shoreline substrate and habitats along the Point Reyes National Seashore coast (Research Planning, Inc. 1993).

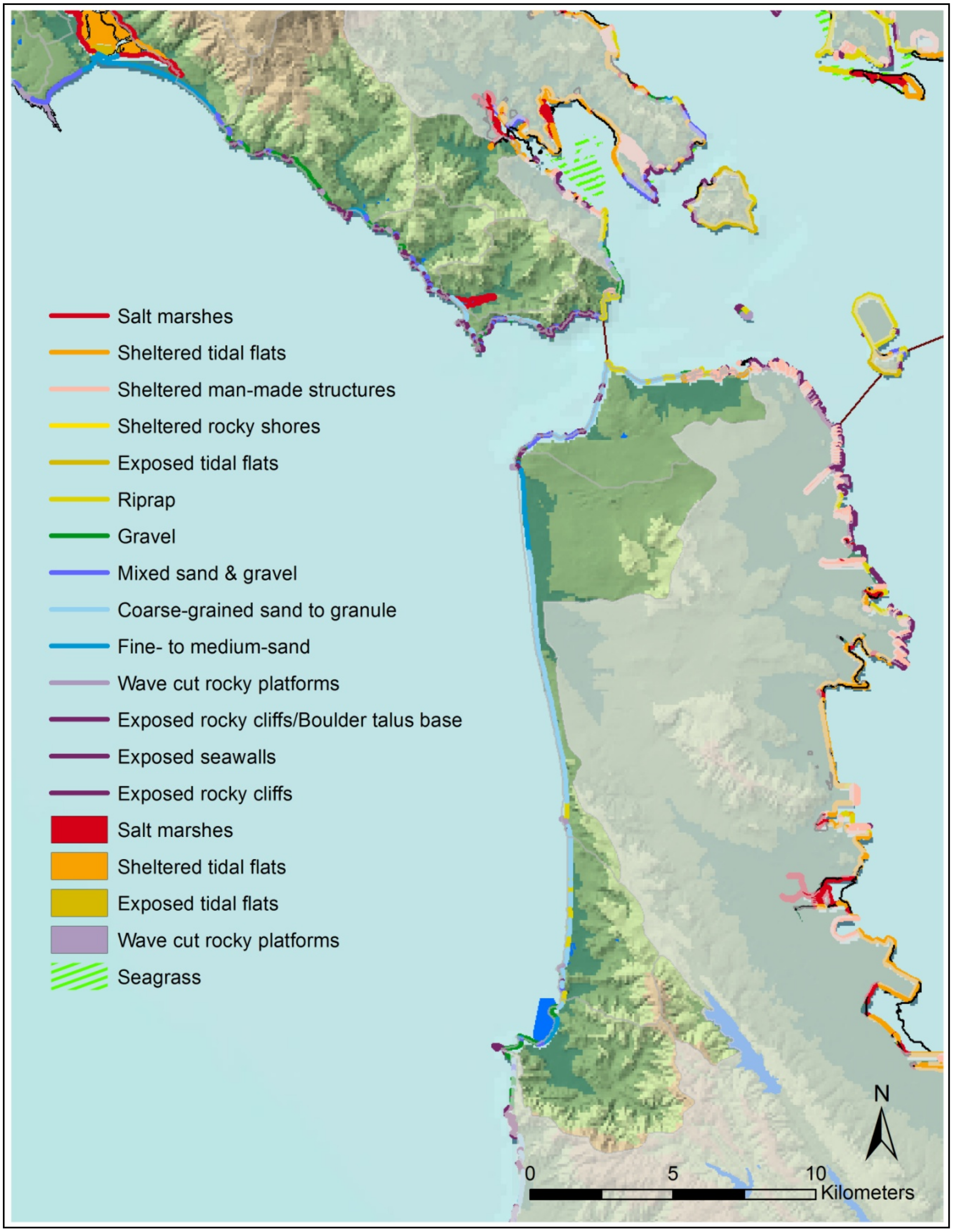


Figure 35. Coastal shoreline substrate and habitats for the Golden Gate National Seashore (Research Planning Inc. 1993).

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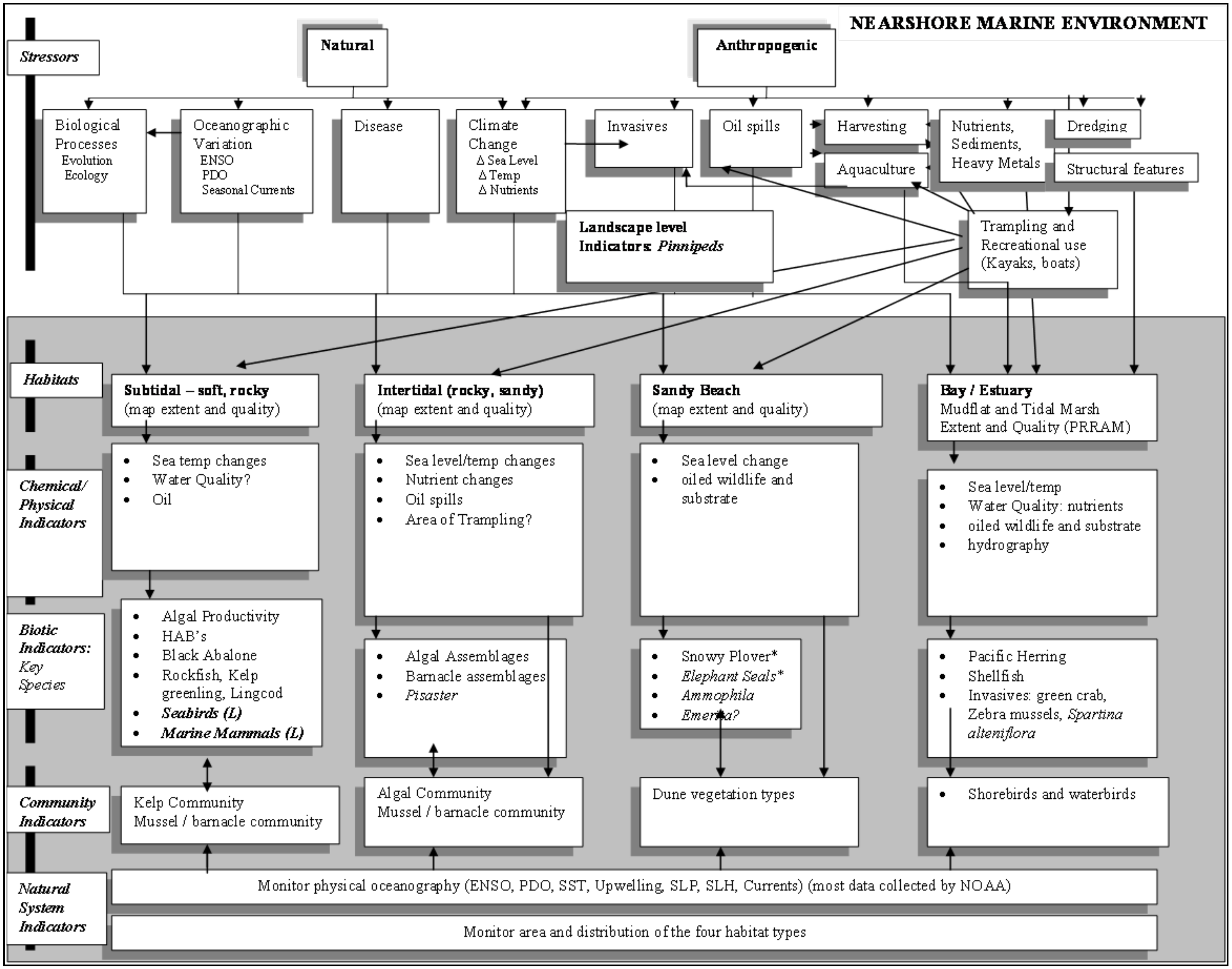

Figure 36. Nearshore environment ecosystem conceptual model.

A key question for park managers is how much local impacts affect nearshore biological communities compared to large scale natural processes. Developing indicators of anthropogenic stress for nearshore marine systems is difficult because separating the effects of variation due to large scale oceanographic processes compared to locally derived impacts, is extremely challenging. Though research and monitoring of nearshore aquatic systems is evolving, most programs focus on landscape level scales broader than park jurisdictions, offering only a glimpse of processes and species responses at local park levels. Furthermore, limited resources requires that park researchers must make hard choices about how much landscape-scale research to engage in as they strive to understand local nearshore park resources and issues.

In the SFAN Inventory and Monitoring program planning process, the western snowy plover (*Charadrius alexandrinus nivosus*) and pinnipeds ranked high as vital sign indicators (Table 12). The life history strategies and population levels of these species reflect both landscape level and local processes. They also were chosen because both GOGA and PORE have existing monitoring programs for plovers and pinnipeds. SFAN also identified other marine/estuarine indicators; however, they received a lower ranking (Table 13). The marine-related indicators in Table 13 may have been ranked lower by ranking process participants because they were monitored within the parks by other organizations as part of regionally-based programs. For example, USFWS conducts aerial surveys annually during the seabird nesting season to monitor colonial nesting birds all along the central California coast. Oil spill restoration funds have been used to monitor recovery of seabird populations at the two parks for example; under the Apex Houston Restoration Plan (McChesney et al. 2006). NOAA conducts aerial surveys of cetaceans and sea turtles along the central California coast.

Table 12. Vital signs ranking for long-term monitoring protocol development (Adams et al. 2006).

SFAN Vital Signs	Rank	SFAN Vital Signs	Rank
Weather and Climate[1,2]	1	Pinnipeds[1,2]	10
Invasive Plant Species (early detection)[2]	2	Plant Community Change	11
Freshwater Quality [1,2]	3	Landscape Dynamics	12
Air Quality[1]	4	Threatened and Endangered (T&E) Butterflies[1]	13
Stream Fish Assemblages[1,2]	5	Freshwater Dynamics[1,2]	14
Rare Plant Species[1,2]	6	Wetlands	15
Northern Spotted Owl [1,2]	7	Riparian Habitat	16
Amphibians and Reptiles	8	Landbird Population Dynamics[1,2]	17
Western Snowy Plover[1,2]	9	Raptors and Condors[1,2]	18

[1] Previous monitoring data exist

[2] Adopted as a long-term vital sign to receive monitoring funding

Of the list of lower-ranked vital signs, PORE and GOGA have been monitoring rocky intertidal habitats and targeting sea stars, barnacles and algae at fixed stations since 1996 and 1989, respectively. Both parks are transitioning towards a regional intertidal monitoring program established by the Multi-Agency Rocky Intertidal Network (MARINe) program that will allow for the analysis of data on a regional scale.

Table 13. Lower ranked SFAN marine/estuarine vital signs for long-term monitoring (Adams et al. 2006).

SFAN Vital Signs	Rank
Coastal Dynamics	19
Marine Oceanography	21
Shorebirds	24
Seabirds	25
Marine and Estuarine Fish	28
Rocky Intertidal Community	32
Marine Water Quality	33
Subtidal Monitoring	44
Pelagic Wildlife	50
Sandy Intertidal Community	59
Cetaceans	60

To assist in the continuing process of choosing and developing indicators, we have developed a list of coastal protection, research and monitoring programs (Appendix 5). Throughout this assessment report, we suggest linkages of these programs to park research and ideas for furthering collaborative efforts. Research/assessment questions (Table 14) were also adapted from various sources, in particular the NOAA Sanctuary Integrated Monitoring Network (SIMON) program (SIMON 2000), to guide the investigation of PORE/GOGA nearshore condition. Nearshore habitats and associated indicators (usually key species) illustrated in the conceptual framework are presented in the report in an effort to address these questions; though many of these research questions remain unanswered. Additional research is needed to verify the efficacy of these indicators as useful measures of "health" and communication tools for NPS. The habitats grade from one to another, as do species distributions, so developing tight relationships between habitat types and species distributions is frequently difficult. To augment discussion of coastal species, Appendices 1–4 summarize many of the fish and invertebrates that inhabit these areas and what is known about commercial fishery and population status/trends. The summaries were developed using the 2001 document, California's Living Marine Resources: A Status Report (Leet et al. 2001) as a primary resource.

Subtidal Zone

Because the continental shelf extends far from the coast (Figure 33) and upwelling occurs nearshore, the coastal portion of the parks, which extends into marine waters 0.25 mi (0.40 km) offshore, offers a shallow, highly productive habitat for seabirds, fish and marine mammals. Currents, bathymetry (depth), biogenic habitat (kelp forests) and substrate determine the distribution of marine communities in the subtidal zone. These factors in turn affect more inland habitats such as the intertidal zone and bays and estuaries to varying degrees. Though much of this discussion focuses on coastal subtidal areas, it should be noted that estuarine areas also include subtidal areas. Subtidal habitats are particularly threatened in San Francisco Bay and the surrounding coastline due to intense coastal development and expansion of marine transportation systems. Dredging, sand mining and alteration of rocky reef habitats near navigation channels can severely impact subtidal habitats. A NOAA document summarizes these resource values, threats and goals within the San Francisco Bay, including GOGA waters (Schaeffer et al. 2007).

Table 14. Research and assessment questions for nearshore marine habitats.

Basic Ecology
Where are species located geographically within habitats?
What coastal habitats are found in the parks and how have they been impacted?
What are the temporal, spatial and geographic patterns of target taxa in rocky subtidal and intertidal habitats?
What are the impacts of changes in activity, abundance and distribution of apex predators (e.g., sea otters and harbor seals)?
What are the effects of long-term primary productivity changes on near-bottom and benthic communities?
What are the patterns of extreme storm cycles, waves, currents, runoff and sediment transport?
What is the impact of long-term fluctuations on ecological systems?
What are the spatial and temporal changes in temperature, storm activity, nutrients, upwelling, light transmission, current patterns, sea levels, river input and cloud cover / fog?
What is the paleo-oceanographic context of present day variability?
What are the sources and sinks of carbon and other material in nearshore habitats?
Effects of Stressors
What are the impacts of direct exploitation (e.g., fishing)?
What is the frequency and distribution of trawling activity?
What are the impacts of trawling in deep water habitats (>1000m)? Do they trawl in shallow habitats?
What are the impacts of non-consumptive disturbances (e.g., trampling) on intertidal and subtidal habitats?
What is the pathogen, pollutant and parasite (ppp) load in sea mammals (live and dead), shellfish and birds?
What are the effects of recreational and commercial shellfishing on the coastal environment?
What are the possible effects of sea level change on the coastal environment?
What are the sedimentary, biological, chemical inputs to the nearshore system from individual watersheds?
What are the ecological effects of sedimentary, biological, chemical inputs to the nearshore system from individual watersheds?
What are the impacts of chemical pollutants / contaminants on benthic habitats and communities?
What are the impacts of acoustic monitoring on the health of the system being studied?
What are the major influences of fisheries and other stressors on distribution and abundance patterns of pelagic megafauna?
What is the abundance and distribution of invasive species and what are the pathways of entry?
What is the abundance and distributions of sensitive species?
What are the rates and causes of dune and bluff erosion over time? (Coastal Dunes)
How has the distribution and structure of buff and dune systems change on long-term time scales? (Coastal Dunes)
What are the impacts of habitat modification on coastal dune/bays and estuarine processes? (Beaches, Coastal Dunes, Mudflats, Tidal Marshes)
What are the effects of climate change (including shoreline change, sea surface temperature, or increased ENSO events) on species distribution, abundance and interactions with other species?
Do ENSO events alter shoreline configuration and substrate?
Effects of Park Resource Management:
How do spatial and temporal patterns of subtidal and intertidal taxa differ within and outside of park areas?
How do management practices on park lands affect coastal resources?

Surface Waves, Tides and Coastal Currents

Coastal water movement can have complex flow patterns. These patterns are a function of temperature, salinity and wind patterns on local and regional scales which change with location, time of day, season, year and climate (Largier et al. 2010). Surface waves, the highest frequency water movement, are ubiquitous and typically from 3–18 second periods. Waves break on and erode coastal bluffs. Large waves scour the sea floor, stirring and re-suspending bottom sediment out to water depths of 330 ft (100 m). Waves also redistribute sands, accreting on beaches during the summer months. Tides cause beaches to be covered and exposed twice a day, moving nutrients and other suspended materials vertically and back and forth, but generally not large distances. Along the Point Reyes to San Francisco Bay coastal shoreline, tides typically range from 5–7 ft (2-3 m) in amplitude and depict a mixed, semi-diurnal cycle. Tides result in strong tidal circulation patterns ("currents"), in bays, estuaries (i.e., Tomales and San Francisco Bay) and harbors where water movement is restricted; however, tides diminish offshore as water depth increases and ocean current effects strengthen (Noble 2001). As described in Park Description, the cold water California Current and comparatively warm water Davidson Current influence productivity in coastal ecosystems through coastal upwelling processes.

Until recently, not much was known about how strong the currents are, in what direction they flow, or how rapidly flow patterns change with time or location. Even less was known about how current patterns affect organisms that live in the coastal ocean, how currents modify the natural sediment on the sea floor, or about the eventual fate of natural sediment or materials deposited on the seafloor. During the 1990s, several research programs were started by the USGS and other organizations to gather information about how currents, nutrients and suspended material move through GFNMS, an area along the parks' borders (Figure 37). The area studied by the USGS in the 1990s covered about 1,000 nautical mi^2 (3,430 km^2) of the sanctuary and ranged in water depth from 660–10,500 ft (200–3,200 m). These studies showed that the general features of the current patterns in the area are similar to those observed elsewhere along the central and northern California continental margin (Noble 2001). Currents over the continental shelf tend to flow southeastward and slightly offshore in summer, causing upwelling of nutrient-rich cool waters on the shelf (Figure 38). Shelf currents flow mostly northwestward in winter. The strong waves that occur during winter storms commonly cause sediment on the sea floor to be resuspended and carried both along and off the shelf (Noble 2001).

Many of the current patterns in the region are altered by the area's unique sea-floor topography; therefore, the local characteristics of flow, such as the amplitude of currents, their detailed response to winds, and the strength of the summer upwelling, are specific to an area. In summer, the promontory of Point Reyes causes shelf currents to turn offshore and flow over the slope. The abrupt steepening of the slope in the northern part of the area studied also causes northwestward-flowing slope currents to turn toward the deep ocean. Both of these features enhance the exchange of water, nutrients and other suspended materials among the shelf, slope and deep ocean relative to what happens along the simple, straight shelf more common north of the gulf (Noble 2001).

These patterns are being further elucidated by real-time current monitoring from adjoining nearshore areas of PORE and GOGA and inside the Golden Gate using Coastal Radar and Acoustic Doppler data established by the Bodega Marine Lab at the Point Reyes Headland in 1999 and more recently from Point Reyes south to and including parts of San Mateo County

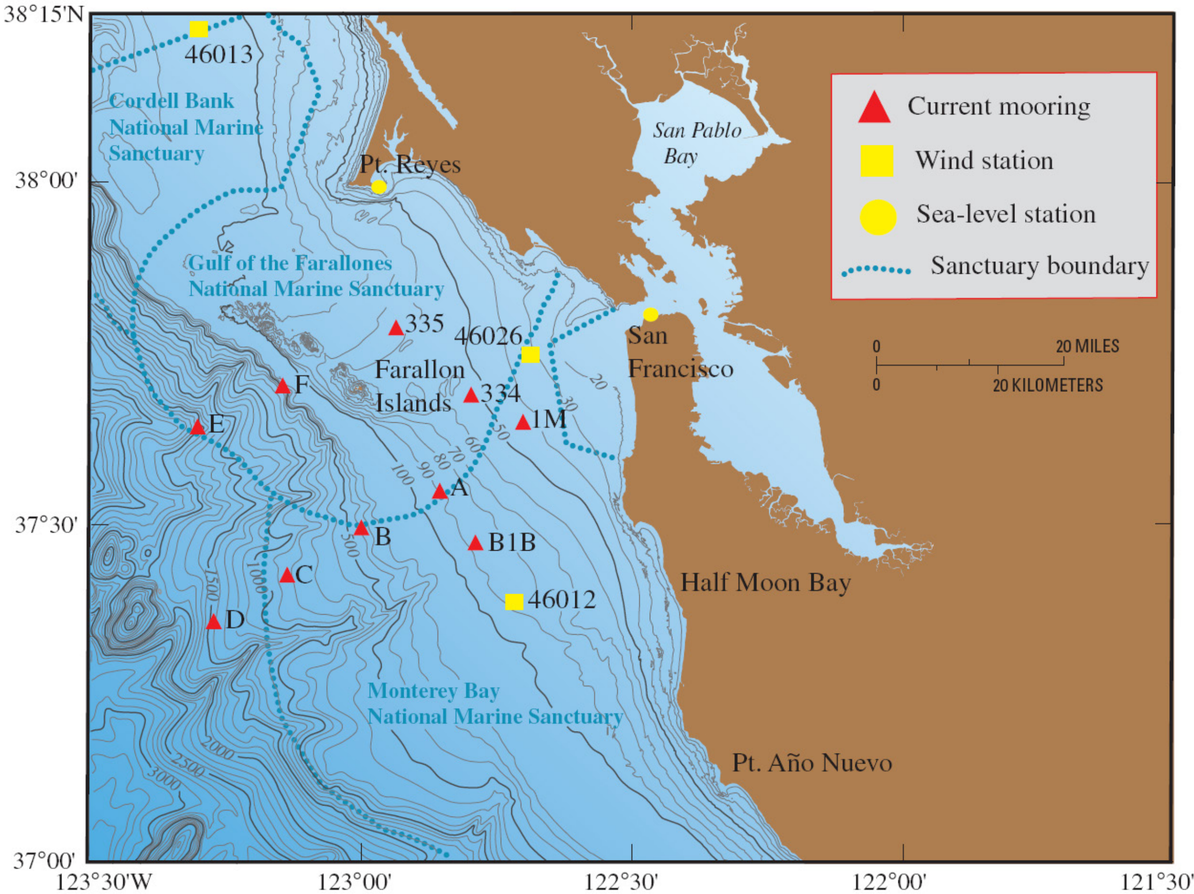

Figure 37. Offshore study area showing locations of various ocean measurement stations. 10-m (33 ft) contour intervals for water depths down to 100 m (330 ft) (Noble 2001).

through a regional organization that is a consortium of groups and agencies supporting coastal monitoring (http://www.cencoos.org/). The purpose of the Coastal Ocean Currents Monitoring Program in Northern California (COCMP-NC; http://norcalcurrents.org/COCMP) is to develop and deploy systems and infrastructure necessary for real-time monitoring of surface currents in California coastal waters. COCMP-NC is making the data available to the public to enrich existing oceanographic monitoring programs.

Open water oceanic habitats are semi-permanent and are formed by the dynamic movement of waters driven by wind, currents, temperature, salinity and upwelling. Oceanographic features can form fronts and eddies where fish, birds and mammals concentrate to feed. Point Reyes Headland is located at the heart of an eastern boundary coastal upwelling system, and consequently, there is high biological diversity of vertebrates and invertebrates. Concentrations of krill are the foundation of the food web and attract large concentrations of feeding fish, seabirds and marine mammals. Examples of large schooling fish that occur in the nearshore waters of the parks include anchovy and sardine. When fish are abundant, more than 20 species of marine birds and mammals will come to gorge, including several federally or state listed species such as rhinoceros auklet (*Cerorhinca monocerata*), common murre, brown pelican,

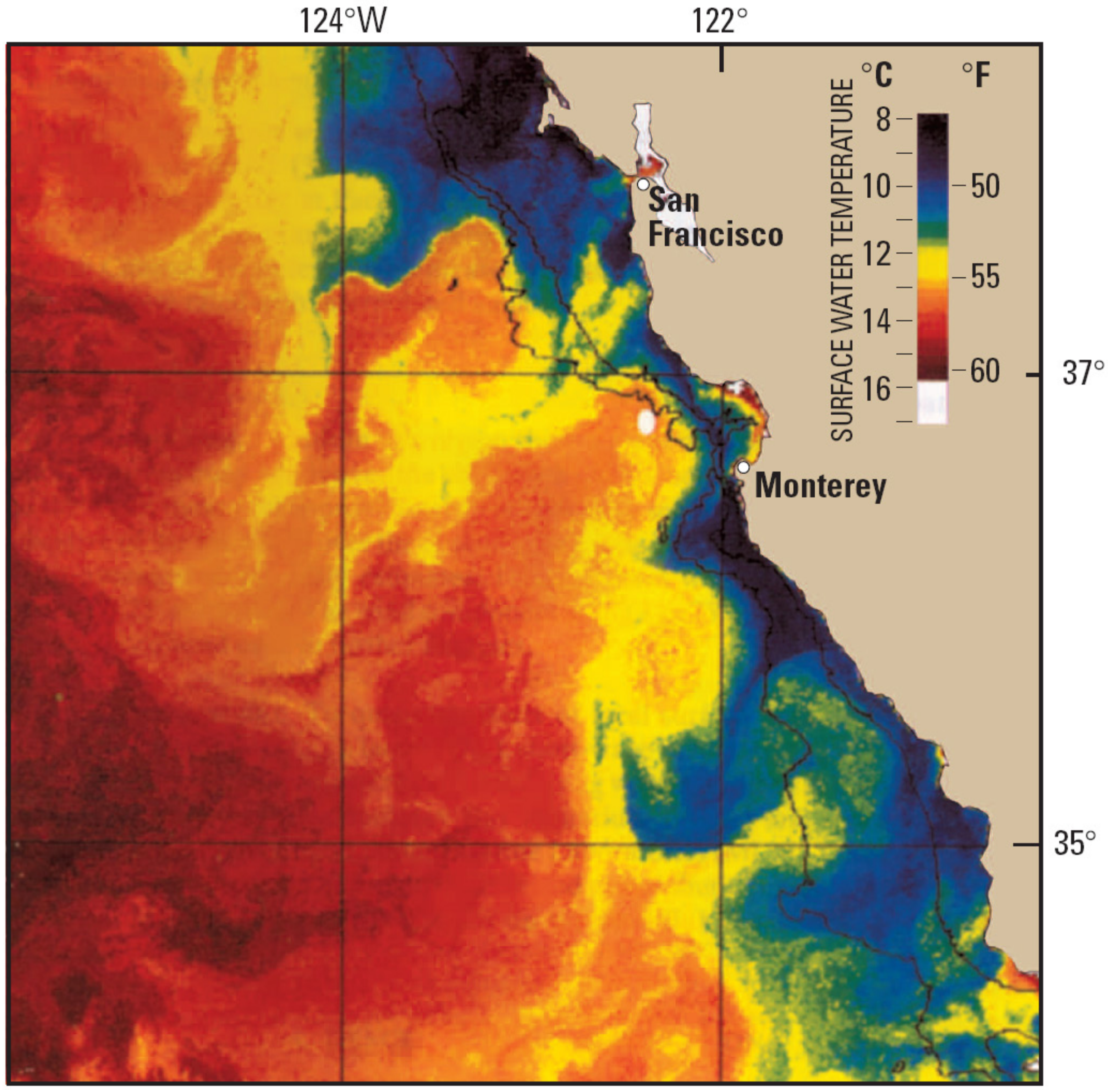

Figure 38. Satellite image of the central coast of California showing water temperature (blue is cold, red is warm) along central California coast in summer (Noble 2001 [using NOAA AVHRR satellite data, processed at Naval Postgraduate School]).

Steller sea lion (*Eumetopias jubatus*), California sea lion (*Zalophus californianus*), humpback whale (*Megaptera novaeangliae*), fin whale (*Balaenoptera physalus*) and blue whale (*Balaenoptera musculus*).

Subtidal Habitats
A generalized depiction of the continental shelf does not reflect seafloor heterogeneity in substrate type (silt, sand, rock) and depth resulting in a complex topography (Figure 39). Examples of topographic habitat types include such features as seamounts, submarine canyons and shelf breaks. These features also affect hydrology causing heterogeneity in hydrographic habitat types including regions of upwelling, eddies and convergence zones. Increases in habitat heterogeneity is linked to a higher diversity in many species, however, we are only now acquiring a full understanding of this heterogeneity.

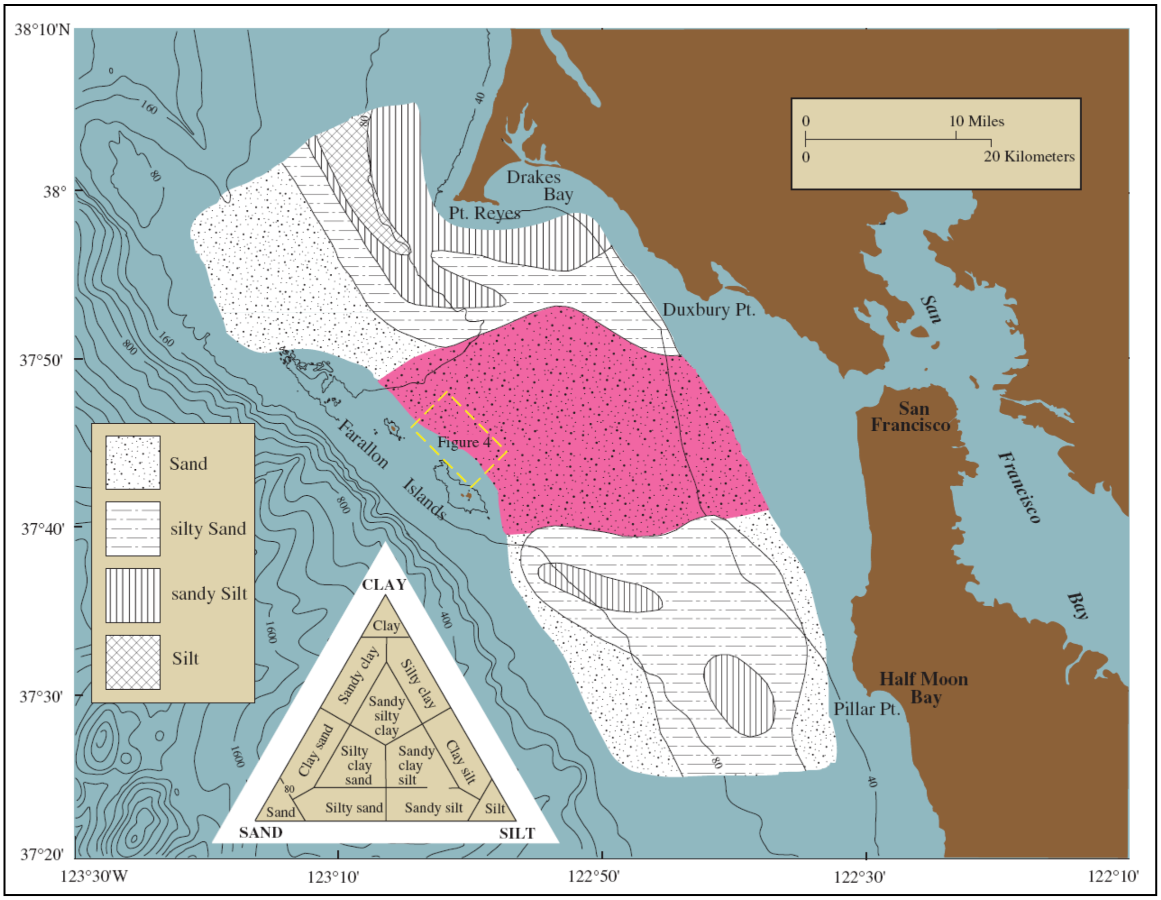

Figure 39. Gulf of the Farallones study area showing sea-floor surficial-sediment texture. Ternary diagram (triangle) shows sediment described by its sand, silt and clay content. Bathymetry in meters. Adapted from USGS Circular 1198 (Karl et al. 2001).

New techniques such as multibeam sonar are enabling a much more detailed view of habitat complexity. The products of these newer technologies and older techniques were documented by the 2003 National Marine Sanctuary Seafloor Habitat Desktop Study as inventories of the known substrate and bathymetric data for GFNMS and CBNMS (Murai and Greene 2003). The study is an important resource for locating studies, paper maps and GIS resources of bathymetry and habitat (substrate) for the area. Paper maps at a 1:250,000 scale are available for the survey area; high-resolution mapping is only available for a small subset of the area. Geologic transects have been performed throughout much of the area and digital data are available for the project site from NOAA (Appendix 5 has more information on datasets).

In 2005 as part of an effort to support the development of Marine Protected Areas along the coast of Marin County, the NPS contracted with Gary Greene of the California State University Monterey Bay–Seafloor Mapping Lab (CSUMB-SFML) to develop high-resolution habitat maps of the Point Reyes Headlands as well as nearshore areas of Drake's Bay from Arch Rock to Duxbury Reef (Greene et al. 2011). Using Sun-Illuminated Multibeam Bathymetry and side-scan sonar, the CSUMB-SFML produced high-resolution habitat maps detailing marine habitat throughout the Point Reyes Headlands ASBS (Figure 40). The areas closest to parklands are predominantly rock and sand; whereas soft sediment lies farther towards the continental shelf.

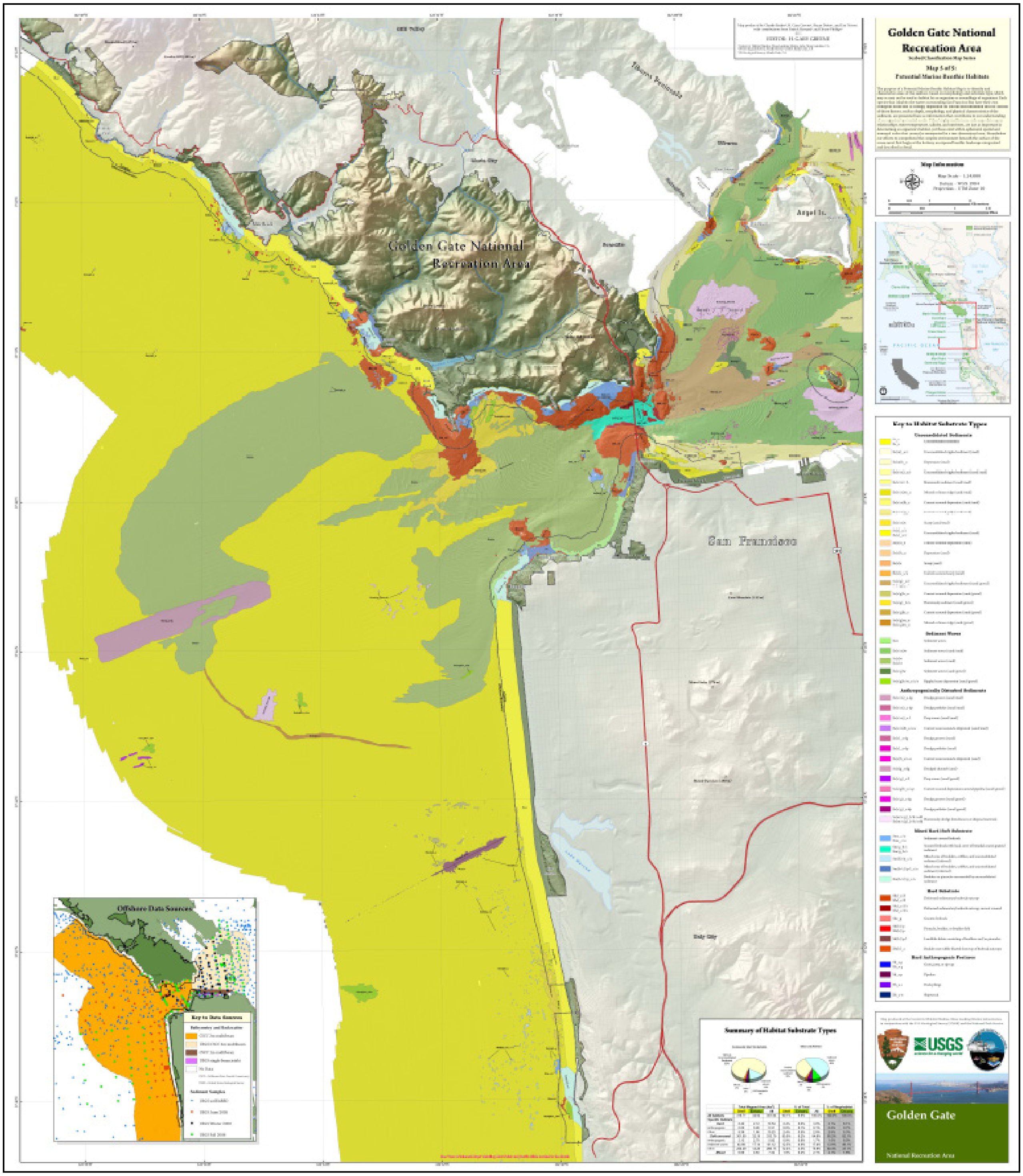

Figure 40. Golden Gate National Recreation Area benthic map showing of sand and gravel sediment waves at mouth of San Francisco Bay (Greene et al. 2009).

Benthic habitat maps were completed for the offshore waters of GOGA through a team led by Charlie Endris and Gary Greene from Moss Landing Marine Laboratories (Greene et al. 2009). They compiled available regional seafloor mapping data for San Francisco Bay and interpreted newly collected data provided through the California Seafloor Mapping Program (CSMP) and

USGS to construct benthic habitat and geologic maps of GOGA submerged lands. The CSMP goal is to create a comprehensive coastal/marine geologic and habitat base map series for all of California's state waters. Authorized by the California State Ocean Protection Council, the project is collecting bathymetry and backscatter data (providing insight into the geologic makeup of the seafloor) that will be turned into habitat and geologic base maps for all of California's state waters (mean high water line out to 3 nautical mi [5.6 km]). Among other benefits, this cooperative project will improve climate change and ocean circulation models, improve the understanding of sediment transport and sand delivery and identify submerged rocky habitat, faults and improve our understanding of tsunami potential. The GOGA habitat maps were constructed using the same habitat classification scheme and mapping code presently being used for the development of the CSMP habitat maps (Greene et al. 1999, 2005, 2007).

Evidence for the character of substrates along the continental shelf near park boundaries can be derived from a Karl et al. (2001) study of sediment and mineral composition in the GFNMS region (Figure 39). Most of the surficial sediment on the continental slope in the area is very sandy (pink area in Figure 39), a condition that is considered unusual; slopes are generally characterized by silt and clay. The reason for the abundance of sand is not fully understood (Karl et al. 2001).

Bathymetry

Detailed bathymetry data are available for the offshore coastal waters of GOGA and PORE that are within the GFNMS from USGS (Figure 41, Chase et al. 1991). The resolution ranges from 1–10 m (3.3–33 ft) elevation contours (Figure 41). Bathymetric maps at the finer 1-m (3.3 ft) resolution may be useful for assessing benthic habitat.

Rocky Reefs and Kelp Forests

Production in subtidal rocky reef habitats depends on light and nutrient levels and exposure to physical forces. Kelp, among the most productive of marine plants, grows on rocky substrates in waters of 20–120 ft (7–30 m) and provides a substrate for numerous benthic and epibenthic invertebrates, as well as food and shelter for many fishes, seabirds and marine mammals. Where light levels are low and kelp is unable to flourish, productivity is lower. Annual bull kelp (*Nereocystis luetkeana*) dominates in northern California and perennial kelps (*Macrocystis integrifolia* and *M. pyrifera*) dominate in central and southern California. The PORE and GOGA coastlines have a mixture of these species. In the late summer and fall, sloughing and deterioration of the perennial kelp occurs and winter storms lead to the complete disappearance of some canopies (Leet et al. 2001).

Kelp forests are complex communities scattered along the parks' coastlines; predominantly along Tomales Point, along the southern portion of Point Reyes from the southern portion of Drake's Bay to Bolinas and bordering the extreme southern portion of GOGA (Figures 42 and 43). There are also kelp beds off Point Reyes Headlands and the western part of Drake's Bay and Tomales Point around Bird Rock; however, these communities are not reflected in Figure 43[13]. The absence of kelp along the San Francisco peninsula (and GOGA) is a natural occurrence as there are few rocky outcrops for kelp to attach.

[13] S. Allen, National Park Service, Point Reyes National Seashore, CA, pers. comm., 2006.

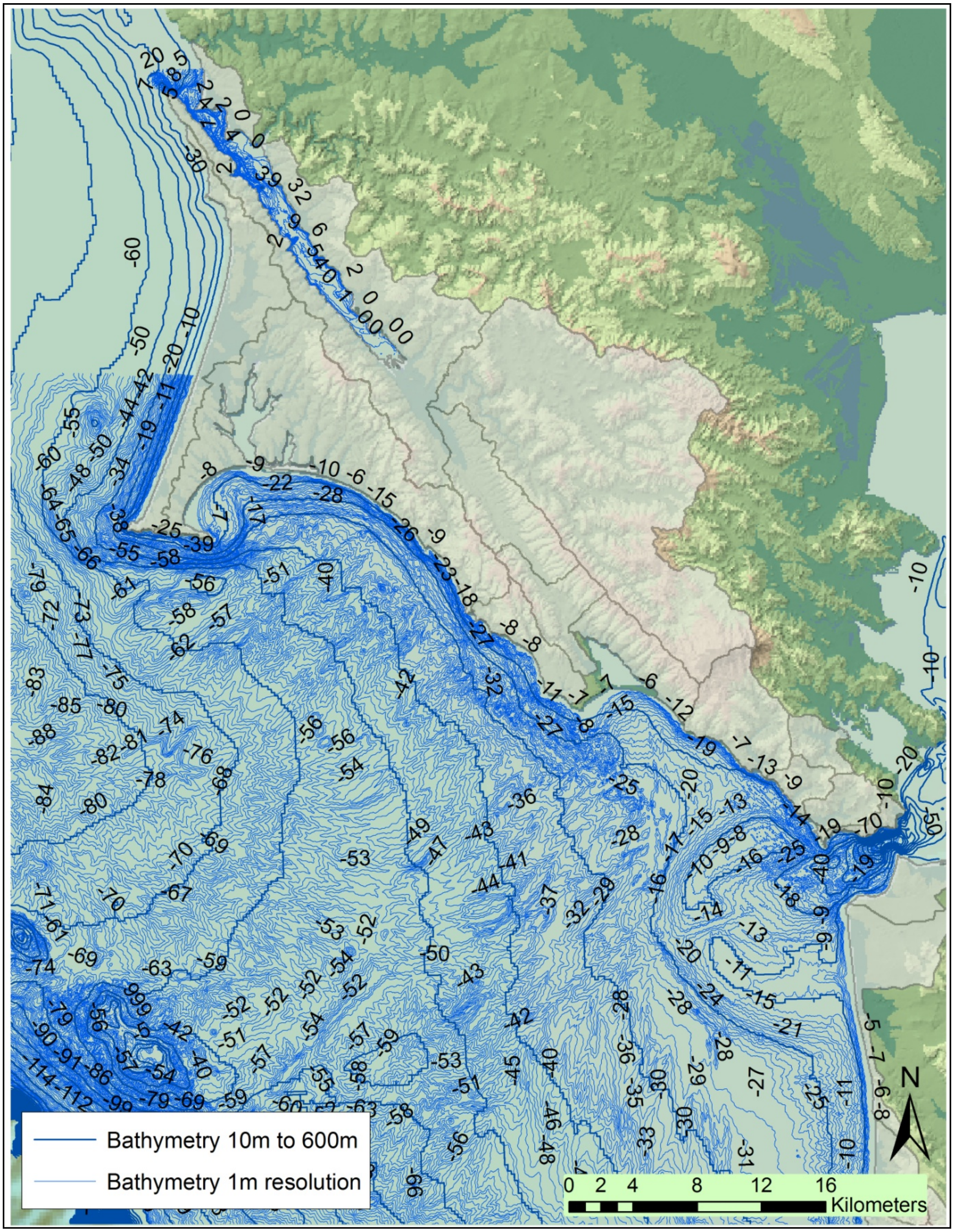

Figure 41. Coastal bathymetry at 1 m (3.3 ft) for Point Reyes National Seashore and Golden Gate National Recreation Area (data sources: 10–600 m [33–1,969 ft] from CDFG and 1 m [3.3 ft] from Chase et al. 1991).

Figure 42. Kelp communities near the Point Reyes coastline (photo: Donald Kinney, http://www.photoarrow.com/).

The first survey of kelp communities along the northern coast was performed in 1912 and subsequent knowledge of the *Nereocystis* populations were based on 1989 and 1999 surveys. Despite year to year variation in kelp coverage, the 1912 and 1989 surveys yielded similar acreage estimates (Leet et al. 2001). However, the 1999 survey indicated a 42% decline in kelp extent from Shelter Cove, Humboldt County to Point Montara, San Mateo County, possibly due to the decline state-wide related to the 1998 ENSO and to winter storms (Leet et al. 2001). Areas within park jurisdictions are closed to harvest, so changes in kelp status within park boundaries could serve as a control for studies of sites where harvesting is allowed.

Rocky reef kelp forest communities provide shelter and feeding grounds for numerous invertebrates and fishes. Colonies of bryozoans grow on kelp fronds, while other invertebrates, such as snails, abalones, and occasionally sea urchins feed on kelp (NCCOS 2003). At the surface, floating kelp masses are important habitats for juvenile fishes, particularly rockfishes and kelp surfperch (*Brachyistius frenatus*). Schools of larger rockfish and greenlings, cabezon (*Scorpaenichthys marmoratus*), lingcod (*Ophiodon elongatus*) and other species segregate among the middle and lower kelp forest communities (ICF Jones and Stokes 2009). White sharks (*Carcharodon carcharias*) are associated with the edges of these biogenic habitats where they prey on pinnipeds that forage in and adjacent to kelp beds. The sea otter is a "keystone species" for its role in structuring kelp communities. By consuming sea urchins (herbivores), the sea otter facilitates increased kelp growth. Though they were present historically, sea otters no longer occur in significant numbers along the parks' shoreline, so kelp may be more impacted by sea urchins and less abundant in the park than under pre-European conditions. Kelp beds along the coast may be sea otter habitat in the future as they rebound after significant declines; the northern boundary of their range is Half Moon Bay just to the south of GOGA.

Although some rocky subtidal monitoring has occurred along the West Coast over the past several decades, there was no coast-wide effort to monitor ecosystem patterns and change until1999 when PISCO initiated an intensive program to monitor kelp forests. PISCO shared their subtidal monitoring protocol diver surveys with other institutions in hopes of expanding the

Figure 43. Kelp map based on aerial kelp harvester surveys for the central coast region for 1990–2002. The data are point coverage, so aerial extent at this scale may be exaggerated and missing data from Point Reyes Headlands (California Department Fish and Game kelp survey data).

number of sites along the West Coast. The PISCO subtidal protocol relies solely on scuba divers to conduct the surveys. Qualified, research divers measure community structure parameters, such as fish density, fish size, algal density, macroinvertebrate density and percent cover of benthic algae and invertebrates. Features of the habitat such as substrate type and relief are also measured. Currently, the sites are distributed across oceanographic regimes, reef habitat and inside and outside of MPAs. To date, several patterns over space and time are starting to emerge from the kelp forest monitoring and reef fish monitoring.

Kelp forest surveys from 1999 to 2002 showed regional changes in kelp abundance, as well as strong differences between nearby sites. Historically, kelp tends to decline along the coast during El Niño and increase during La Niña conditions; however, PISCO's study has revealed dramatic local variability, even when large-scale climatic shifts are not a factor (PISCO 2009). Even between sites separated by only a few kilometers, such as along the Monterey Peninsula, trends in kelp abundance can differ markedly. PISCO has also found that coastal currents strongly influence patterns of reef fish population replenishment (PISCO 2009).

Soft and Sandy Bottom

Soft and sandy bottom habitats of the subtidal continental shelf lack the physical structure and high biological production of kelp forests and rocky reefs, and have traditionally been overlooked by researchers. Species that live on the continental shelf are subjected to shifting sediments by wave action and bottom currents (NCOOS 2003). Some species that live in these habitats, such as crustaceans and mollusks, secure themselves in tubes and burrows. Other species, such as flatfishes, are camouflaged by their color and shape. California halibut and starry flounder are common in sandy areas around the mouth of Drake's Estero, south of Double Point, Tomales Bay and near Stinson Beach; estuarine fish (e.g., sculpins, sanddabs, leopard sharks [*Triakis semifasciata*]) forage on tidal flats at high tide (ICF Jones and Stokes 2009).

Soft-bottom habitats are prevalent along the continental shelf of the parks, but little is known about their extent and physical variability and even less is known about associated biota. These areas are difficult to survey because of poor water clarity. Benthic habitat mapping of Point Reyes Headlands and Drake's Bay by Erday-Heydorn and Greene (2006) offers a means to define these areas and differentiate substrate types, such as sandy and gravel bottom habitat types nearshore from the soft gravel and sediment types further offshore (Figure 40).

Seabirds and marine mammals forage on fish and invertebrates in soft and sandy bottom habitats. Gray whales are occasionally observed foraging on invertebrates buried in the soft sediments of the outer coast of Drake's Bay within PORE boundaries and around Tomales Bay[14]. Seabirds and seals feed on fishes such as flatfish and invertebrates such as mysid shrimp. White sharks occur in some sandy bottom habitats where seals occur, such as the mouth of Drake's Estero.

Intertidal Zone

The intertidal zone is where the land and sea intersect, includes rocky headlands, sandy bottom areas and estuaries. Intertidal life is dependent on nutrient rich diurnal tides and is adapted to wide variations in conditions, including changes in salinity and desiccation. Fresh water, both surface water from rainfall and subsurface flow, can also impact populations. Waves carry and

[14] S. Allen, National Park Service, Point Reyes National Seashore, CA, pers. comm., 2006.

deposit plankton, macroalgae, and occasional corpses of fishes, birds and marine mammals in the intertidal zone, providing an unpredictable and patchy source of food. As a whole, the intertidal zone, influenced by the daily ebb and flow of tides is considered one of the most diverse on earth.

Tidal communities are distributed at different tidal levels, or zones, sustained by the sporadic deposition of food from the ocean (Figure 44). The high intertidal zone exhibits the widest range of heat and cold. Thus, desiccation is a significant problem for marine organisms in the summer, and freezing is a problem in the winter. Because of the limited inundation time, marine food resources are frequently limited.

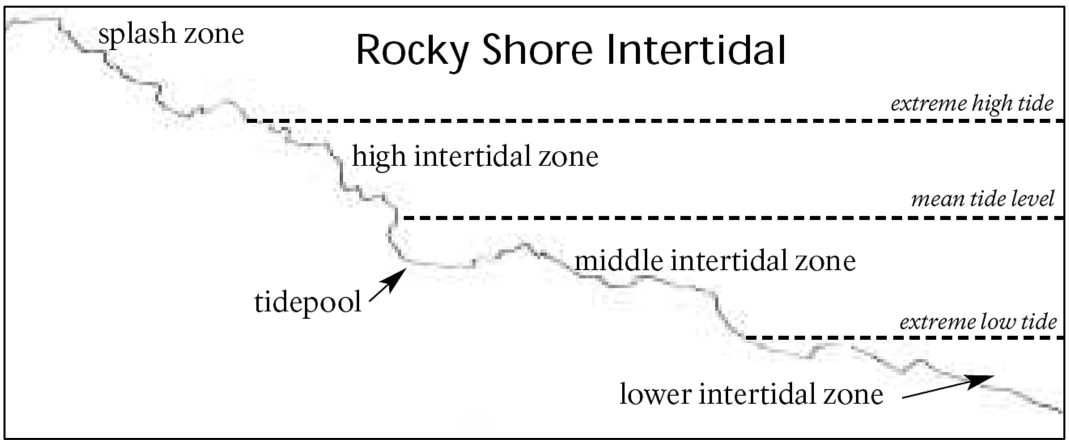

Figure 44. Generalized zonation pattern for rocky shore intertidal habitats.

Rocky Intertidal

Rocky intertidal areas can be found in many areas along the parks' coastline and are best observed at the lowest tides. The seaweed encrusted habitats of the rocky intertidal zones support a variety of marine species. Marine invertebrate species including a variety of sponges, sea anemones, mollusks (abalone, mussels and clams), crustaceans (barnacles, crab and shrimp) and echinoderms (sea stars and sea urchins) flourish in the rich intertidal zone of the nearshore environment. Some fish species are adapted to invade these areas when conditions allow, taking advantage of the rich sea life present. The federally-endangered black abalone (*Haliotis cracherodii*) can be found in very low numbers along the rocky shores of both parks.

In the margins between land and sea, the intertidal experiences a wide variety of impacts including pollution, harvesting, fishing (collecting, poaching), handling and trampling. Until designated as protected, the parks' intertidal zones were frequently heavily exploited. Exploited species included abalone, mussels, limpets, monkey-faced eel and seaweed including *Porphyra* and *Silvetia* spp. Many species experience impacts as it is difficult to enforce protective regulations and some species are not protected through state or federal regulations. Assessing impacts is difficult, because significant differences between sites can occur over scales of meters (Applied Marine Sciences 2002). In some areas, limited access or special regulatory protection has allowed some species to increase as fishing pressures are eliminated.

Until recently, rocky intertidal sites were studied in specific locales for relatively short periods (3–5 yrs). Most intertidal studies occurred close to major research institutions, such as the

University of California Bodega Bay Marine Laboratory to the north, but not within the parks. Recent or expanded rocky intertidal research programs will provide more comprehensive information along park coastlines, providing specific information on species composition, biodiversity and in some instances long term trends.

Beginning in 2001, PISCO took the lead role in developing a large-scale intertidal monitoring program located between Glacier Bay, Alaska to Baja California, with two focuses, Coastal Biodiversity Program and Community Structure Program. The Coastal Biodiversity Program is conducted every 3–5 years at over 100 sites throughout the northeastern Pacific coastline. The MARINe protocol used for the Community Structure Program is now used by park staff at multiple monitoring sites located within the parks and monitoring data are uploaded to the MARINe monitoring program database.

The Minerals Management Service (now Bureau of Ocean Energy Management) Intertidal Team (MINT) has studied rocky intertidal communities since 1991. MINT biologists have teamed up with biologists from five university campuses (UC Santa Cruz, UC Santa Barbara, UCLA, UC Davis and California State University Fullerton) to monitor mussels, sea stars, algae and other intertidal plants and animals along the coast. MINT continues the long term study of four rocky intertidal communities in northern and central California from 1985–1998 to determine the recovery time needed for mussel beds following a major disturbance.

Several NPS-led inventories were initiated to better describe the habitat and biota of nearshore habitats. Applied Marine Science conducted studies in the early 1990s surveying three sites within PORE to identify a baseline in case of oil spills (Applied Marine Sciences 2002). San Francisco State University conducted an intertidal fish inventory at four long-term rocky intertidal monitoring sites in the parks (Durand et al. 2006). A coastal biophysical inventory was completed in 2009 that described and mapped the shoreline habitat into segments based on substrate conditions (Kinyon and Gaddam 2009). In 2010, park-initiated inventories for black abalone found very low abundances and no recruitment[15].

Migratory and overwintering shorebirds forage throughout the rocky intertidal region and the black oystercatcher (*Haematopus bachmani*) breeds in the supratidal area and are dependent on the intertidal during the breeding season. Seals and sea lions regularly rest onshore on rocky intertidal areas, usually at specific sites such as Duxbury Reef, Point Reyes Headlands and Tomales Point.

Sandy Intertidal Beaches

Sandy beaches exist near lagoons and estuaries and are scattered along the coastline. From north to south, beaches include those along Tomales Bay, the Great Beach, Abbotts Lagoon, Drake’s Bay, Bolinas Lagoon, Stinson Beach, Muir Beach, Big Lagoon, Rodeo Lagoon, the Golden Gate, Crissy Field, Lands End, Baker Beach, Ocean Beach and Fort Funston. The Great Beach in PORE is approximately 10 mi (16 km) long and the longest undeveloped beach in California. Fauna that live on beaches bury themselves in the shifting sands, moving up and down the sandy beach as waves break and the tide turns. One of the most common animals of the lower beach,

[15] D. Fong, National Park Service, Golden Gate National Recreation Area, CA, pers. comm., 2011

the mole crab (*Emerita* sp.) buries itself to avoid being eaten by sandpipers that follow the waves in and out (Hedgpeth 1971).

In the parks, surfperch congregate just below the breakers amongst shifting sands along the Pacific Ocean and Drake's Bay sandy shorelines. Typical surfperch include shiner surfperch (*Cymatogaster aggregate*) and barred surfperch (*Amphisticus argenteus;* McCormick 1991).

Unlike the estuary that produces its own food, little sustenance is produced by the sandy beach. The major food sources include plankton, dead seaweed and corpses of fishes, birds and marine mammals brought ashore by the waves. The high sandy intertidal fauna consists mostly of scavengers, which rely on "islands" of wrack material for sustenance. Beach wrack supports an intricate food-web. Wrack-line communities go through successional stages, colonized first by highly motile talitrids and flies and later by terrestrial isopods and beetles. A diverse array of wintering waterfowl and shorebirds rely on the invertebrates either in the wrack material or in the shifting wet sands; western snowy plover winters over at both parks and nests at PORE. Other scavengers that occur on the beach include turkey vultures (*Cathartes aura*), American crows (*Corvus brachyrhynchos*), common ravens (*Corvus corax*) and gulls. Also, coyotes (*Canis latrans*), skunks, gray foxes (*Urocyon cinereoargenteus*) and raccoons (*Procyon lotor*) visit the beach at night in search of a fresh bird or fish carcass. The importance of wrack resources was not understood until fairly recently (Polis et al. 1997). In the past these resources were removed from park beaches; however, the current policy it to leave these resources to perform their role as a vital part of the "sandy beach food web."

Beaches are heavily visited by humans during the late spring and summer except at remote areas such as portions of the Great Beach, so species that overlap in their timing and distributions can be negatively impacted. There is evidence that human and dog visitation can impact both birds, such as least tern (*Sternula antillarum)* and western snowy plover which live on the beaches and nest in the nearby coastal dunes (Peterlein 2009) and mammal populations, such as harbor and northern elephant seals (*Mirounga angustirostris)* that have numerous haul out sites along the parks' coastline (Flynn et al. 2009).

The NOAA Beach Watch program monitors the presence of oil on beaches and collects supplementary data on visitor and resource presence. Beach Watch volunteers monitor 41 beach segments every two to four weeks from Bodega Head in Sonoma County to Año Nuevo County on the San Mateo/Santa Cruz county line. Survey methods along each beach segment include:

- Live bird and marine presence,
- Visitor/dog activity notation,
- Beached (dead) bird and mammal documentation,
- General wrack and invertebrate assessment and
- Oil/tarball documentation.

Additional Seacoast Habitats

Cliffs and Headlands

Along the sea cliffs of the Marin Headlands in the north to Fort Funston to the south, seabirds such as the brown pelican, common murre, pigeon guillemot (*Cepphus columba*), western gull (*Larus occidentalis*), pelagic cormorant (*Phalacrocorax pelagicus*), double-crested cormorant (*P. auritus*), California gull (*L. californicus*), Brandt's cormorant and the black swift (*Cypseloides niger*), among many other birds, find shelter for roosting, breeding and nesting. The cliffs are also close to their food source, which consists primarily of fish and squid. Bank swallow (*Riparia riparia*) colonies at Fort Funston are declining as they have been threatened by competitors, predators, erosion caused by coastal storms and human impacts (NPS 2005).

The Golden Gate Raptor Observatory, a project of the Golden Gate National Parks Conservancy and the NPS, conducts educational talks and demonstrations on Hawk Hill, which is located just above the Golden Gate Bridge. Species of raptors observed include the red-tailed hawk (*Buteo jamaicensis*), Cooper's hawk (*Accipiter cooperii*), sharp-shinned hawk (*A. striatus)* , turkey vulture, osprey (*Pandion haliaetus*), red-shouldered hawk (*B. lineatus*), white-tailed kite (*Elanus leucurus*), northern harrier (*Circus cyaneus*), American kestrel (*Falco sparverius*), prairie falcon (*F. mexicanus*), broad-winged hawk (*B. platypterus*) and peregrine falcon (*F. peregrinus*), among others. Many of the raptors can be viewed from Sweeny Ridge in San Mateo County, as they migrate south. Many raptors nest along the coastal bluffs of the parks including at Tomales Point and Point Reyes Headland.

In the coastal scrub and chaparral communities of the headlands, species of wildlife include: mammals, such as the California mouse (*Peromyscus californicus*), Merriam's chipmunk (*Neotamias merriami*), striped skunk (*Mephitis mephitis*); reptiles like racer snakes, southern alligator lizard (*Elgaria multicarinata*) and the endangered garter snake (*Thamnophis sirtalis tetrataenia*; Milagra Ridge); and birds, such as several owl species, wrentits (*Chamaea fasciata*), western scrub jays (*Aphelocoma californica*), California quail (*Callipepla californica*) and bushtits (*Psaltriparus minimus*). At least 44 species of butterflies occur in the Marin Headlands and 34 species occur at Milagra Ridge. The federally endangered Mission blue butterfly (*Plebejus icariodes missionensis*) lives in the Marin Headlands, Milagra Ridge and Sweeny Ridge. The endangered San Bruno elfin (*Callophrys mossii bayensis*) occurs at Milagra Ridge, where it inhabits rocky outcrops. The federally endangered Myrtle's silverspot butterfly occurs in coastal scrub communities at PORE.

Offshore Rocks and Island Habitats

Along the parks' coastline, there are numerous offshore rocks, forming islands for seabirds, pinnipeds and other hardy species. To breed successfully and maintain populations, these species have evolved to use areas that are inaccessible to most predators. In modern times they are subject to numerous disturbances. For example, Alcatraz Island (GOGA), home to the historic prison in San Francisco Bay, receives 1.5 million visitors a year. Alcatraz is a significant bird refuge and important nesting area for several species of seabirds, including the recently delisted brown pelican and other federally endangered or threatened species. Other important islands where seabirds nest and roost include Bird Rock (PORE) and Bird Island (GOGA) and Stormy Stack (PORE).

Bays/Estuaries

At various points along the shore, cliffs are broken by creek mouths, which are usually blocked by a sand bar or spit, forming an area of quiet water called a coastal estuary or lagoon. Examples of lagoon habitats include Abbotts Lagoon (PORE), Big Lagoon (GOGA) and Rodeo Lagoon (GOGA). These areas are more protected and less exposed to the ocean surf. Lagoons are geologically “temporary” features that begin with a river mouth drowned by rising sea level. Littoral drift creates a spit or barrier bar across the mouth so that its access to the ocean is restricted to a narrow inlet. The combined riverine influence and reduced wave action allows mudflats to form, seagrasses to colonize (Figure 45 and 46), and in shallow areas, emergent vegetation to colonize, creating in some instances large areas of tidal marsh (Figure 47). Eventually, the lagoon becomes a flat plain that may be eroded by waves lapping against its seaward edge. The life of a lagoon depends on the rate at which sediment is entrapped in the lagoon (Ritter 1970). Many coastal lagoons within the park lands have been reduced or filled as a result of past land use practices and increased watershed sediment production and delivery. As examples, Big Lagoon, at the mouth of Redwood Creek and Bolinas Lagoon have both undergone extensive study to determine processes controlling lagoon formation and maintenance.

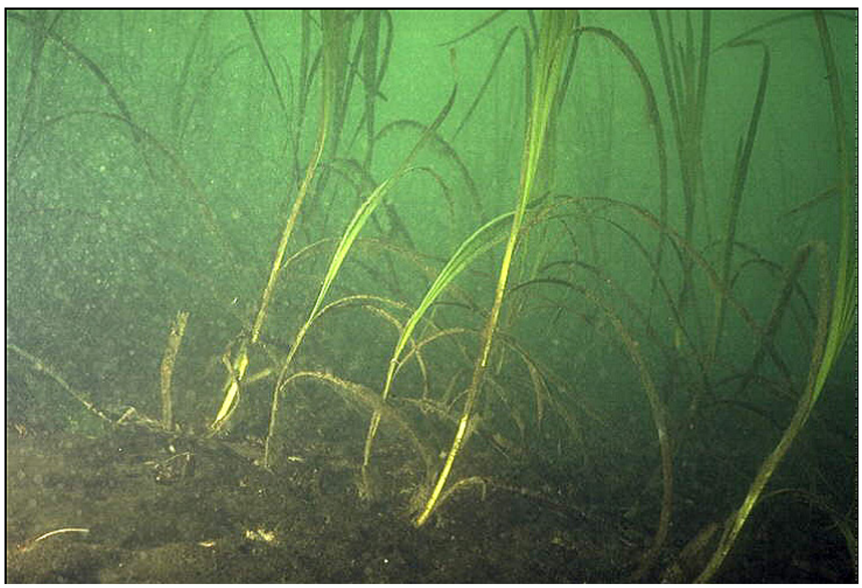

Figure 45. Eelgrass (*Zostera marina*) habitat (photo: R.C. Phillips).

Estuaries are influenced by water exchange with the coastal ocean; however, the degree of exchange varies with the volume of freshwater inflow, the physical geometry of the estuary and tidal exchange. These variables in turn have important consequences on how coastal runoff affects these systems. Direct nutrient input from the ocean is minimal to San Francisco Bay which has large riverine outputs, a narrow opening and a tidal exchange ratio of less than 50% (Smith and Hollibaugh 1998). Much of San Francisco Bay is heavily influenced by runoff from the Sacramento and San Joaquin River systems. Tomales Bay with its unique linear shape and its narrow mouth also places constraints on tidal exchange with the ocean. As a result, salinities in the southern end of Tomales Bay are highly variable, ranging from nearly fresh after heavy winter runoff to slightly hypersaline in summer, whereas regular tidal mixing at the northern seaward end of Tomales Bay maintains salinities that consistently reflect those of the outer

Figure 46. Coastal seagrass communities along the Point Reyes National Seashore and Golden Gate National Recreation Area coastlines. Seagrass is concentrated in Tomales Bay, Drake's Estero and small portions of San Francisco Bay (California Department Fish and Game seagrass GIS data).

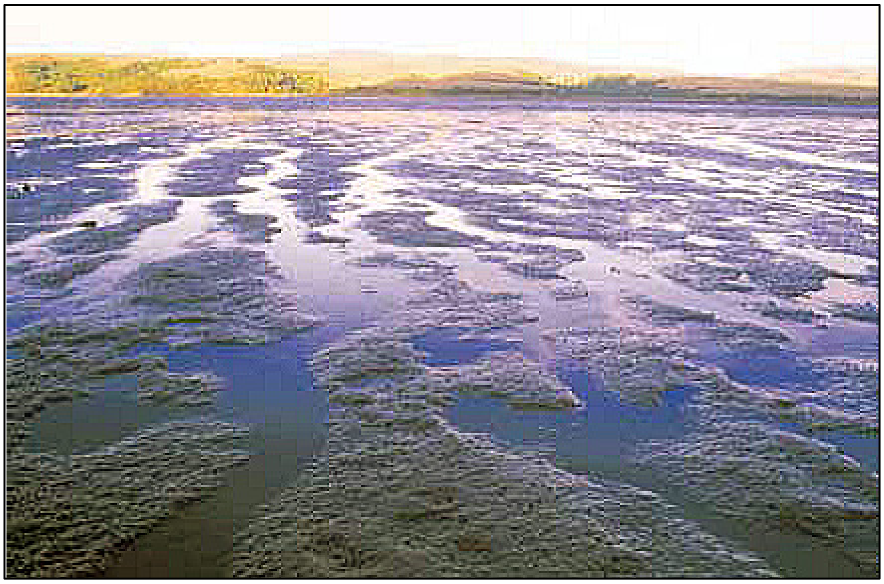

Figure 47. Tidal mudflat in Tomales Bay, Point Reyes National Seashore (photo: Lorraine Parsons).

coastal waters (Hollibaugh et al. 1988; Kelly and Tappen 1998). It is estimated that water in the northern 6 km (3.7 mi) of Tomales Bay exchanges with nearshore coastal water on each tidal cycle, while water in the southern bay, is resident for approximately 120 days (Smith and Hollibaugh 1998). In the summer, inorganic phosphorus builds up in the water column, and dissolved inorganic nitrogen largely disappears. The phosphorus buildup reflects releases of phosphorus during the oxidation of organic matter, while nitrogen disappearance represents the net effect of denitrification.

Despite the minimal tidal influences in the upper reaches of estuaries such as Tomales Bay, there are likely important indirect effects of coastal upwelling on the nutrient dynamics of these bays. By stimulating primary production in coastal waters, upwelling elevates the concentration of particulate organic matter in coastal waters which is delivered to the bays by tides and particle settling (Smith and Hollibaugh 1998). The influence of coastal processes on larval transport to San Francisco Bay is well known, as many of the population dynamics of migratory species cannot be explained by local processes alone (Kimmerer 2004).

Estuarine areas such as Tomales Bay, Drake's Estero, Bolinas and Rodeo Lagoons are extremely important habitats for migrating and nesting bird species including osprey, great blue heron (*Ardea herodias*), the recently federally delisted brown pelican, white pelican (*Pelecanus erythrorhynchos*), canvasback duck (*Aythya valisineria*), greater scaup (*Ay. marila*), lesser scaup (*Ay. affinis*), red-breasted merganser (*Mergus serrator)*, ruddy duck (*Oxyura jamaicensis)*, least tern, Caspian tern (*Sterna caspia*), long-billed curlew (*Numenius americanus)*, black-bellied plover (*Pluvialis squatarola)*, willet, short-billed dowitcher (*Limnodromus griseus)*, greater yellowlegs (*Tringa melanoleuca)*, whimbrel (*N. phaeopus)*, dunlin, western sandpiper (*Calidris mauri*) and several species of egrets, cormorants and gulls. Black brant (*Branta bernicla*) migrate to and overwinter in only a few estuaries along the west coast, including at Tomales Bay and Drake's Estero, where thousands of birds will congregate and feed on eelgrass. Brown pelicans bathe, feed and roost in Rodeo Lagoon, Abbott's Lagoon, Tomales Bay and Drake's Estero, so the preservation of this habitat is critical to their survival. Tomales Bay, Drake's Estero, Bolinas

Lagoon and San Francisco Bay are designated as Western Hemisphere Shorebird Reserve Network sites of Regional Importance in the U.S. Shorebird Conservation Plan because they are important to a great diversity and abundance of shorebirds (Hickey et al. 2003). Other wildlife in the estuarine community include fish like the commercially important Pacific herring (below), the endangered tidewater goby and migrant species such as the federally threatened steelhead trout (*Oncorhynchus mykiss*) and coho salmon, marine mammals such as harbor porpoise (*Phocoena phocoena*), seals and sea lions, including the federally threatened Steller sea lion (*Eumetopias jubatus*).

Seagrass Communities

Seagrass ecosystems vary from a few plants or clumps of plants to extensive single or multi-species meadows covering large areas of shallow bays or lagoons. Seagrasses stabilize fine sediments and help maintain water quality. Eelgrass (*Zostera* sp.) is a particularly important seagrass species found in the upper reaches of shallow bays (Figure 45). Eelgrass beds provide feeding, shelter and breeding habitat for many species of invertebrates, fishes, and even some waterfowl (Schaeffer et al. 2007). The economically important Pacific herring spawns in eelgrass beds; seabirds and marine mammals forage on small fishes found there (Schaeffer et al. 2007). Eelgrass is also an obligate food for black brant along the Pacific flyway (Goals Project 1999).

Sunlight, nutrient levels, turbidity, salinity, temperature, current and wave action affect the distribution of seagrass beds. Seagrass along the PORE/GOGA coastline is distributed predominantly in Tomales Bay and Drake's Estero (Figure 46). A 1987 NMFS survey of San Francisco Bay found only 316 ac (128 ha; 0.1% total bottom area) of eelgrass throughout the bay with much of the existing habitat exhibiting conditions of environmental stress (Wyllie-Echeverria and Rutten 1989; Wyllie-Echeverria 1990); however, a more recent mapping effort in 2003 by Merkel and Associates for the California Department of Transportation and NOAA Fisheries measured 2,618 ac (1,059 ha) of eelgrass during the Baywide Eelgrass Inventory (Merkel and Associates 2004). These data suggest that either a significant expansion of eelgrass habitat has occurred since 1987 or that improved survey techniques have identified more eelgrass than was detectable using prior techniques (Greene and Bizzarro 2003). There are 1,000 ac (405 ha) or 13% coverage in Tomales Bay compared to 1% in San Francisco Bay; the major limiting factor appears to be light attenuation (Merkel and Associates 2004).

A study in Drake's Estero (PORE) provided baseline data for the detection of disturbance from oil spills and other disturbance, indicated low variability in some eelgrass populations between sites and seasons (Applied Marine Sciences 2002), suggesting that eelgrass communities could be especially appropriate for detecting long-term trends.

Tidal Flats

Tidal flat habitat includes mudflats, sandflats and shellflats occurring between mean lower low water and mean tide level supporting less than 10% cover of vascular vegetation (Goals Project 1999). During the twice-daily high tides, tidal flats provide foraging habitat for many species of fish, and during low tides they are the major feeding area for shorebirds. In the estuaries of PORE and northern GOGA, mudflats comprise large areas.

Mudflats are composed of fine-grained silts and clays (Figure 47) that support an extensive community of diatoms, worms and shellfish, and more complex vegetation including green algae, red algae and sea lettuce. Eelgrass can also be an important component of mudflats. Most mudflat faunal species are burrowers and "deposit feeders." For example, the geoduck (*Panopea abrupta*) lives in burrows up to 1.5 m (4.9 ft) deep in low intertidal flats near eelgrass beds. Other common low intertidal species include the gaper clam (*Tresus capax)*, which grow up to 4 lbs (1.8 kg) and the Washington clam (*Saxidomus nuttalli)*, also called the "money-shell" clam, since the native Californians used the shell for money. Leopard sharks and bat rays (*Myliobatis californica*) come in on the tide and snip off exposed clam siphons with their teeth. The "innkeeper" worm (*Urechis caupo)* inhabits U-shaped burrows and gathers food for itself and other "guests," the red scale worm (*Arctonoe vittata),* goby species and a pea crab (*Pinnotheres pisum)*. Starry flounder (*Platichthys stellatus*) and bat rays can extract bottom dwelling animals by using their broad, flattened bodies to suction the prey out.

Higher up where the mud flat meets the shore and tidal sloughs meander through the tidal marsh, the Oregon shore crab, *Hemigrapsus* sp., burrows in holes along the bank and feeds mostly at night on diatoms and green algae that grow along the muddy shore. Mussels (*Mytilus* spp.) live along the upper shore as well, especially in undercut banks.

Shorebirds, waterbirds, seabirds and harbor seals use exposed tidal flats for resting and/or breeding. A community of birds and harbor seals will congregate on exposed sandbars at several locations in Tomales Bay, Bolinas Lagoon and Drake's Estero. These animals will typically rest through an entire tidal cycle, unless disturbed by humans approaching too close. Bird species include brown and white pelicans, gulls, terns and shorebirds. Shorebirds will also forage in the exposed tidal flats where they probe for worms and invertebrates.

Tidal Salt Marshes

A typical tidal salt marsh depicts a transition from intertidal mudflat up a relatively short and steep low marsh zone of Pacific cordgrass (*Spartina foliosa*) to a middle marsh zone dominated by perennial pickleweed (*Salicornia virginica*) and a high marsh zone dominated by saltgrass (*Distichlis spicata*). The high marsh transitions into upland in a "wetland-upland transition zone," which varies spatially in response to annual rainfall, storm surges and sea level rise and serves as critical habitat and refugia for several species, most notably the California black rail (*Laterallus jamaicensis corturniculus*). Rare plants include Point Reyes bird's-beak (*Cordylanthus maritimus* ssp. *palustris*), California sea-blite (*Suaeda californica*), Marin knotweed (*Polygonum marinense*) and small spikerush (*Eleocharis parvula*); PWA and Faber 2004). Birds, including rails, shorebirds and wading birds are often found foraging and roosting in these salt marshes and several species of rail breed in tidal salt marshes. Predatory mammals include coyotes and river otters (*Lontra canadensis)* that forage on various prey items.

Historically, salinity and tidal elevation have been viewed as the primary drivers of plant distribution (Pennings and Callaway 1992; Peinado et al. 1994). The classic paradigm of salt marsh structure portrays a subtle elevation gradient from "low marsh" adjacent to creeks, building gradually to a mid-marsh plain that transitions into a "high marsh" zone at the marshes' highest elevations near the upland ecotone. While some marshes do display this textbook, gradually sloping topography, there are many others that do not (Zedler 2001), including those in Tomales Bay and adjacent coastal watersheds[16]. For example, deltaic wetlands such as those at

[16] L. Parsons, National Park Service, Point Reyes National Seashore, CA, pers. comm., 2001.

the mouth of Lagunitas and Redwood creeks often support only a thin fringe of "low marsh" along the narrow intertidal creek banks. These banks often rise steeply to the natural alluvial levees, which often consist of "high marsh" or even "high marsh/upland ecotone" vegetation communities. These alluvial levees then slope down to expansive marsh plains that include both mid-marsh and even high marsh communities depending on microtopographic complexity such as depressions and mounds. The transition between the Bay and marsh is more gradual on the bay-ward side of these deltas, with marsh plains very gradually sloping into vegetated or unvegetated mudflat.

Historically, unlike San Francisco Bay, the Tomales Bay and Drake's Estero estuaries did not appear to have had such an extensive network of fringing salt marshes. U.S. Coast Survey maps from the 1860s and 1870s depict small amounts of marsh habitat along the edges of Tomales Bay, with the largest extent in the southern portion of Tomales Bay in the East Pasture, Olema Marsh and the Bear Valley and Olema Creek floodplains. Small salt marsh estuaries are shown at the mouth of some of the other creeks, including Grand Canyon, Millerton Gulch and the drainage to Audubon Canyon Ranch's Livermore Marsh. In the last decade, the extent of Pacific cordgrass, which was once noted as being conspicuously absent from Tomales Bay (MacDonald and Barbour 1974), has surged dramatically, primarily through colonization of the Lagunitas Creek delta mudflats. Expansion of Pacific cordgrass has remained more limited in the Drake's Estero system.

Brackish Marshes

Brackish marshes are transitional between freshwater and salt marshes. While there is a recognizable brackish flora of alkali bulrush (*Scirpus maritime*), California bulrush (tule; *Scirpus californicus*) and cattails (*Typha* spp.), their distribution depends on fluctuating salinity conditions (Figure 48). In years of heavy rainfall, brackish species extend their range and in years of drought the trend is reversed. Species diversity increases markedly in brackish versus saline marshes.

Figure 48. Tidal brackish marsh along Lagunitas Creek (NPS photo).

Brackish marsh is not as common within central California coastal maritime systems, as in large estuarine systems with strong freshwater influences such as San Francisco Bay. The central coast brackish marshes tend to be isolated and few because of the steep shoreline with few valleys or wave-sheltered environments (Baye and Faber 2000). Those that do exist typically have extensive sandy substrates; relatively small, local inputs of fine sediment and freshwater discharges, and are inundated with water approaching marine salinity during most of the growing season (Baye and Faber 2000). Some coastal tidal marshes associated with stream mouths have relatively more freshwater influence and brackish marsh vegetation, but these conditions are often perpetuated by seasonal reductions in tidal inflow because of partial or complete closure of the tidal inlet through berming by sand beach ridges (Baye and Faber 2000).

As with tidal marshes, birds, including rails, shorebirds and wading birds are often found foraging and roosting in these marshes. Saltmarsh common yellowthroat (*Geothlypis trichas sinuosa*) nest in salt marshes throughout the parks including Tomales Bay and Drake's Estero (Flannery et al. 2001). Predatory mammals include coyotes, raccoons and river otters that forage for various prey species.

Water diversions, diking and mechanical removal of sand berms have significantly altered salinity dynamics within many of these small coastal lagoons, often creating artificially elevated salinities and/or poor water quality conditions. For example, historically, Tomales Bay appeared to have a number of "mini" lagoons, small open embayments protected by parallel-oriented sand bars with a dynamic, mobile inlet, particularly along its eastern shore (Parsons and Allen 2004). The number of lagoons within Tomales Bay has dropped since the 1860s, but some pocket back barrier systems that maintain fresh-brackish conditions throughout most of the year due to seasonal berming of the inlet mouth still exist[17].

<u>Efforts to Assess and Restore Tidal Marshes</u>

As a whole, California has lost more than 95% of its coastal wetlands and extensive development along its scenic coastline has eliminated hundreds, if not thousands, of acres of brackish and saline tidal marshes. In general, the Marin County coastline has not been as heavily impacted by development as that of San Francisco and San Mateo counties to the south; however, the western portion of Marin County was heavily logged in the late 1800s to early 1900s, and the area continues to be largely agricultural supporting dairy and beef cattle operations. Historically, many of the wetlands were grazed, converted into stock ponds, disked, leveled, or drained to create better pasture conditions (Parsons 2005b). In other areas affected by high levels of sedimentation, such as Tomales Bay, tidal saline marsh lands have actually increased in extent (Parsons 2005b). Tidal marshes are generally sparse along the southern GOGA coastline which has few rivers and large cliffs.

NPS established a directive for parks to inventory wetlands within their boundaries, supporting the performance-based goal-setting process established by the Government Performance and Results Act (GPRA) in the 1990s. Wetlands and riparian areas are also subject to the Council of Environmental Quality Regulations for Implementing the National Environmental Policy Act (Section 1508.27) and regulatory oversight under the Clean Water Act (federal) or other state and local legislative mandates, such as riparian "setbacks" or development buffers implemented by many county and municipal agencies. In addition to regulatory mandates, the NPS Management Policies (NPS 2006) require parks to implement a "no net loss of wetlands" policy

[17] P. Baye, pers. comm. from Parsons and Allen, Annapolis, CA, 2004.

and to strive over the long term for a net gain in wetland acreage. NPS is also required to avoid "impacts to watershed and riparian vegetation" and other aquatic habitats and is encouraging wetland restoration where feasible.

Comprehensive detailed estimates of historic tidal marsh loss have not been made for the parks; though efforts to map wetland change are underway. U.S. Coast Survey maps exist from the 1860s and 1870s and these can be used as a baseline to compare current estimates of tidal marsh extent. Modern information on tidal wetland extent is underestimated by as much as 50% in the currently available, National Wetland Inventory (NWI; USFWS 1991). The Central California NWI layer is derived from the 1987 NWI digital wetland map (1:24,000) obtained from USFWS (USFWS 1991). The color infrared photography used by NWI was taken in April 1985 at a scale of 1:65,000. The NWI has limitations for tracking wetlands at the park scale, due to quality of the base aerial photography and the minimum mapping unit of 1–3 ac (0.4–3.6 ha), which causes smaller wetlands to be omitted.

Beginning in 2000, PORE started mapping wetlands within high-priority (e.g., areas supporting special status species) or degraded areas of PORE, using funds from the NPS Water Resources Division and the I&M Program. After the first phase of analysis determined that the NWI significantly underestimated wetland acreage, phase 2 of the project utilized an enhanced method to inventory and map wetlands within PORE and GOGA (Schirokauer and Parravano 2003). The approach was utilized to map wetlands in the Abbotts Lagoon watershed, which supports many special status plant and wildlife species, and later in other areas, specifically pastoral zones or grazed areas and areas proposed for restoration (Schirokauer and Parravano 2003). During the first two phases of this project, more than 911 ac (369 ha) within 230 wetlands units (polygons) were inventoried and mapped.

In 2003, PORE began the third phase of wetland mapping within the Tomales Bay watershed, utilizing a functional assessment approach. A number of different methodologies exist for assessing wetland condition and/or functions, including the USFWS Habitat Evaluation Procedure, the Wetland Evaluation Technique, the U.S. Army Corps of Engineers' Hydrogeomorphic Assessment Method and the California Rapid Assessment Method. PORE created a hybrid assessment method that incorporated components from the Hydrogeomorphic Assessment Method, California Rapid Assessment Method and additional issues specific to PORE including grazing (Parsons et al. 2005a). Because wetland functions vary according to type, functional assessments are separated on the basis of wetland types such as depressional, lacustrine, riverine, seep and estuarine wetlands. (While similar in nomenclature to the Cowardin classification systems, these wetland classes are, to some degree, defined differently.) As part of this project, NPS staff started identifying hydrologic sources (e.g., seep, headwater flooding, tidal flooding) for mapped wetlands, with the idea that understanding sources will help the park understand how these wetlands function. To ensure that mapping efforts would remain relatively "rapid," PORE evaluated new methods to streamline the inventory process by increasing the minimum mapping unit size and eliminating the exhaustive inventory of plant species that was conducted as part of earlier mapping efforts (Parsons et al 2005a).

The revised mapping approach will improve the information for future PORE wetland inventory efforts by incorporating assessments of condition and functionality. Through these efforts, the parks will be able to ascertain the existing condition of wetlands within watersheds and to better determine what the desired future condition of wetlands should be, as set forth under the Land Health: Wetland Areas goal under GPRA by the NPS. Source reduction and restoration activities will enable the parks to move toward desired future conditions. PORE has already implemented cattle exclusion fencing, fish passage improvement and erosion control projects, and helped fund loafing barns for dairy cattle. PORE is not only looking to improve conditions within park boundaries, but within entire watersheds such as the Bolinas and Tomales Bay watersheds through collaboration with other private individuals and local/state agencies. Large wetland restoration projects have been implemented (i.e., Crissy Field in the Presidio in southern GOGA and Giacomini in northern GOGA to enhance and increase the acreage of intact tidal marsh.

Freshwater Habitats

Streams

On their way to the ocean, PORE and GOGA streams flow through the canyons and valleys of coastal mountains, linking forest, chaparral, scrubland, grassland and marsh. Riparian woodlands develop along stream banks and floodplains and coastal wetlands and estuaries form where the rivers enter the sea. The streams transport nutrients, sediments and oxygen through the watershed, and support numerous animals, including, frogs, salamanders, snakes, muskrats and river otters. Broad-leaved deciduous trees, such as maples and cottonwoods or shrubs such as alders and willows grow along the stream banks providing shelter and shade for many animals. Leaves fall in the stream and decompose, adding nutrients and organic matter. Algae and mosses proliferate in the water and on rocks providing food for invertebrates (including insects), fish and birds. Anadromous fish, such as coho salmon and steelhead trout, migrate from the sea to freshwater to spawn and die and decompose bringing nutrients from the sea upstream.

Most of the streams in PORE and GOGA are not large and their tributaries are frequently ephemeral (Table 15 and Figure 49). River runoff, the amount of water discharged through surface streams, is determined by a combination of factors, including local geology, topography, drainage area and rainfall patterns. As streams flow from their headwaters toward the coast, rivers carve steep, narrow canyons through the mountains. As they approach the coast they lose speed, depositing sediment to build broad floodplains with rich, deep soils. Coastal rivers also play a crucial role in replenishing sand lost from beaches. As rainfall and moisture diminish southward along the California coast, runoff decreases and rivers are accordingly smaller in size.

The overall condition of these streams reflects impacts of more than a century of intensive agricultural land use, combined with the instability associated with the highly active San Andreas Fault. The effects of past land use practices (logging, agriculture and grazing) have changed the condition of the watershed, altering its ability to support fish populations at their historic levels. Dam construction, channelization, water diversion projects for agricultural irrigation and the increased water demands of growing urban areas have dramatically altered the natural hydrologic regime and sediment transport. Dams can also block the path of migrating fish, damage fish spawning gravels, deprive estuaries of needed fresh water and reduce sediment nourishment of beaches (See the Stressors chapter for more information).

Loss of native perennial vegetation, soil compaction and loss, gullying and incision of swales and meadows have changed the runoff patterns and reduced the capacity of the watershed to attenuate pollutant loading and surface runoff to streams. Although land use activities have been

Table 15. Streams in Point Reyes National Seashore, Golden Gate National Recreation Area and the Presidio (Cooprider and Carson 2006a).

Stream/Creek	Park	County	Coastal Watershed Assessment Watershed Unit
Alamere Creek	PORE	Marin	Drake's Bay and Esteros
Arroyo Hondo	PORE	Marin	Double Point/Duxbury
Bear Valley Creek	PORE	Marin	Tomales Bay
Coast Creek	PORE	Marin	Drake's Bay and Esteros
Crystal Lake	PORE	Marin	Drake's Bay and Esteros
Easkoot Creek	GOGA	Marin	Bolinas Drainages
East Schooner Ck.	PORE	Marin	Drake's Bay and Esteros
Glenbrook Creek	PORE	Marin	Drakes Bay and Esteros
Haggerty Gulch	PORE	Marin	Tomales Bay
Home Ranch Creek	PORE	Marin	Drake's Bay and Esteros
Lagunitas Creek	GOGA	Marin	Lagunitas Creek
McKinnan Gulch	GOGA	Marin	Bolinas Drainages
Morses Gulch	GOGA	Marin	Bolinas Drainages
Muddy Hollow	PORE	Marin	Drakes Bay and Esteros
Nyhan Creek	GOGA	Marin	Unmapped San Francisco Bay Unit
Olema Creek	PORE	Marin	Olema Creek
Pike County Gulch	GOGA	Marin	Bolinas Drainages
Pine Gulch	PORE	Marin	Pine Gulch Creek
Redwood Creek	GOGA	Marin	Redwood Creek
Rodeo Creek	GOGA	Marin	Gerbode/Rodeo
Santa Maria Creek	PORE	Marin	Drake's Bay and Esteros
Stinson Gulch	GOGA	Marin	Bolinas Drainages
Tennessee Valley	GOGA	Marin	Tennessee Valley
Lobos Creek	PRES	San Francisco	Presidio
Milagra Creek	GOGA	San Mateo	Milagra/Sweeney
West Union Creek	GOGA	San Mateo	Unmapped San Francisco Watershed Unit

greatly reduced and upgraded to more environmentally sustainable practices, current land use continues to influence water quality within many watersheds. Despite a general understanding of the stressors and evidence of impacts across the parks, a comprehensive assessment of stream health has not been performed. Some areas are being extensively surveyed and monitored due to proposed restoration, while for other areas, information is severely limited.

Lakes, Ponds and Lagoons

Open-water habitat, such as ponds, lakes and stock ponds, are characterized by standing water and are typically devoid of vegetation. Most of these facilities were constructed by former landowners for stock watering or development. PORE contains more than 75 impoundments (NPS 2004a). These ponds are now part of the "natural" landscape and support populations of

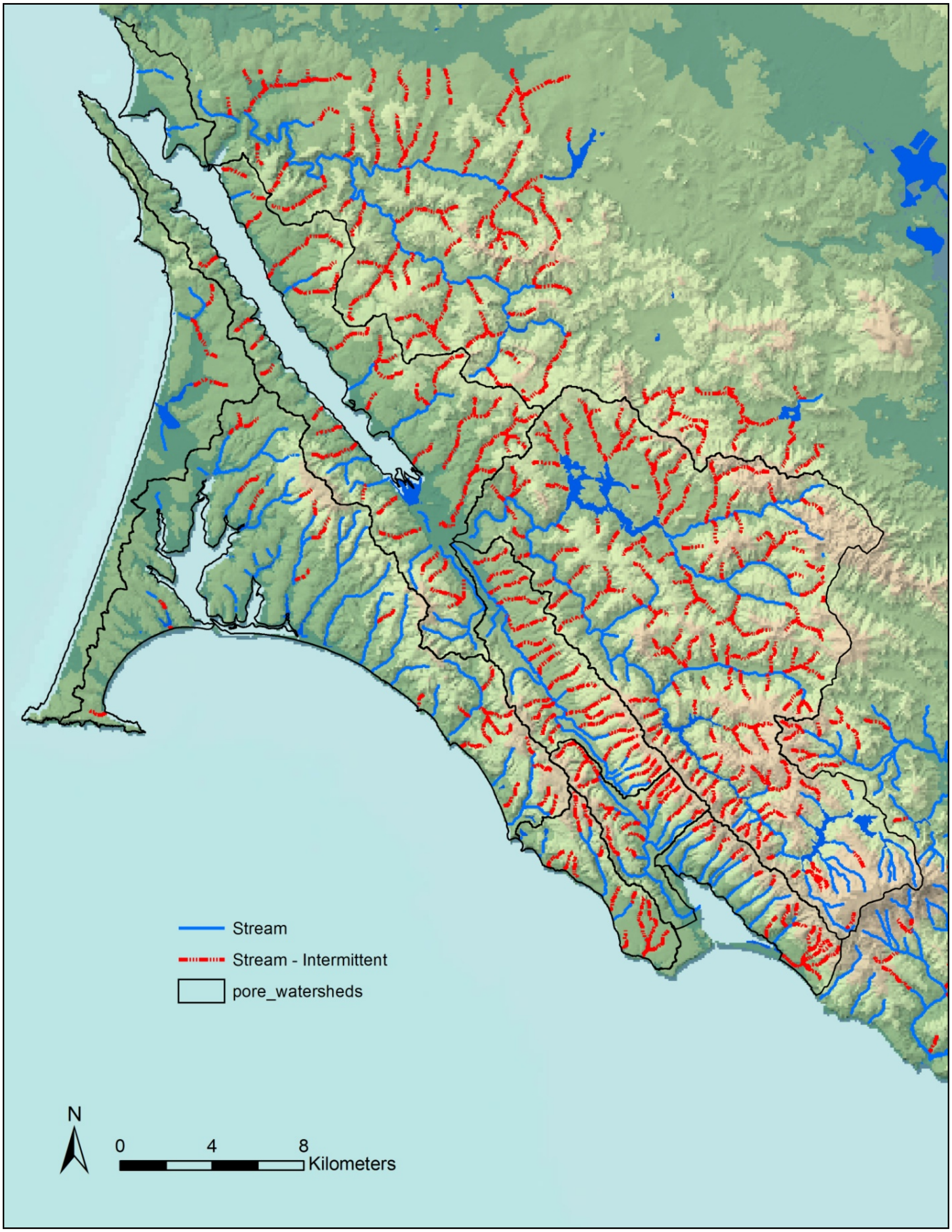

Figure 49. Point Reyes National Seashore watershed map illustrating the large number of intermittent streams in the region.

songbirds, waterbirds and amphibians, such as California red-legged frog, a species that has been displaced in other regions[18].

Within the Olema Creek valley, a number of naturally occurring sag ponds associated with the San Andreas Fault provide unique aquatic habitat. The southwestern part of PORE, from Double Point is dotted with ponds and lakes derived from massive slope failure events (NPS 2004a) Water bodies, such as Bass, Pelican and Crystal Lakes in the Double Point/Duxbury CWA Watershed Unit, are naturally occurring.

Some lagoons, such as Abbotts and Rodeo, have periodic saltwater intrusion with higher high tides; open, freshwater vegetation characteristics; and provide wildlife habitat like large ponds. Bolinas Lagoon and Horseshoe Pond (now a lagoon in Drake's Bay and Esteros CWA Unit) have regular tidal influence and a broader spectrum of saltwater to freshwater habitats. Wintering waterbirds, such as ruddy duck, American coot (*Fulica americana*), bufflehead (*Bucephala albeola*), mallard (*Anas platyrhynchos*) and many gull species occur in Rodeo Lagoon, Rodeo Pond and Abbotts Lagoon during winter surveys (White 1999, Osbourn 2001).

Freshwater Wetlands

The region supports many different types of freshwater wetlands, including vernal marsh (depressional wetlands, including wet meadows and coastal swales), seasonal wetlands associated with streams, seeps and springs and lacustrine (open water) wetlands (Cowardin 1979; Parsons and Allen 2004). Seasonal coastal swales or ravines are a freshwater marsh occurring in depressions in the coastal prairie, coastal dune or bluff scrub. Often agricultural, residential or commercial use of the adjacent area has enhanced the wetlands. Small patches of wet meadow occur interspersed in the coastal prairie. Wet meadows support dense cover of herbaceous vegetation such as bulrush, hydrocotyle species, Baltic rush (*Juncus balticus)*, curly dock (*Rumex crispus*) and sedges (Figure 50). Seasonal wetlands are also dominated by herbaceous vegetation and occur as isolated areas interspersed in non-native grassland and coastal prairie.

Figure 50. Clumps of tall emergent (cattails and bulrush) occur in a blanket of low-growing species (hydrocotyle and water parsley) in the Giacomini West Pasture's Freshwater Marsh (Parsons and Allen 2004).

[18] G. Fellers, US Geological Survey, Biological Resources Division, pers. comm., 2004.

Freshwater and seasonal wetlands provide habitat for numerous species. Within these habitats in the Redwood Creek watershed, surveys have documented six reptile species, 83 bird species and eight mammal species (Stillwater Sciences 2011). Documented reptile species include the common garter snake (*Thamnophis sirtalis*) and western pond turtle (*Emys marmorata*). Documented amphibians in GOGA wetlands include newts (*Taricha* spp.), California red-legged frog and Sierran tree frog (*Pseudacris sierra*; Fong et al. 2010). Common bird species include the mallard, American wigeon (*Anas americana*), American coot, killdeer (*Charadrius vociferus*), black phoebe (*Sayornis nigricans*), marsh wren (*Cistothorus palustris*) and red-winged blackbird (*Agelaius phoeniceus*; Stallcup 1995). Documented mammal species include the river otter (Stillwater Sciences 2011).

Upland Habitats

From the coastal dunes and bluffs to interior grassy knolls and valleys, PORE and GOGA include several distinct plant communities, often grading into one to another. The underlying geologic formations, soils and the influence of a moist, maritime climate determine the configuration and diversity of plant communities.

For this analysis, PORE and GOGA have been divided into broad land cover types through a park-based mapping effort started in 1995 after the Vision Fire. Land use and land cover types (vegetation) of PORE and GOGA were mapped and incorporated into the parks' GIS using aerial 1994 photography and interpolation (Schirokauer et al. 2003). Aerial photograph interpreters delineated over 12,000 land cover polygons within the 155,000-ac (62,726 ha) mapping area that includes PORE, GOGA, Tomales Bay State Park, Samuel P. Taylor State Park and Mount Tamalpais State Park. This mapping effort used the National Vegetation Classification System, with groupings based on structure and environmental factors such as elevation and hydrologic regime, resulting in over 80 vegetation associations.

Alliances were grouped into 14 upland land cover types: Coastal Dunes, Coastal Scrub/Chaparral, Grasslands, Pasture, Herbaceous Wetlands, Riparian Forest/Shrubland, Bishop Pine, Monterey Pine/Cypress, Hardwood Forest and Douglas-fir/Coast Redwood. Other categories included, but not described here, include Built-up/Developed Urban Lands, Unvegetated Shorelines (unvegetated shorelines and dunes), Disturbed Lands and an undefined cover type for those areas that were not within mapping boundaries (Figures 10 and 11). Acreage estimates (Tables 16 and 17) were created from the PORE and GOGA vegetation maps (NPS 1994).

In addition to the map, a botanical classification following the California Native Plant Society's and national standards was developed for the region (Keeler-Wolf 2004). Mapped land cover types (Figures 10 and 11) correspond most closely to the vegetation management community level in the vegetation map classification hierarchy (Schirokauer et al. 2003). A statistically rigorous accuracy assessment evaluated how well the photo interpreters labeled the land cover types delineated in the draft map.

Coastal Dunes

The western portion of Limantour and the Great Beach have extensive areas of coastal dunes; smaller patches are present along the Point Reyes Headlands, Marin Headlands and Tomales Bay areas. Native dune grass (*Leymus mollis*) mixes with forbs such as yellow sand verbena (*Abronia latifolia*) and beach pea (*Lathyrus littoralis*). The coastal dunes are the only habitat

Table 16. The land cover types for Point Reyes National Seashore (PORE) and PORE-managed Golden Gate National Recreation Area (GOGA) watersheds in acres. The Bolinas watershed includes PORE- and GOGA-managed lands (data source: Vegetation PORE/GOGA 1994 coverage)

Cover Type	Abbotts, Kehoe, & Pacific Drainages	Double Point/ Duxbury	Bolinas Drainages	Lagunitas Creek	Drake's Estero & Bay Drainages	Olema Creek	Pine Gulch Creek	Tomales Bay
	(acres)							
Undefined (no data – outside park boundary)	0	352	12	43166	0	0	318	15861
Bishop Pine	7	21	5	0	1686	10	16	1954
Built-up/Urban Developed	104	43	28	126	95	133	28	438
Coastal Dunes	1682	0	0	0	172	0	0	9
Coastal Scrub	2106	1238	718	531	11405	346	588	2180
Disturbed	20	1	6	33	15	8	0	23
Douglas-fir/ Coast Redwood	0	1454	1512	2997	5904	3091	2657	2724
Unvegetated Shoreline (Dunes)	189	90	0	0	173	0	0	5
Grassland	3549	801	242	3382	6105	4050	230	1993
Hardwood Forest	29	88	966	2646	423	1376	1041	1947
Herbaceous Wetlands	442	71	20	10	1007	32	8	608
Pasture	1759	19	9	40	1416	106	42	629
Riparian Forest/ Shrubland	74	85	23	280	1199	266	135	399
Water	340	48	6	12	460	12	2	249

where some threatened and endangered plants such as beach layia (*Layia carnosa*), Sonoma spineflower (*Chorizanthe valida*) and Tidestrom's lupine (*Lupinus tidestromii*) exist and are adapted to the shifting sandy areas (USFWS 1998).

Coastal dunes provide habitat for small mammal species such as deer mouse (*Peromyscus maniculatus;* Fellers and Pratt 2002), Point Reyes jumping mouse (*Zapus trinotatus orarius*[19]) and invertebrates such as the sandy beach tiger beetle (*Cicindela hirticollis gravida*), globose dune beetle (*Coelus globosus*) and federally endangered Myrtle's silverspot butterfly (USFWS 1998). The federally threatened western snowy plover feeds in coastal dune systems in both parks and nests on the PORE coastal dunes along the Great Beach (USFWS 2007).

Prior to development in the early 1900s, there were significant dunes along the San Francisco Peninsula. Currently, the majority of dune habitat is dominated by non-native species. Non-native European beachgrass represents roughly 50% of the coastal dune vegetation, and non-

[19] S. Allen, National Park Service, Pacific West Region, pers. comm., 2012

Table 17. The acreage of land cover types for the Golden Gate National Recreation Area (GOGA) watersheds for each watershed (data source: Vegetation PORE/GOGA 1994 coverage).

	Fort Funston	Gerbode & Rodeo	Milagra & Sweeney	North Shore	Presidio	RedwoodC reek	Tennessee Valley
Cover Type				**(acres)**			
Undefined (no data)	6763	0	1755	0	3000	689	0
Bishop Pine	44	9	129	59	57	11	1
Built-up/Urban Developed	209	110	313	116	1124	176	13
Coastal Dunes	251	5	10	23	7	0	2
Coastal Scrub	234	1721	1126	581	45	3040	1395
Disturbed	58	18	63	25	0	38	15
Douglas-fir/ Coast Redwood	0	3	2	0	0	1971	0
Unvegetated Shoreline (Dunes)	31	5	1	99	25	44	56
Grassland	0	708	177	124	0	591	429
Hardwood Forest	16	36	91	32	154	988	16
Herbaceous Wetlands	0	49	18	4	0	9	19
Pasture	0	17	51	0	0	110	0
Riparian Forest/ Shrubland	7	101	35	14	17	131	27
Water	3	45	20	43	13	25	11

native iceplant (*Carpobrotus edulis*), roughly 25% (Schirokauer et al. 2003). In areas where these two species dominate, they form dense monocultures, with few or no other species present. The remaining 25% of the land cover type is remnant patches of native plant community comprised of native dune grass, dune sagebrush (*Artemisia pycnocephala*), coast buckwheat (*Eriogonum latifolium*), dune lupine (*Lupinus chamissonis*), or goldenbush (*Ericameria ericoides*). Often native patches are mixed with the two invasive species—European beach grass and/or iceplant. Total vegetation cover is often low and interspersed with bare sand. These invasive species in turn influence the types and extent of habitat available to marine biota. For example, shifting sands around non-native European beach grass are invaded by species tolerant of sand cover, which are then able to spread over larger areas and stabilize those areas. These stabilized areas creates suitable habitat for species that are not tolerant of sand burial, first low-growing or herbaceous vegetation and then shrubs and trees.

Grasslands

Pristine coastal prairie, dominated by perennial bunchgrasses, is considered one of the most decimated ecosystems in California. Much of the native vegetation has been replaced by European Mediterranean region annual species that arrived with domestic cattle and their feed. Remaining native grasslands are threatened by disturbance and invasions by non-native plant species. Fire suppression has allowed coyote brush and Douglas-fir (*Pseudotsuga menziesii*) to encroach, converting grasslands to shrubland and forest. Roughly 80% of PORE grasslands are currently dominated by non-native grasses (NPS 2004a); however some portions of the parks remain pristine. For example, the Redwood Creek Watershed in GOGA supports very good stands of the native perennial grassland, a highly intricate composition of bunchgrasses such as red fescue (*Festuca rubra*), California oatgrass (*Danthonia californica*) and native wildflowers. Other common native species include Pacific reedgrass (*Calamagrostis nutkaensis*), tufted hairgrass (*Deschampsia cespitosa*), meadow barley (*Hordeum brachyantherum*) and California brome (*Bromus carinatus*). Where Pacific reedgrass is in association with rushes (*Juncus* spp.) and sedges (*Carex* spp.), grasslands are considered wetland land cover types. Native grasses are often found mixed with annual non-native grasses, coyote brush, California blackberry and a variety of native and weedy herbs (NPS 2004a, 2005). Common invasives include invasive perennial purple velvet grass (*Holcus lanatus*), annual Italian wild rye (*Lolium multiflorum*), farmer's foxtail (*Hordeum murinum*) and rattail fescue spp. (*Vulpia* spp.). Pasture is distinguished from grasslands as it is used to graze cattle or horses, or managed to produce silage for cattle, or used for other agricultural purposes.

At PORE, coastal prairie grasslands adjacent to coastal dunes provide habitat for the federally endangered Myrtle's silverspot butterfly larval host plant (*Viola* spp.) Herds of tule elk graze the coastal grasslands around Drake's Bay and Tomales Point along the Point Reyes Peninsula.

With the continuing loss of native grasslands, grassland associated bird species are in decline in most parts of the country (Sauer et al. 2004). Though, little information is available regarding California's grassland bird species' distribution, productivity and survivorship, numerous species have been documented in these habitats including the white-crowned sparrow (*Zonotrichia leucophrys*), red-winged blackbird, savannah sparrow (*Passerculus sandwichensis*) and song sparrow (*Melospiza melodia*; Flannery et al. 2001). The western harvest mouse (*Reithrodontomys megalotis*) was only detected in this habitat type (Fellers and Pratt 2002). At least three bird Species of Concern were detected in annual grasslands in the region, California quail, Allen's hummingbird (*Selasphorus sasin*) and chipping sparrow (*Spizella passerina*).

Coastal Scrub

Coastal scrub is one of the most widespread plant community types and includes the shrublands and a small amount of chaparral. Approximately 90% of coastal scrub is dominated by coyote brush (*Baccaris pilularis*), a small-leaved evergreen shrub, which ranges from fairly low open areas where coyote brush associates with grasses, to tall dense multi-species scrubs. Coffeeberry (*Rhamnus californica*), thimbleberry (*Rubus parviflorus*), California blackberry (*Rubus ursinus*), California sagebrush (*Artemisia californica*) and poison oak (*Toxicodendron diversilobum*) are commonly associated with dense coyote brush scrub. Coyote brush may also be found in association with sedges (*Carex* spp.) and rushes (*Juncus* spp.). With fire in less than 5-year intervals, or with overgrazing, coastal scrub generally reverts to annual non-native grassland. Fire exclusion in coastal sage scrub and mesic chaparral communities allows coast live oak, California bay and other shade tolerant species to increase in density and reduce understory diversity and abundance (NPS 2004a).

The federally endangered San Francisco lessingia (*Lessingia germanorum*) is found only in the Presidio and in one site south of the city in San Mateo County. It grows in open sandy areas in mature dune scrub. The federally endangered Raven's manzanita is one of the San Francisco peninsula's unique subspecies of Hooker's manzanita (*Arctostaphylos hookeri* ssp. *ravenii*) and was reduced to a single plant found in the Presidio. Cuttings from the Raven's manzanita plant are being grown and outplanted in other areas of serpentine soils in coastal scrub.

In the San Francisco Bay area, coastal scrub supports low bird diversity and abundance compared to other habitat types. The most abundant bird species documented in the scrub habitats include the white-crowned sparrow, wrentit and spotted towhee (*Pipilo maculates*; Flannery et al. 2001). Six bird Species of Concern have been detected in coastal scrub habitats, including the red-tailed hawk, California quail, Bewick's wren (*Thryomanes bewickii)*, Wilson's warbler (*Wilsonia pusilla)*, yellow warbler (*Dendroica petechia)* and song sparrow. A variety of mammals can be found in coastal scrub habitats within both parks, but are generally dominated by deer mouse (Fellers and Pratt 2002, Semenoff-Irving and Howell 2005).

Riparian Forest/Shrubland

Streamside forests and shrublands are dominated by broad-leaved deciduous trees or shrubs, such as red alder (*Alnus rubra*), arroyo willows (*Salix lasiolepis*) and mixed willow stands. The alder understory is usually composed of moderate to dense berry species, such as salmonberry (*Ru. spectabilis*), thimbleberry, California blackberry and red elderberry (*Sambucus racemosa*). Hedgenettle (*Stachys ajugoides*), sedges (*Carex* spp.), rushes (*Juncus* spp.), small-fruited bulrush (*Scirpus microcarus*) and ferns dominate the herbaceous layer. Arroyo willow in its shrub form stands 5–7 m (16–23 ft) high and dominates the canopy. Taller willows or alder may be present in small quantities. The understory is usually extremely dense because of the thicket-forming growth habit of this species. Shrubs (e.g., berry species) are commonly found in the understory. Wax myrtle *(Myrica californica*) or poison oak may be present. Sedges, rushes, small-fruited bulrush along with hedgenettle, beeplant (*Scrophularia californica*) and ferns dominate the herbaceous layer. Forested riparian areas are dominated by mixed willow forest, represented by yellow willow (*Salix lucida*), often associating with other willows (NPS 2004a).

Riparian woodlands in PORE and GOGA provide breeding and foraging resources for over 80 bird species and 14 mammal species. This habitat supports above-average to high bird species diversity and abundance in the San Francisco Bay area compared to other habitat types in the watershed (Flannery et al. 2001). Common species documented include the song sparrow, Swainson's thrush (*Catharus ustulatus)* and Wilson's warbler. Brown-headed cowbirds (*Molothrus ater)*, black-headed grosbeaks (*Pheucticus melanocephalus)*, black phoebes, orange-crowned warblers (*Vermivora celata)*, song sparrows, warbling vireos (*Vireo gilvus)*, western wood-pewees (*Contopus sordidulus)*, Wilson's warblers, ash-throated flycatchers (*Myiarchus cinerascens)*, yellow warblers, Bullock's orioles (*Icterus bullockii) and* common yellowthroats are more abundant in this habitat compared to other land cover types in the watershed.

Redwood Creek provides one example of GOGA's efforts to restore riparian habitat. In the mid-1990s, researchers determined that nearly one-third of the riparian shrub and herb species in the Redwood Creek riparian corridor were non-native (Philip Williams and Associates et al. 1993). Since understory plant volume and diversity are important for nesting riparian birds in coastal watersheds (Gardali et al. 1999), recent efforts have been made to remove non-native plant species such as cape-ivy. Following cape ivy removal in the Redwood Creek area, bird diversity, richness and abundance increased significantly in the breeding season (Scoggin et al. 2000).

Hardwood Forest

Hardwood forest is comprised of hardwood trees such as California bay, coast live oak (*Quercus agrifolia*), eucalyptus, tanoak (*Lithocarpus densiflorus*), madrone and giant chinquapin (*Chrysolepis chrysophylla*). California bay is by far the most abundant hardwood, comprising roughly 75% of these forests while coast live oak is found in 20% and is often associated with bay. Of the remaining forested area, less than 5% is non-native eucalyptus, while tanoak, madrone and giant chinquapin each comprise less than 1%. Douglas-fir and California buckeye (*Aesculus californica*) may also have a significant presence. The understory is variable, including moderately dense shrub understory dominated by hazel (*Corylus cornuta*), coffeeberry, elderberry and/or poison oak or alternatively, swordfern (*Polystichum munitum*). Coast live oak woodlands are dominated by coast live oak usually with a significant component of California bay, sometimes co-dominating with bay. Individual Douglas-firs may also be present. Understory is usually open to moderate with poison oak being the most commonly found shrub, often fairly high in cover. Coffeeberry, coyote brush, toyon (*Heteromeles arbutifolia*) and hazel can be present. Herbaceous cover is usually low (NPS 2004a).

The plant pathogen *Phytophthora ramorum* has caused outbreaks of Sudden Oak Death in 14 coastal California counties killing over a million native oak and tanoak trees (Kelly et al. 2004). The pathogen also infects the leaves and twigs of common ornamental nursery plants, such as rhododendrons and camellias, which serve as vectors for pathogen dispersal. Sudden Oak Death is a growing forest health problem in Marin County (Figure 51) and results in hazardous fuels as well as other safety and resource management concerns. The distribution and number of areas of pathogen infestation increased since 2001 (Kelly et al. 2004). It is important for the parks to be vigilant in detecting and preventing this problem. While there is no cure for *P. ramorum* associated diseases, there are preventive measures that may protect plants, and a treatment that prevents or slows the progression of the disease in some hosts.

Hardwood forest provides habitat to at least 40 species of birds and eight mammals. The forests support average to above-average bird species diversity and average to high species abundance in the San Francisco Bay area (Flannery et al. 2001). Detected species of greatest abundance include the chestnut-backed chickadee (*Parus rufescens)*, song sparrow, dark-eyed junco (*Junco hyemalis)*, Wilson's warbler, Pacific-slope flycatcher (*Empidonax difficilis)* and spotted towhee. Rare species include the belted kingfisher (*Ceryle alcyon)*, black-throated gray warbler (*Dendroica nigrescens)*, pileated woodpecker (*Dryocopos pileatus)* and red-breasted nuthatch (*Sitta canadensis)*. Fourteen bird Species of Concern were detected in the mixed hardwood forest, including the threatened northern spotted owl. In Marin County, 6% of spotted owl pairs nested in hardwoods, and researchers recommend that all evergreen-forested habitats within the watershed be considered potential spotted owl habitat. Mixed hardwood forest provides an important food source – acorns – to birds and mammals. The dusky-footed woodrat (*Neotoma fuscipes*) is biologically important as one of the major prey species, both in frequency and biomass, of the spotted owl (Fehring 2003). Dusky-footed woodrats are found in greatest abundance in the coast live oak-California bay habitat and may rely on oaks for food and cover.

In a 2002 study, densities of woodrat houses were highest in California bay and red alder (*Alnus rubra*) habitats and lowest in grassland habitat where no houses were found (Fehring 2003).

Figure 51. Locations of confirmed *Phytophthora ramorum*, a pathogen responsible for Sudden Oak Death and areas where host plants exist (Kelly et al. 2004, California Oak Mortality Task Force 2012).

Douglas-fir/Coast Redwood Forest

The Douglas-fir and coast redwood (*Sequoia sempervirens*) forest is the most common forest type in PORE and the GOGA park lands managed by PORE. The forests reach a maximum height of 165–230 ft (50–70 m) in the project area. Approximately 90% of this type of forest in the park is dominated by Douglas-fir while 10% is primarily redwoods (NPS 2004a).

The Douglas-fir-dominated forest is characterized by a strong component of hardwood trees, usually California bay, but tanoak or individual coast live oaks may be present. The shrub understory is highly variable, but is usually moderate to very dense. In those areas where redwood is the dominant tree in the forest canopy, tanoak is often a significant component, sometimes co-dominating with redwood. California bay or Pacific madrone is also often present in significant cover. California hazel and huckleberry (*Vaccinium ovatum*) are the most common understory shrubs, with shrub cover usually sparse to moderate. Swordfern may dominate the herbaceous layer (NPS 2004a).

Extensively harvested in the 1800s and into the early 1900s, these forests have been significantly altered, and most are riddled with networks of old logging roads. Stands of old growth redwoods remain, notably in Roy's Redwoods in San Geronimo Valley and Muir Woods. In Samuel P. Taylor State Park, mainstem Lagunitas Creek flows through a spectacular stand of second-growth redwoods—their tall, straight trunks hinting at the stature of the pre-harvest trees (Marin County 2004). These forests support an average-to-high bird diversity and low bird abundance compared to other habitat types in the watershed. Common species documented include the chestnut-backed chickadee, Pacific-slope flycatcher, spotted towhee, Swainson's thrush, Wilson's warbler and winter wren (*Troglodytes troglodytes*; Flannery et al. 2001). Rare species detected in the watershed include the hermit warbler (*Dendroica occidentalis)*, red-breasted nuthatch and pileated woodpecker. Mammals, including the trowbridge shrew (*Sorex trowbridgii)*, deer mouse (*Peromyscus maniculatus)*, Sonoma chipmunk (*Neotamias sonomae)*, western gray squirrel (*Sciurus griseus)*, gray fox, raccoon and striped skunk prefer redwood-Douglas fir habitat to other habitat types in the watershed.

Seventeen Species of Concern have been detected in the redwood-Douglas-fir habitat type, including four bat species and 13 bird species. Three of these species, the fringed bat (*Myotis thysanodes)*, long-legged bat (*Myotis volans*) and Townsend's big-eared bat (*Corynorhinus townsendii)*, utilize redwood hollows in MUWO as day roosts, night feeding roosts, or maternity roosts (Heady and Frick 2002).

Bishop Pine Forest

Bishop pine (*Pinus muricata*) is the dominant tree species in the forest/woodland community found on the northern portions of Inverness Ridge. Madrone, tanoak, coast live oak and California bay are often present in significant cover. Huckleberry is important to dominant in the shrub layer. Other species common in the understory include salal (*Gaultheria shallon*) and swordfern. Stands of Bishop pine tend to be even-aged, usually originating after a stand-destroying fire. In PORE, approximately 65% of the Bishop pine forest is mature; the remaining 35% burned in the 1995 Mount Vision wildfire. Areas burned in 1995 are characterized by a patchwork of extremely dense stands of 12-15 ft (3.7–4.6 m) tall, regenerating pines alternating with extremely dense stands of blue blossom (*Ceanothus thrysiflorus*) and Marin manzanita (*Arctostaphylos virgata*). Bishop pine forest also includes a small amount of non-native

Monterey pine (*Pinus radiata*) and Monterey cypress (*Cupressus macrocarpa*) stands, amounting to less than 5% of the total forest/woodland acreage. The stands are characterized by planted groves dominated by either tree species, invasive in some areas, usually with sparse to low shrub and herbaceous cover. The understory species are often non-native (NPS 2004a).

Urban Island Habitats

Unique to GOGA, and other natural open spaces that border large urban areas, is the concept of urban island habitats. Urban islands have unique issues, challenges and impacts, which require specialized resource management and wildlife conservation. Within GOGA, the Presidio is a quintessential example of an urban island. The habitats of the Presidio vary from historic non-native forests, coastal scrub and grasslands, to riparian habitats.

Common and widespread species, such as the California slender salamander (*Batrachoseps attenuates)*, alligator lizard (*Elgaria multicarinata)*, California vole (*Microtus californicus)* and western harvest mice occupy a wide range of habitats and appear to have stable populations inside the Presidio. However, the isolated conditions of an urban island reserve may not be able to support the Coast Range newt (*Taricha torosa torosa)*, western skink (*Plestiodon skiltonianus)*, sharp-tailed snake (*Contia tenuis)*, Pacific ring-necked snake (*Diadophis punctatus amabilis)*, Santa Cruz garter snake (*Thamnophis atratus)* and the gray fox in the longer term. Most vertebrate species in the Presidio are birds, including spring and fall migrants or winter visitors. Approximately 60 bird species may be nesting in the Presidio. The forests in the Presidio are important habitat for the olive-sided flycatcher (*Contopus cooperi)*, vireos, warblers, tanagers, grosbeaks, California quail, western screech owl (*Megascops kennicottii)*, wrentit, Hutton's vireo (*Vireo huttoni)* and the hooded oriole (*Icterus cucullatus)*. At least six species of bats have been detected by their sounds. The bats prefer the shelter of the historic World War II structures found at the Presidio.

Water Quality

The parks have a long history of water quality problems due to their proximity to urban and rural land uses. The parks' surface waters and groundwater provide important "beneficial" uses, including agricultural supply, cold freshwater habitat, fish migration, municipal and domestic water supply, preservation of rare and endangered species, contact water recreation, non-contact water recreation, shellfish harvesting, fish spawning, warm freshwater habitat and wildlife habitat. The California Environmental Protection Agency regulates water quality through the State Water Resources Control Board (State Water Board), whose mission is to preserve, enhance and restore the quality of California's water resources and ensure their proper allocation and efficient use for the benefit of present and future generations. California is divided into nine Regional Water Quality Control Boards (CRWQCB); the waters in GOGA and PORE fall under the jurisdiction of the San Francisco Bay Regional Water Quality Control Board (SFRWQCB). Through the creation of Basin Plans the CRWQCBs have set beneficial uses for water bodies and numerical and narrative objectives to meet the uses.

Additional beneficial uses for the Pacific Ocean include commercial and sport fishing, industrial service supply and marine habitat. Freshwater systems within the network support federally protected species, including the California freshwater shrimp, coho salmon, steelhead and the California red-legged frog. The CRWQCB has numerical objectives for water quality parameters (pH, dissolved oxygen, un-ionized ammonia and fecal indicator bacteria) in surface waters.

The main management issues facing PORE and northern GOGA are related to balancing the historical and cultural traditions of ranching and dairy establishments with the very high water quality needed for endangered species such as coho salmon, steelhead trout, California freshwater shrimp and California red-legged frogs. In GOGA, particularly in areas south of the Golden Gate Bridge, the primary issues are storm water discharge and legacy contaminants from abandoned military installations.

The impairment designation of the State Water Board and EPA (Table 18) requires the development of TMDLs for a variety of parameters and streams within park jurisdictions. The 2007 SFRWQCB Basin Plan (Basin Plan) is the master policy document for the San Francisco Bay Region (Region 2). The Basin Plan identifies beneficial use designations for most water bodies, water quality objectives to protect those beneficial uses and a strategy to achieve designated water quality objectives. The SFRWQCB has established a timeline for the development of TMDLs associated with the highest priority impairment listings (Table 19). TMDLs are the pollutant load levels necessary to attain the applicable water quality standards identified in the Basin Plan. A complete TMDL refers to the process and elements associated with establishing a TMDL that include a problem statement, numeric target(s), source analysis, linkage analysis, wasteload and load allocations, implementation plan and monitoring plan (CRWQCB 2007a). The TMDL process for Tomales Bay Watershed pathogens was completed in 2005 (CRWQCB 2005). NPS is currently working with the state and local agencies to develop and implement monitoring and enhancement efforts to address additional impairment issues. Olema Creek, a tributary to Tomales Bay, is monitored by PORE for pathogens in coordination with the CRWQCB as required by the established TMDL (Skancke and Carson 2009). In September 2008, the SFRWQCB approved the Basin Plan amendment incorporating a TMDL for mercury in the Walker Creek and Soulajule Reservoir watersheds.

Table 18. Proposed 2006 Clean Water Act (CWA) Section 303(d) list of water quality limited segments (CRWQCB 2006).

Water Body	Park Unit	Pollutant
Coyote Creek	GOGA	Diazinon
Lagunitas Creek	PORE, GOGA	Pathogens, sediment, nutrients
Richardson Bay	GOGA	High coliform mercury, polychlorinated biphenyls (PCBs), pesticides, exotic species
San Francisco Bay	GOGA	Mercury, PCBs, nickel, pesticides, exotic species, dioxin, selenium
San Francisco Bay Urban Creeks	GOGA	Diazinon
San Francisquito Creek	GOGA	Diazinon, sediment
San Pedro Creek	GOGA	High coliform
Tomales Bay	PORE, GOGA	Sediment, nutrients, mercury, pathogens

Table 19. Completed San Francisco Bay Region total maximum daily load projects (CRWQCB 2007a).

Water Body (Watershed)	Park Unit	Pollutant
San Francisco Bay	GOGA, PRES	Mercury
Tomales Bay	PORE, GOGA	Pathogens
Walker Creek	GOGA	Mercury

Other water quality programs are associated with the three counties within Region 2, Marin, San Francisco and San Mateo counties. Water districts and some watershed groups also monitor water quality. A comprehensive list of water quality programs is located in Appendix 6.

Impairment status (Table 18) highlights the importance for parks to assess the relative impact of uses on water quality. Past water quality monitoring programs were not designed to summarize water quality conditions or to compare or contrast the condition of each park or individual watersheds. In 2003, the SFAN I&M program began to develop a long-term freshwater quality monitoring protocol. The SFAN I&M program is a network of park units that share funding and a core professional staff to conduct long-term ecological monitoring on ‘vital signs’ selected to represent the overall health or condition of park resources. The SFAN protocol was designed to assess and compare freshwater quality throughout the parks and watersheds in the network. The SFAN protocol includes a set of comprehensive standard operating procedures (SOP) that detail the field and laboratory methods, data collection and management standards and analyses to be used for freshwater quality monitoring in the network (Cooprider and Carson 2006a,b,c,d,e,f). In November 2006, the SFAN I&M program began implementation of long-term freshwater quality monitoring following a peer-reviewed, approved protocol (Skancke and Carson 2009).

Historically, NPS sampling programs in the parks were designed to satisfy certain regulatory requirements and/or study discreet water quality problems resulting in a sampling design that is not consistent across sites or randomly applied. Though it is not advisable statistically to generalize the results across the park regions or sub-regions, specific questions can be posed and answered by statistical analyses of existing data. There are also generalizations that can be made from pre-existing studies. Using a “weight of evidence approach” and key datasets, we sought to answer the assessment questions listed Table 20.

Table 20. Water quality assessment questions. The assessment questions were developed by Anitra Pawley and adopted by the I&M Water Quality Monitoring Protocol (Cooprider and Carson 2006a)

Category	General Questions	Specific Questions
Monitoring	Is water quality monitoring designed to report on the overall condition of the park system?	What areas were and are being monitored? What gaps are apparent in the monitoring of these park systems? Are nearshore coastal areas being monitored?
	Which parameters are monitored?	
	Which parameters are not monitored and should be?	
Pollutants	Which measure parameters exceed standards for human health and/or for aquatic health?	
	Of the measurements made, which water bodies exceeded established RWQCB objectives and for which pollutants?	
Hot spots	Where does sampling indicate acute or chronic water quality pollution?	
	What can we infer about differences between watersheds from existing monitoring?	
Causes of pollution	What can we infer about pollution sources?	
Trends over time (long- and short-term)	Are things getting better or worse at stations where monitoring has been consistently performed?	

Numerous water quality monitoring and assessment programs are conducted within or near the two parks (Appendix 6). The programs range from nearshore storm water quality sampling by municipalities (i.e., City of San Francisco Storm Water Monitoring Program) to more comprehensive, large-scale programs whose goal is to summarize conditions off the entire coast (Western EMAP). State programs include the statewide Surface Water Ambient Monitoring Program (SWAMP), the Mussel Watch Program for bioaccumulation of contaminants by resident and deployed bivalves, the Toxic Substances Monitoring Program that measures the contaminant load in fish in freshwater systems and the California Department of Health Services Shellfish Monitoring Program. Federal programs in the region include the USGS, NOAA's Status and Trends Program (2000 to 2002) and EPA's Western EMAP. There is ongoing monitoring of urban creeks by municipal storm water agencies and citizens' volunteer monitoring programs. Coordination and integration with regional monitoring efforts is critical to understanding what data are available and to identify data gaps. For a more thorough discussion of the local programs, see the SFAN I&M Program preliminary water quality status report (Cooprider 2004) in which the parks' monitoring data were analyzed to evaluate water quality. Non-NPS monitoring programs are described in Appendix 6; important findings from the programs are included in the discussion of Freshwater and Estuarine Results under Other Regional Water Quality Monitoring Programs.

Water quality indicators guide these analyses of park water quality and the following discussion of key parameters. SFAN identified and developed freshwater quality monitoring indicators, including targets and SOPs (Indicators 1–4, Table 21). Water quantity (Indicator 5 in Table 21), also an SFAN I&M vital sign indicator is measured in some park programs. Heavy metals (Indicator 6 in Table 21) have also been measured, particularly in urban areas in GOGA, but were not identified as a network priority for ambient monitoring. The present analysis does not include an analysis of flow; however, flow data are collected at several sites in GOGA and PORE in accordance to the SFAN streamflow protocol (Fong et al. 2011).

Table 21. San Francisco Bay Area Network (SFAN) Freshwater Quality Monitoring Protocol indicators, targets and protocol sections (Cooprider and Carson 2006a-f)*.

Indicators	Targets	SFAN Freshwater Quality Monitoring Protocol Section
1. Core parameters	Dissolved oxygen, specific conductance, pH, water temperature	SOP 5: Field Methods for Measurement of Core Parameters
2. Fecal indicator bacteria	Fecal/total coliforms, E. coli, enterococcus (in marine waters only)	SOP 6: Field Methods for Sampling Fecal Indicator Bacteria
3. Sediment	Turbidity, total suspended solids (TSS), suspended sediment concentration (SSC)	SOP 8: Field and Laboratory Methods for Sediment
4. Nutrients	Total Kjeldahl nitrogen, ammonia, nitrate	SOP 7: Field Methods for Sampling Nutrients
5. Water flow and water level	Flow velocity, stream cross-sectional area	Not included here.
6. Heavy metals		Included in past sampling in GOGA, but currently no protocol

*Additional indicators should be considered in the SFAN NPS water quality monitoring program. Some indicators receive statewide and national attention and could be included in future reports. These potential indicators include the presence of harmful algal blooms (HABs), N/P ratios and biomarkers.

PORE and Northern GOGA

In 1999, PORE began ambient surface water quality monitoring in Olema Creek and three recreational ponds to identify pollution sources. Table 22 outlines the monitoring efforts that are ongoing in PORE and northern GOGA. The sites range from wilderness areas to those areas directly downstream of dairies. Much of the water quality monitoring effort has been focused on the Olema Creek watershed and areas of the park with agricultural operations. Olema Creek supports four federally threatened aquatic species and drains to Tomales Bay, which is listed as impaired by the RWQCB for pathogens, sediments, nutrients and mercury. The Olema Creek watershed is the subject of a detailed analysis, including an analysis of hydrologic response and fecal coliform time-series in one of the appendices of the 1999 to 2001 report (Ketcham 2001).

Four programs assess water quality conditions. TMDL monitoring is focused on the Olema Creek watershed to assess performance associated with the Tomales Bay Pathogen TMDL. The Pastoral Zone Salmonid Water Quality Performance Monitoring Program is conducted in accordance with the National Marine Fisheries Service grazing consultation, which required NPS to monitor water quality to determine the effects of ranching on salmonids. Kehoe Creek and Abbotts Lagoon Watersheds Monitoring Programs are conducted to detect source area response

Table 22. Point Reyes National Seashore water quality monitoring programs. Indicators are: 1) core parameters, 2) fecal indicator bacteria, 3) sediment, 4) nutrients, 5) water flow and water level and 6) heavy metals. See Table 21 for detailed indicator descriptions.

Program	Purpose	Location	Indicators	Frequency/Duration
SFAN I&M Freshwater Quality Monitoring Program	Long-term monitoring	Lagunitas Creek [b]	(1) (2) (4)	Monthly, plus one storm event.
		Olema Creek [c]	(1) (2) (4)	Monthly, weekly for 5 weeks in summer and winter, continuous at one site; one storm event.
		Pine Gulch Creek [d]	(1) (2) (4)	Monthly
Pastoral Zone Salmonid Water Quality Performance Monitoring Program	Grazing consultation (NMFS); to monitor the effects of ranching (beef and dairy cattle and horses) on salmonids	Lagunitas Creek [e]	(1) (2) (4) (5)	Monthly, plus one storm event.
		Olema Creek [f]	(1) (2) (4) (5)	Monthly, plus one storm event
		Drake's Estero [g]	(1) (2) (4)	Monthly, plus one storm event
Kehoe Creek Watershed[h]	Effect of dairy cattle ranching; occasional used by children and dogs despite signs warning not to contact the water.	Kehoe Creek [i]	(1) (2)	Monthly
		Kehoe Lagoon [j]	(1) (2)	Monthly
Abbotts Lagoon Watershed	Effects of dairy cattle ranching; popular birding spot and has occasional use by swimmers.	Abbotts watershed [k]	(1) (2)	Quarterly
Beach Monitoring	Identify bacteriological water quality criteria for contact recreation (swimming, kayaking)	Various beaches [m]	(2) (including *Enterococcus*)	April-October weekly
Water Quality Baseline Studies for Coastal Waters of PORE and GOGA (est. June 2006)	Goals include (i) identification of high priority areas based on circulation patterns; (ii) water quality monitoring at selected sites and (iii) spatial surveys of water quality and bio-indicators.	Near shore sites distributed across the PORE and GOGA study region and located near key resource areas	(1) (2) (3) (4) (5), biomarkers, TSF (temp., florescence, turbidity sensor)	Boat-based surveys of pollutant levels and bio-indicators conducted twice during the study period – once in the upwelling season, once in the runoff season.

[a] Monitoring program subsumes the Tomales Bay Pathogen TMDL program (focus on Olema Creek including tributaries John West Fork (Blueline Creek) and Davis Boucher Creek.

[b] Three tributaries are monitored: Cheda Creek (LAG2), Devil's Gulch (LAG1) and Bear Valley Creek (LAG3). There are no sites on the main stem. These streams will be monitored on a two year, rotating basis beginning fall 2008. The rotating schedule allows park staff to monitor more streams with limited funds.

[c] Six sites in Olema Creek: Bear Valley Road (OLM11), Olema mainstem lowest point (OLM10B), Olema mainstem at Five Brooks (OLM4), Olema mainstem at Randall (OLM18), John West Fork (Blueline Creek) (OLM1) and Davis Boucher Creek (OLM6A).

[d] Three sites in Pine Gulch Creek: Pine Gulch Creek Delta (PNG1), near Dogtown (PNG2) and upstream of Texiera Ranch (PNG3).

Table 22. Point Reyes National Seashore water quality monitoring programs (continued).

[e] One tributary is monitored: Cheda Creek (LAG2). There are no sites on the main stem.

[f] Two tributaries are monitored: Giacomini Gulch (OLM2) and Quarry Gulch (OLM4). There are no sites on the main stem.

[g] Two tributaries are monitored: East Schooner Creek (DES2) and Home Ranch Creek (DES3), tributaries to Drake's Estero.

[h] Kehoe Creek monitoring is a source assessment which may not be done continuously in the future.

[i] Seven sites are monitored: three on Kehoe Creek South (PAC1A, PAC1B, PAC1S) and four on North Kehoe Creek (PAC2, PAC2A, PAC2B, PAC2D).

[j] One site is monitored (PAC3)

[k] Sites monitored include mainstem Abbotts, one tributary, one runoff/swale from ranch and one lagoon site (ABB1, ABB2, ABB3, ABB4).

[m] Sites monitored include Drake's Estero, Drake's Beach , Limantour Beach (Drake's Bay), Redwood Creek/Muir Beach.

to dairy improvement projects. The Beach Monitoring program focuses on sites with swimming and kayaking in conjunction with a county-wide recreation site monitoring effort.

In 2006, researchers at the Bodega Marine Lab conducted the "Water Quality Baseline Study for Coastal Waters" of the parks. At each site, core water properties (temperature, salinity, chlorophyll fluorescence, pH, dissolved oxygen, nitrate and turbidity) and analyses of nutrients, metals, total organic carbon were conducted. Sea urchin embryos were used to assess toxicity of water samples; mussels were assessed for their contaminant defense activity (bio-indicator of exposure to organic contaminants); and crabs were inspected for reproductive impairment as an indicator of exposure to contaminants (and, if impact observed, crab embryos were returned to the laboratory to identify specific contaminants). Water properties were monitored continuously along the vessel track from Tomales to Point San Pedro (TSF and turbidity).

GOGA

Water quality monitoring in GOGA has been conducted since the late 1980s, though not continuously (Table 23). Water quality monitoring has been conducted in Redwood Creek and tributaries from at least 1990. Several datasets exist for discrete (i.e., short-term, focused) monitoring projects. For example, monitoring by the NPS in the Redwood Creek watershed was conducted in 1986–1988, 1990–1991 and 1993–1996. Much of the water quality monitoring focus has been on lower Redwood Creek due to concerns related to nutrient and bacteria inputs in this locale (Cooprider 2004). Short-term datasets exist for Rodeo Creek and Tennessee Valley (1994–1996). Rodeo and Tennessee Valley were monitored along with Green Gulch from 1998 to 2001 as part of intensive sampling related to stable operations and other potential sources of bacteria and nutrients. The data are included in STORET and were analyzed by the WRD Baseline Water Quality Data Inventory summarized below. Until January 2004, no routine monitoring of surface water had been conducted by NPS in the southern GOGA lands. Some limited water quality monitoring was conducted within the San Francisquito Creek watershed (West Union Creek is located within this watershed), but no monitoring has been conducted on NPS lands. The EPA and the City of San Francisco Waste Water Treatment Plant conducted water quality monitoring (including indicator bacteria) in San Pedro Creek (Cooprider 2004).

Table 23. Current Golden Gate National Recreation Area water quality monitoring projects. Indicators are: (1) core parameters, (2) fecal indicator bacteria, (3) sediment, (4) nutrients, (5) water flow and water level and (6) heavy metals. See Table 21 for indicator descriptions.

Monitoring Program	Purpose	Location	Indicators	Frequency/Duration
SFAN I&M Freshwater Quality Monitoring Program [a]	Long-term monitoring	Redwood Creek	(1) (2) (3) (4)	Monthly, plus one storm event.
		Rodeo Creek [b]	(1) (2) (3) (4)	Monthly, plus one storm event.
		Tennessee Creek [c]	(1) (2) (3) (4)	Monthly, plus one storm event.
		West Union Creek	(1) (2) (3) (4)	Monthly, plus one storm event.
Beach Monitoring	Identify bacteriological water quality criteria for contact recreation (swimming, kayaking)	Various beaches [d]	(2) (including *Enterococcus*)	April-October weekly
Stables Study	Characterize surface water quality in the vicinity of Marin County horse stables operations in GOGA	Redwood, Tennessee and Rodeo Creeks	(1) (2) (3) (4) (6)	After storms; periodically through the winter
Water Quality Baseline Studies for Coastal Waters of PORE and GOGA *(est. June 2006)*	Goals include (i) identification of high priority areas based on circulation patterns; (ii) water quality monitoring at selected sites and (iii) spatial surveys of water quality and bio-indicators.	Near shore sites distributed across the PORE and GOGA study region and located near key resource areas	(1) (2) (3) (4) (5), biomarkers, TSF (temperature, florescence, turbidity sensor) *– see above for details*	Boat-based surveys of pollutant levels and bio-indicators will be conducted *twice* during the study period – once during the upwelling season and once during the runoff season.

[a] This monitoring program subsumes the Tomales Bay Pathogen TMDL program which focused on Olema Creek including tributaries John West Fork (Blueline Creek) and Davis Boucher Creek.

[b] Two sites are monitored in Rodeo Creek watershed: Rodeo Creek below stables (RC1), Gerbode Creek confluence with Rodeo Cr. (GERB1).

[c] Tennessee Valley Creek includes two sites: Tennessee Valley Creek (TV3), Tennessee Valley Creek above Haypress (TV2).

[d] Rodeo Beach, Horseshoe Cove, Stinson Beach and Muir Beach.

GOGA began a winter water quality monitoring program targeting stable operations in 1998 (GOGA Stables Study) supplemented by work from U.C. Berkeley. Parameters include flow (though flow data have been sporadic), pH, temperature, dissolved oxygen, conductivity, biological oxygen demand, salinity, TSS (total suspended solids), fecal and total coliform, nitrates, ammonia, phosphates, Total P, metals (emphasis on copper), methyl blue activated substances and chloride. Not all parameters were monitored at every site. A synthesis of available information on equestrian impacts on water quality is provided by Silkie and Nelson (2007).

Data Availability

Legacy STORET

The STORET Legacy database (http://www.epa.gov/STORET) contains data submitted from a variety of sources through 1999, including the parks. This legacy database is "complete" in that no additional data will be added to it; any more recent data that are submitted will be input into the modernized STORET. Two WRD Baseline Water Quality Data Inventory and Analysis Reports (Horizon reports) analyzed Legacy STORET data for: 1) PORE and the northern GOGA park lands (NPS WRD 2003); and 2) GOGA park lands (NPS WRD 2005). The data extracted for these analyses were obtained and used to assess water quality for pre-1999 conditions. It is important to note that each of these analyses/reports included sites within 3 miles (4.8 km) of the park boundaries, and the reports provide a general indication of regional water quality and parameters that exceed standards to assess in future studies. Upstream results, especially in urban areas may overemphasize problems relative to water quality issues that exist within park boundaries.

NPS Water Quality Data

Sites within PORE and GOGA have been monitored for various parameters since the 1950s, resulting in datasets of varying quality. Many of these sampling events targeted specific water quality problem areas, specifically pastoral and horse stable operations, and were not intended to document basic water quality conditions for the entire park system. For both parks, most of the data were entered into the Legacy STORET database through 1998. Most available data from 1999 to 2005 have been entered in a Microsoft Access database for PORE and northern GOGA; however, for southern GOGA data are available for discreet studies (Table 23) in the form of Excel spreadsheets. For most of the earlier studies, information on Quality Assurance/Quality Control (QA/QC) and intent of the data collection are not easily accessible; reports listed below provide information on NPS data collection efforts since the early 1990s.

- NPS 1996 Fall Fish Kill Evaluation for Rodeo Lagoon, Golden Gate National Recreation Area, Marin Co. (Fong 1997)
- NPS Winter 1997–1998 Water Quality Monitoring at Golden Gate Dairy Tributary (Fong and Canevaro 1998)
- Golden Gate National Recreation Area Storm Water Monitoring Program 1997/1998 (Beutel 1998)
- Winter 1999 to 2000 Water Quality Monitoring at Golden Gate National Recreation Area Stables (NPS 2000)
- Winter 2000 to 2001 Water Quality Monitoring at Golden Gate National Recreation Area Stables (NPS 2001)
- Point Reyes National Seashore Water Quality Monitoring Report, May 1999 – May 2001 (Ketcham 2001)
- Baseline Water Quality Data Inventory and Analysis Report, Point Reyes National Seashore (PORE Horizon Report; NPS WRD 2003)

- Baseline Water Quality Data Inventory and Analysis Reports, Golden Gate National Recreation Area (GOGA Horizon Report; NPS WRD 2005)

The long-term water quality monitoring program for the parks was re-evaluated as part of the SFAN I&M approach (Cooprider and Carson 2006a). The design for PORE and northern GOGA continues to include targeted monitoring of specific watersheds. The monitoring sites were selected to understand the condition of specific watersheds, including particular watersheds which have experienced pollution problems in the past.

SWAMP Database

A statewide repository of data is being developed to support SWAMP, undertaken by the CRWQCB. The SWAMP database is a standardized data management, evaluation and reporting system which serve as the mechanism for data sharing among project participants. Data sharing is required if the SWAMP goal of producing an integrated hydrologic unit assessment of the state's surface waters is to be achieved. While data sharing is the primary focus, the Information Management System has been developed with the recognition that SWAMP is an initial effort toward data standardization among regions, agencies and laboratories, and that protocols adopted here will be used for data sharing across other projects in the state. The database, specific documentation and further information can be found at the SWAMP website (http://www.swrcb.ca.gov/water_issues/programs/swamp/). The SWAMP program has initiated monitoring at sites within both parks. Existing data is summarized in (CRWQCB 2008).

The California Environmental Data Exchange Network (www.ceden.org) is a growing statewide cooperative effort of various groups involved in the water and environmental resources of the State of California. This network is open to federal, state, county and private organizations interested in sharing data throughout the state. At the time of this analysis, the SWAMP database was being developed, so the following summaries do not include SWAMP coastal data.

Methods and Water Quality Monitoring Standards

To evaluate water quality, we reviewed existing documents and analyzed water quality data for the last 15 years. This period was a somewhat arbitrary decision as there is no official guidance at the statewide, regional, or park level on appropriate time scales for assessment[20]. When possible we compared the condition in the 1990s determined from data obtained from Legacy STORET with more recent data collected (1999 to 2005).

Importing Data

We summarized the results found in existing Horizon Reports (NPS WRD 2003, 2005)by creating data summary tables for the analysis of historic data (pre-1999 data, see Appendices 7 and 8) and extracting data to provide an overview of park conditions in the 1990s for comparisons with post-1999 datasets. We imported the station, parameter and parameter code files into ESRI Arc GIS Version 9.0 to perform queries for the parameters outlined in the following narrative and associated standards. These queries resulted in our ability to construct a series of maps to describe the spatial distribution of water quality stations and results for pre-1999 conditions (Figures 52 and 53).

[20] B. Ketcham, National Park Service, Point Reyes National Seashore, CA, pers. comm., 2002.

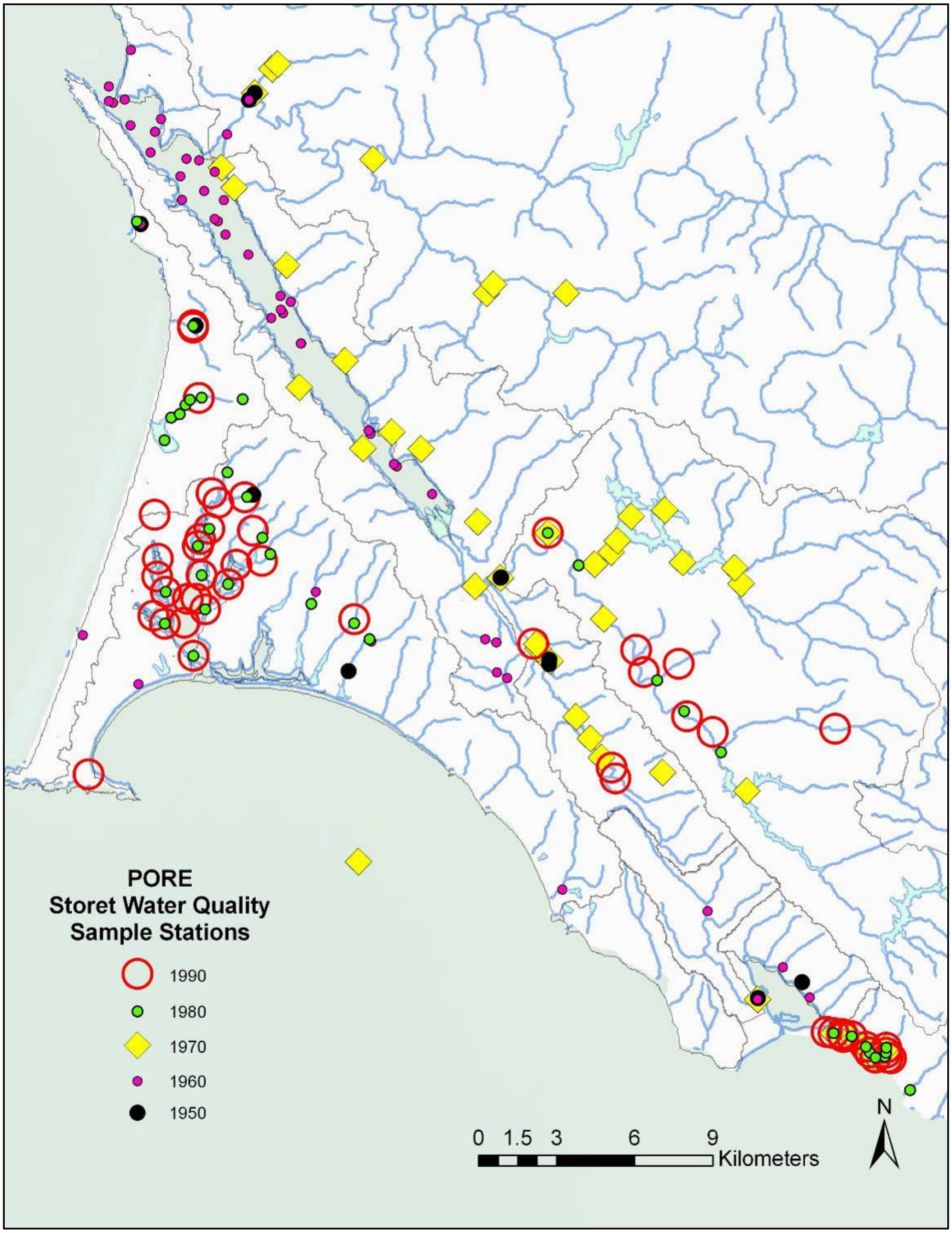

Figure 52. Legacy STORET sampling stations in the 1950s, 1960s, 1970s, 1980s and 1990s in Point Reyes National Seashore and northern Golden Gate National Recreation Area. The distribution of stations differs in each decade indicating discontinuous sampling across the landscape, which highlights the difficulty of evaluating long-term (more than a decade) trends at single stations.

Figure 53. Point Reyes National Seashore and northern Golden Gate National Recreation Area water quality monitoring stations sampled from 1999 to 2005 (NPS PORE WQ database).

Post-1999 data for PORE were imported from their Microsoft Access database which includes data collected after 1999. The GOGA data were imported from Microsoft Excel spreadsheets provided by GOGA park personnel. A new database, called NPS STORET, which is EPA STORET compatible, was being developed[21], but was not available at the time of this analysis. The NPS WRD program has since released the NPS STORET Program. This system was fully operational in the SFAN parks in fiscal year 2006.

Choosing Parameters

Important parameters were chosen based on knowledge of water quality impairments, recent reports, the SFAN I&M indicators list, data availability and professional judgment. The parameters, their importance and possible pollutant sources are discussed under "Types of Pollutants and Condition." Scatter plots for each parameter include all of the NPS data from 1999 to 2005 (November 2005); we restricted the GIS analysis to samples taken from 1999 to 2005 and those stations with more than four sampling dates per year.

Choosing Long-Term Stations

In addition to spatial representations of the data, we used GIS comparisons of site locations for pre- and post-1999 sites and in-house knowledge of station locations[22,23] to establish "long term stations" to compare trends in water quality parameters for specific parameters between historical and more recent sampling periods.

PORE and Northern GOGA: Site and parameter comparisons were considered, with only 16 sites that matched or were very close to old sites; historical data for these sites were extremely limited, usually a single sampling date. Four of the sixteen stations were sampled prior to 1980, making comparisons even less meaningful. Monitoring occurred at only three stations for more than a year during a recent period. Consequently, trends are constructed only from the post-1999 data when site locations were consistent (Figure 53).

GOGA: For southern GOGA, the recent data are very spotty for park data resources. Only beach sampling performed by other entities provide consistent data for specific locales.

Statistical Analyses

For the post-1999 data from PORE Microsoft Access database and the GOGA Stables Study, we performed box plot analyses and calculated quantities using JMP software program (SAS Institute, Inc.). Results are provided for PORE and northern GOGA in subsequent sections.

Water Quality Standards

The criteria used to assess water quality data for PORE and GOGA are summarized in Tables 24 and 25 and discussed below. The criteria were drawn from current national (US EPA 2000a, 2000b), California (SFRWQCB guidance documents) and the more recently completed SFAN I&M protocols. Generally, the most stringent criteria were used to assess water quality in park lands. GOGA and PORE are regulated by the SFRWQCB. Through Basin Plans, the regional boards set numerical and narrative objectives for surface waters that in some cases vary

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[21] B. Ketcham, National Park Service, Point Reyes National Seashore, CA, pers. comm., 2002.
[22] M. Cooprider, National Park Service, San Francisco Bay Area Network Inventory and Monitoring Program, Sausalito, CA, pers. comm. 2002.
[23] B. Ketcham, National Park Service, Point Reyes National Seashore, CA, pers. comm., 2002.

Table 24. Water quality standards or guidelines used for this analysis. MPN = most probable number; JTU/FTU/NTU = nephelometric turbidity units.

Contaminant/ Parameter [1]	**Standard or Guideline**	**Water Criterion**	**Source**
Dissolved Oxygen	5 mg/L (warm water), 7 mg/L (cold water)	San Francisco Bay Region Water Quality Control Board	San Francisco Basin Plan (CRWQCB 2007a)
pH Range	6.5 to 8.5	EPA chronic criteria for marine aquatic life or EPA chronic criteria for freshwater aquatic life; San Francisco Basin Plan	US EPA 1976, 1986, San Francisco Basin Plan (CRWQCB 2007a)
Temperature	Not >2.8°C (37°F) over natural conditions 16°C (61°F) and >20°C (68°F)	Recommended	San Francisco Basin Plan (CRWQCB 2007a)
Specific Conductivity	850 µS/cm, 1700 µS/cm	Recommended[2]	Ketcham 2001
Total Suspended Solids	< 50mg/L (guideline)	Recommended[2]	Ketcham 2001
Turbidity	50 JTU/FTU/NTU, 1.2 NTU	WRD screening criterion; EPA Forested Western Streams Criteria	US EPA 2000d
Nitrate	1 mg/L NO_3-N; 10 mg/L NO_3-N	Pristine conditions based on experts; drinking water criterion	Larson, Creager, pers. comm; US EPA (1986) and Water Resources Division screening criteria
Un-ionized Ammonia (NH_3)	0.025 annual median	Lethal to fish	San Francisco Basin Plan (CRWQCB 2007a)
Phosphorus	0.02 mg-P/L, with a range of reference conditions from 0.01–0.05 mg-P/L	EPA Ecoregion III reference conditions.	US EPA 2000c
Total coliform Concentrations	10,000 MPN/100 mL**	Single day sampling criteria	San Francisco Basin Plan (CRWQCB 2007a)
Fecal coliform Concentrations	≤200 MPN/100 mL	Geometric mean of five equally-spaced samples over a 30-day period.	San Francisco Basin Plan (CRWQCB 2007a)
E. coli Concentrations	235 MPN/100 mL	Single day sampling criteria	San Francisco Basin Plan (CRWQCB 2007a)
Enterococci	104 MPN/100 mL (marine), 61 MPN/100 mL (fresh water)	Single day sampling criteria	San Francisco Basin Plan (CRWQCB 2007a); used by counties

[1] Sufficient data on total nitrogen and chlorophyll *a* was not available for this analysis.

[2] These criteria are not standards and should be considered guidelines only.

Table 25. Water quality standards for coliform bacteria. The standards in bold were used as criteria for developing maps of exceedance. Source: Basin Plan (CRWQCB 2007a). MPN = most probable number.

Beneficial Use	Fecal Coliform (MPN/100ML)	Total Coliform (MPN/100ML
Water Contact Recreation [a]	Log mean <200 90th percentile <400	Median <240 no sample >10,000
Shellfish Harvest [b]	Median <14 90th percentile <43	Median <70 90th percentile <230[c]
Non-contact Water Recreation [d]	Mean <2,000 90th percentile <4,000	
Municipal Supply: Surface Water [e] Groundwater	Log mean <20	Log mean <100 <1.1[f]

Note: This table gives the reader a sense of the complexity of applying pathogen standards. We used a simple "rule of thumb" because not enough samples are taken to calculate the geometric mean.

[a] Based on a minimum of five consecutive samples equally spaced over a 30-day period.

[b] Source: National Shellfish Sanitation Program.

[c] Based on a five-tube decimal dilution test or 300 MPN/100 mL when a three-tube decimal dilution test is used.

[d] Source: Report of the Committee on Water Quality Criteria. National Technical Advisory Committee. 1968.

[e] Source: DHS recommendation.

[f] Based on multiple tube fermentation technique: equivalent test results based on other analytical techniques, as specified in the National Primary Drinking Water Regulation, 40 CFR. Part 141.21(f), revised June 10, 1992, is acceptable.

depending on the type of beneficial use (e.g., drinking, contact recreation, support of aquatic life. Several parameters (e.g., nitrates, phosphorus) that are considered of importance to existing park water quality monitoring programs do not have criteria established by the SFRWQCB, but guidance is available through regional criteria documents provided by EPA (US EPA 2000c,d). A separate document, the Ocean Plan, was produced by the State Water Board to regulate ocean waters (California EPA 2005). The Ocean Plan established water quality objectives for all ocean waters (not Bay) as well as stipulates ASBS areas as no discharge zones.

Freshwater and Estuarine Results

PORE and Northern GOGA Data Summaries (PORE)

Pre-1999 Stations and Parameters

Of the 221 monitoring stations in the Legacy STORET database for the region, 147 stations were located within the park managed boundaries covering virtually all of the watersheds. Of the 147 park stations, 75 were located within the PORE park boundary and 72 stations were located within the northern GOGA park boundary. The samples were collected from 1901–1998 (with the majority of observations occurring after 1954). Most of the monitoring stations are either one-time or intensive single-year sampling efforts. Figure 52 illustrates how sampling in the parks has changed from decade to decade, covering differing regions. At Drake's Estero, monitoring by the California DHS for shellfish beneficial uses appeared to be the most consistent during the 1980s and 1990s; however, a comparison of specific stations indicated that data collections were not co-located or continuous. Nearly all of the sites were sampled sporadically for only 1–2 years, which eliminated the possibility of matching new sites with old sites prior to 1999 and developing information on long-term water quality trends.

The "PORE Horizon" report includes the North District Lands of GOGA, which are administered by PORE, and some GOGA acreage south of the Bolinas/Fairfax Road that buffers the North District Lands (NPS WRD 2003). Prior to 1999, eight stations (two within park boundaries) yielded long-term records consisting of multiple observations for several important water quality parameters. Only Fitzhenry Creek near bridge on park trail (PORE 0011) and Easkoot Creek downstream of Parkside Restaurant (PORE 0008) are within park boundaries. The stations yielding longer-term records were generally outside of the park boundaries, are: 1) Inner Seadrift Lagoon at 175 Seadrift Road (PORE 0014); 2) Easkoot Creek at Calle del Arroyo and State Route 1 (PORE 0010); 3) Laurel Creek upstream of Stinson Beach Church (PORE 0009); 4) Bolinas Lagoon near Easkoot Creek Inlet (PORE 0012); 5) Easkoot Creek downstream of Calle del Pinos Street (PORE 0007); and 6) Walker Creek at Camp Tomales (PORE 0213)[24].

Appendix 8 summarizes those parameters for which there were a significant number of samples throughout the course of the study for the PORE managed lands (PORE and northern GOGA). Coliform sampling makes up the bulk of the monitoring effort and was initiated in the early 1970s. Nitrogen nutrients are the second most common parameter studied and were initiated in the mid-1970s. These results are discussed more fully in each parameter section below.

Post-1999 Stations and Parameters

From 1999 to 2005, the Olema watershed was well sampled; other watersheds were either poorly sampled (i.e., Pine Gulch and Lagunitas) or not sampled at all (i.e., Alamere) (Figure 53). Water quality sampling in Lagunitas is performed by the SFRWQCB as part of the TMDL monitoring program, SWAMP collects water quality data, and the Salmon Watershed and Protection Network (SPAWN) completed three years of water quality monitoring upstream in the watershed in 2009. Those data were not included in the PORE database prior to this analysis. The parks should incorporate these data in the future.

Southern GOGA Data Summaries (GOGA)

Pre-1999 Stations and Parameters

STORET retrieval for the study area yielded 146,476 observations for 432 separate parameters collected by the NPS, USGS, EPA, COE, BOR and the State Water Board at 435 monitoring stations from 1901 through 1999. More than half the stations (225) were located within park boundaries and 102 stations (31 within the park boundaries) were established, but contained no data. Eighteen stations (five within the park boundaries) were established, but did not contain data appropriate for statistical analysis. Of the 435 monitoring stations, 14 contained data locked by the EPA, BOR and the State Water Board[25]. Locked data are not included in the 146,476 total observations retrieved from STORET for the southern GOGA study area. Most of the monitoring

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[24] Many of these stations are outside of northern GOGA, but upstream, and represent an indicator of regional water quality conditions and possible influences on the water bodies.

[25] When data are entered into STORET and locked by the controlling agency (EPA, BOR, or the State Water Board), results of a STORET retrieval are limited to general station information and any "unlocked" portions of the data. Additional data must be obtained by contacting the controlling agency (EPA, BOR, or the State Water Board).

stations are either one-time or intensive single-year sampling efforts by the collecting agencies. Figure 54 illustrates how sampling in the parks has changed from the 1950s to 1990s.

Eighteen stations within the study area (seven within park legislative boundaries) yielded long-term records consisting of multiple observations for several important water quality parameters (see Station Period of Record Tabulation). The stations yielding the long-term records within the park boundaries are: 1) Lobos Creek Control (GOGA 0139); 2) Lobos Creek downstream of Lincoln Blvd (GOGA 0154); 3) San Francisco Bay at Fort Point (GOGA 0209); 4) San Andreas Reservoir (GOGA 0077); 5) Lower Crystal Springs Reservoir (GOGA 0043); 6) Pilarcitos Reservoir (GOGA 0051); and 7) 002S006W02JS01M (spring near Lobos Creek) (GOGA 0146). The stations yielding the longest records with the study area, but outside of the park boundaries, are: 1) San Francisco Bay at Treasure Island (GOGA 0234); 2) Colma Creek at South San Francisco (GOGA 0090); 3) Pacific Ocean in line with Fulton Street (GOGA 0128); 4) Pacific Ocean west of San Mateo County Line (GOGA 0101); 5) Pacific Ocean in line with Lincoln Way (GOGA 0124); and 6) Pacific Ocean in line with Vicente Street (GOGA 0112).

Appendix 7 summarizes the parameters with a significant number of samples for GOGA. Similar to PORE and northern GOGA, coliform sampling initiated in the early 1970s makes up the bulk of the monitoring. Dissolved oxygen and pH were the third and fourth most common parameters measured. Unlike PORE, heavy metals were monitored and include mercury, nickel, chromium, copper and lead. Nutrients were measured more infrequently than in PORE and northern GOGA.

Post–1999 Stations and Parameters

The GOGA Stables Study initiated in 1998 focuses on the Redwood Creek, Tennessee Valley Creek and the Rodeo/Gerbode Creek watersheds north of the Golden Gate Bridge to determine the effects of horse stable operations; the stations sampled from 1999 to 2005 (Figure 55). Several of these stations have been included in the SFAN Freshwater Quality Monitoring Protocol implemented in 2007 (Cooprider and Carson 2006a). There are additional monitoring programs operated by City of San Francisco and the counties for storm water monitoring.

Pollutants and Condition

The following narrative provides a park-wide overview of condition from existing reports and our analyses. For each of the parameters, we provide a spatial overview of park condition for PORE and northern GOGA (PORE) and Southern GOGA (GOGA) with scatter plots and watershed maps. See Appendices 7 and 8 for pre-1999 conditions. We discuss the results and suggest possible causes for pollution impacts. Much of the text explaining the parameters were adapted from Cooprider (2004) and Stafford and Horn (2004).

Temperature

Water temperature is affected by air temperature, humidity, percent shading, the turbidity or cloudiness of the water, as well as the temperature of groundwater and storm water inflows (Theurer et al. 1984, Essig 1998). In coastal California, the most important factor in small streams and rivers is the degree of shading provided by the trees and bushes of the riparian zone.

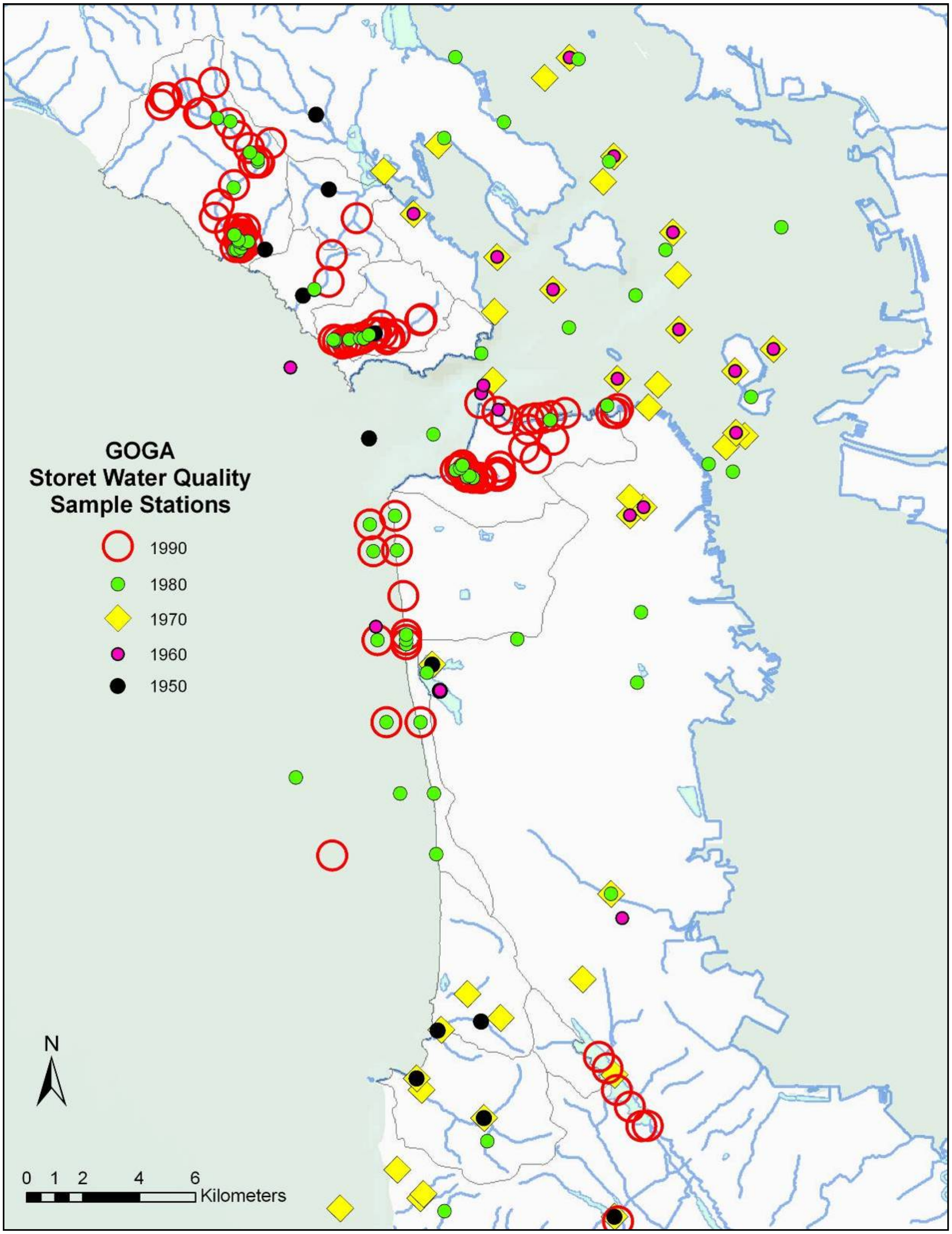

Figure 54. Legacy STORET sampling stations in the 1950s, 1960s, 1970s, 1980s and 1990s in Golden Gate National Recreation Area (GOGA). The distribution of stations differs in each decade; however, sites hold more promise for evaluating trends from the 1980–1990s.

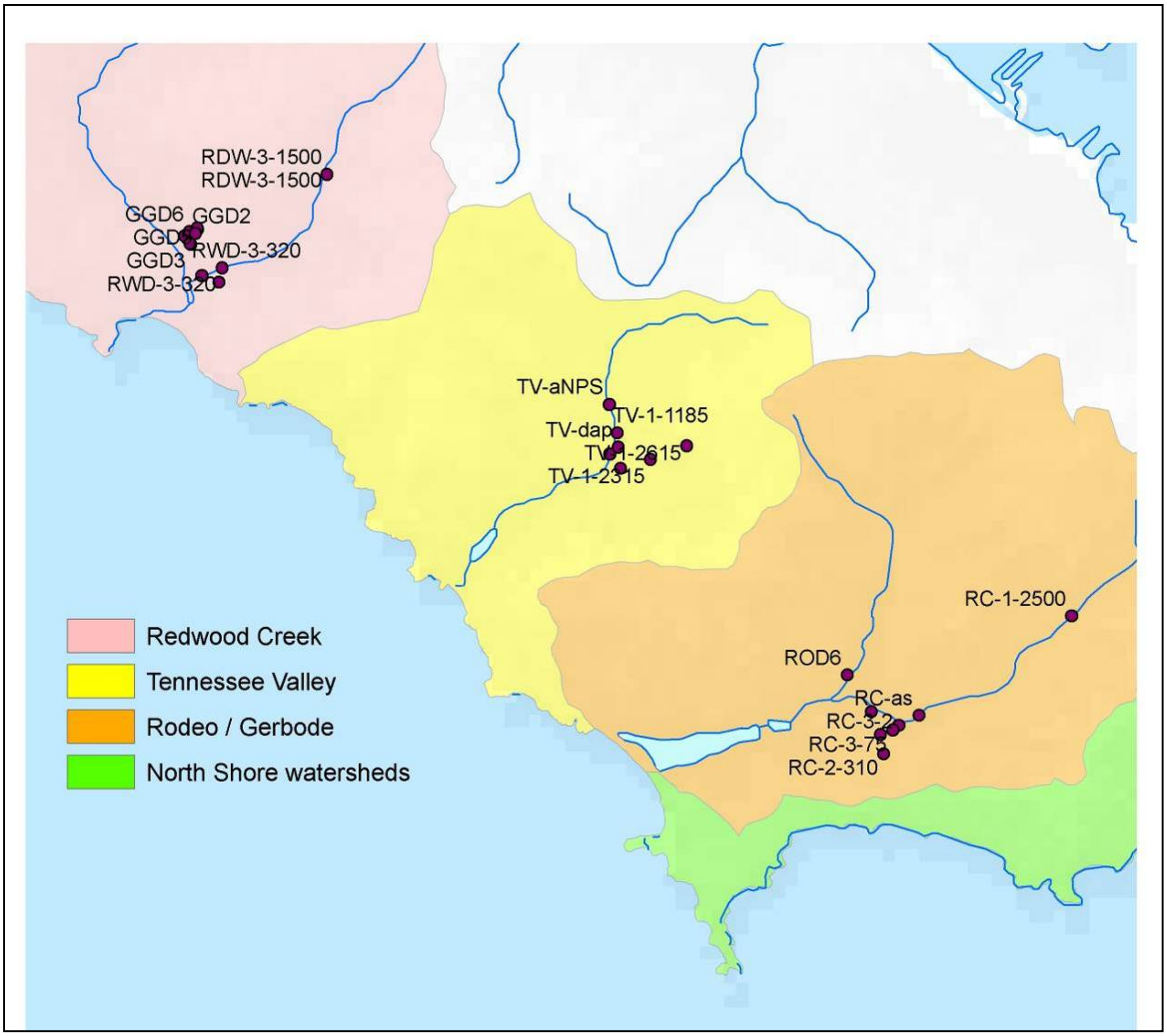

Figure 55. Golden Gate National Recreation Area (GOGA) water quality monitoring stations sampled from 1999 to 2005 as part of the GOGA Stables Study. Stations are located in Redwood Creek, Tennessee Valley Creek and Rodeo/Gerbode Creek watersheds.

Flows also impact temperature regimes (Essig 1998). In small streams, the temperature can vary as much as 10°C (50ºF) over the diel (24-hr) cycle and a similar amount between shady and sunlit reaches (Bilby 1984). In larger rivers, coastal bays and estuaries, the temperature varies less, about 3ºC (5.4ºF) per day, but is generally higher than in shaded streams.

Desired temperatures for streams depend on the stream type and location. The Basin Plan states that "the natural receiving water temperature of inland surface waters shall not be altered unless it can be demonstrated to the satisfaction of the Regional Board that such alteration in temperature does not adversely affect beneficial uses," and that "the temperature of any cold or warm freshwater habitat shall not be increased by more the 2.8ºC (37ºF)above natural receiving water temperatures" (CRWQCB 2007a). The optimal thermal tolerance range for coho salmon is from 11.4–16.6ºC (53–62ºF) (Coutant 1977). Steelhead trout prefer slightly cooler temperatures, from 10–13ºC (50–55ºF) (Bjornn and Reiser 1991). Salmonids and other fishes can survive above their tolerance range if the exposure is brief or if the temperature increase is slow (days). Most salmonids can survive much lower temperatures than their normal range, but growth is slow and long-term population success is adversely affected. For example, for coho the best growth is 11.8–14.6ºC (53–58ºF), which is a good temperature for migrations upstream (Brett 1952, Reiser and Bjornn 1979). In contrast, temperatures, from 4.4–9.4°C (40–49ºF), are best for spawning and the early life stages of the fry (Brett 1952, Reiser and Bjornn 1979).

Water temperature at GOGA and PORE has been measured consistently in the field with hand-held YSI brand meters. Beginning in 1999 as part of the NPS Coho and Steelhead Restoration Project, some streams have had continuous temperature loggers from late spring and removed before the first major storms in fall/winter (see Park Description chapter for more information). The purpose was to conduct long-term temperature monitoring to characterize diurnal variations and thermal range of streams that are critical to the protection of coho salmon and steelhead trout (Ketcham 2001). Measurements were also made during the GOGA Stables Study.

PORE: Based on 999 values from 1999 to 2005, the median value for temperature in PORE streams was 12.6°C (55ºF) with an Interquartile Range (IQR)[26] from 10.8–14.5°C (51–58ºF), indicating that most sampling sites fall in the comfortable range for salmonids during most of the year (Figure 56). On closer inspection, lagoon sites such as Kehoe and Abbotts Lagoons and small swales near ranches in the Abbotts-Kehoe (ABB3 – McClure's dairy swale) and Drakes Estero watersheds (DBY2 – B Ranch) are locations where temperatures exceed the range for cold water salmonid species (>20°C; >68 ºF); however, salmonids do not occur in these areas and the lagoons are important only for warm water beneficial uses. One stream site, OLM10A on Olema Creek below Caltrans (Pasture flow), exceeded the threshold for coldwater species on a single occasion. The mean water temperature value for this station was 16.9°C (62ºF).

GOGA: Based on 279 values from 1999 to 2005, the median value for temperatures measured in the Stables Study is 11.4°C (53ºF) with an IQR from 10.3–12.2°C (51ºF); indicating that all samples fall in the comfortable range for salmonids during most of the year. No sites exceeded the critical temperature of 16°C (61ºF) (Figure 57).

<u>pH</u>

If chemicals such as calcium are present in water, the acid or alkali will interact with the calcium, which acts as a buffer to reduce swings in pH (Hem 1985). In California Coast Range streams, which are well-buffered due to sedimentary rock, pH is fairly stable. The pH will go down as a result of acid-rain deposition or high levels of respiration in the water column, go up due to construction and road run-off, and experience large diurnal fluctuations due to algal photosynthesis and respiration. The SFRWQCB objective for pH is 6.5–8.5 (CRWQCB 2007a). The range is the same for the Central Coast RWQCB (CRWQCB 1994); specific pH ranges vary slightly depending on the beneficial use (e.g., the pH range for contact recreation is 6.5–8.3). In the ocean, pH is always slightly alkaline (~7.5), but is so well buffered that it changes little under normal conditions. Typically, pH has been measured in the field with waterproof Oakton pH meters with a relative accuracy of 0.01 pH units. The SFAN I&M protocol calls for pH measurements to be made to 0.01 pH units.

[26] Interquartile Range (IQR): The interquartile range is a measure of spread or dispersion - highlights the difference between the 75th percentile and the 25th percentile.

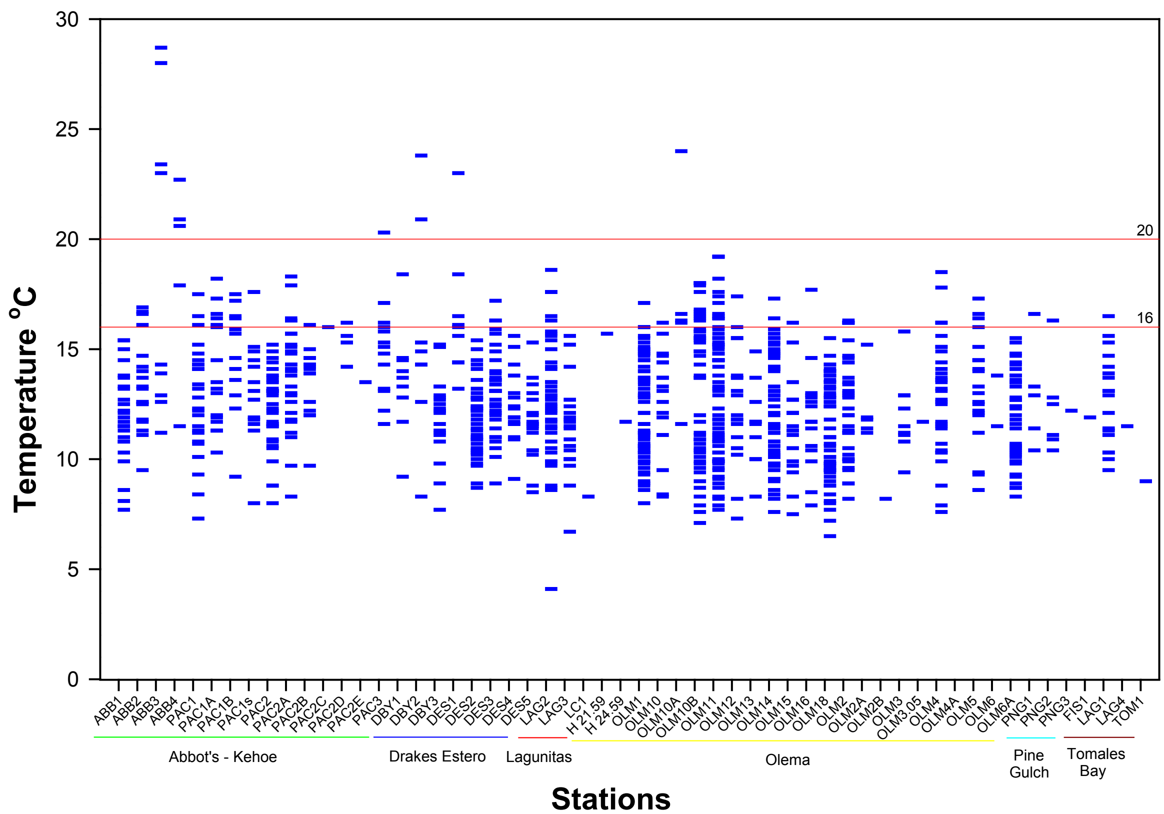

Figure 56. The scatter plot of water temperature measurements in Point Reyes National Seashore and northern Golden Gate National Recreation Area from 1999 to 2005 showing exceedances of 16°C (61ºF) and 20°C (68ºF). Abbotts-Kehoe sites support warm water beneficial uses where high temperatures are expected to be less detrimental to warm water adapted fish species. In this scatter plot and others, Drakes Estero includes Drake's Bay and Drake's Estero.

PORE: pH measurements were taken infrequently prior to 1998 and usually were one-time sampling events. The measurements rarely fell outside of the Basin Plan objective of 6.5–8.5 (CRWQCB 2007a).

From 1999 to 2005, 1,007 pH measurements had a median value of 7.6 with an IQR from 7.2–7.9 and a mean of 7.5. Only 2.5% of the values were above 8.6 and 2.5% of the measurements were below 6.4, indicating that 95% of the time samples had pH values within the acceptable range. This differs from the IQR reported by Stafford and Horne (2004), which included all samples, such as Horseshoe Pond, that had high pH levels. Horseshoe Pond was excluded from the analysis because it was a special, short-duration study. High pH values occurred more frequently than low pH values (Figure 58); however, values are rarely above pH 10. Extreme outliers (pH >10 and <5.5) are likely due to user or equipment error and do not represent the variation at these stations. The outlier data may need to be examined further for QA/QC procedures and flagged in the database. Several sites occasionally exceeded the water quality objective of 8.5; 25% of the exceedences occurred at two sites (DBY2 – B Ranch and ABB4 – in Abbotts Lagoon). Additionally, several sites were below the lower limit of the water quality objective; 10% of samples falling below pH of 6.5 were seen in the Olema watershed above John West Fork and Giacomini Gulch.

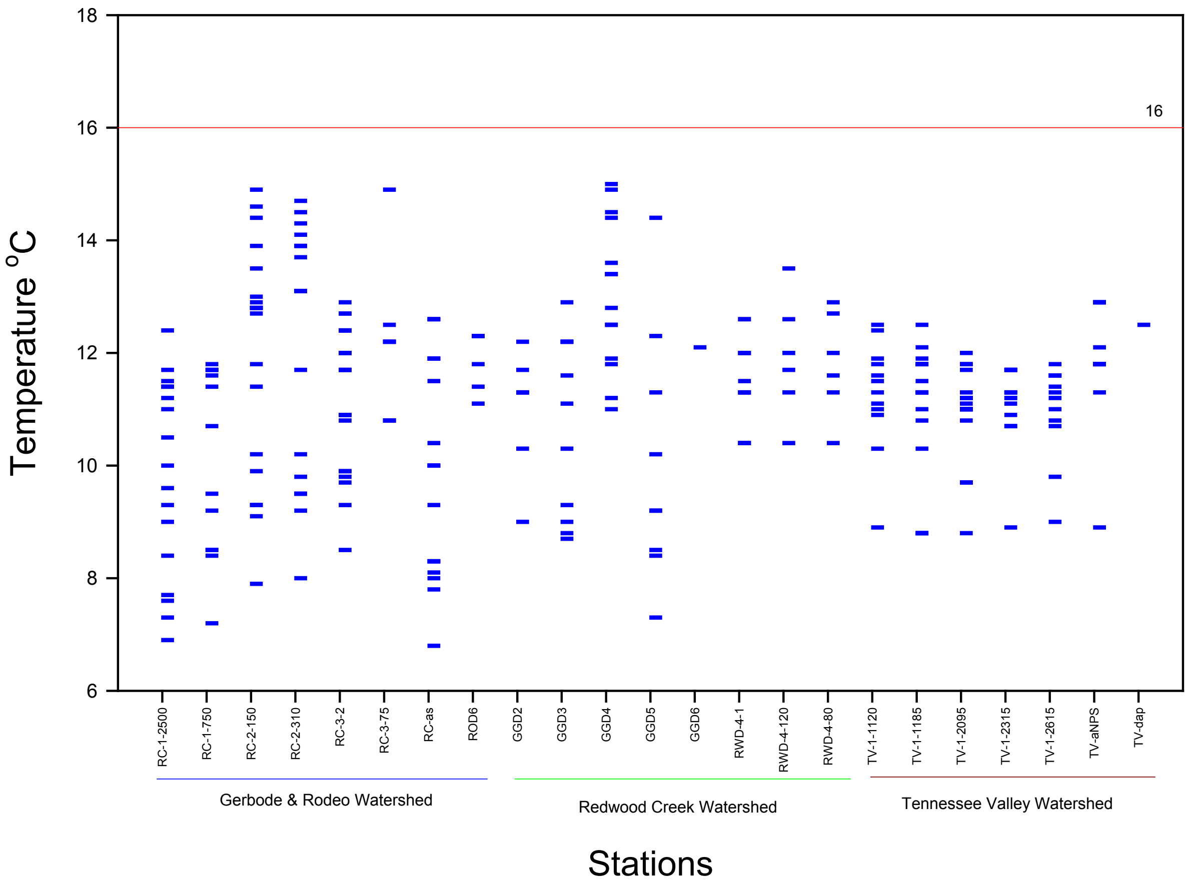

Figure 57. Temperatures measured at water quality sampling locations in Golden Gate National Recreation Area from 1999 to 2005. No temperatures over 16°C (critical temperature for salmonids) were detected at these sites.

GOGA: pH was measured 5,012 times at 155 monitoring stations from 1951 to 1998. Only 62 observations at 19 stations were outside the water quality objective for pH (6.5–8.5) established in the Basin Plan. Less than 2 percent of samples and only 12 percent of stations exceeded the standards. The lowest pH of 6.2 was reported in Denniston Creek at the State Route 1 Bridge (GOGA 0032) in February 1975. The highest pH of 10.8 was reported within GOGA park boundaries in Muir Woods National Monument in Camino del Canyon (GOGA 0379) in December 1997 after NPS staff laid a road in the wet season[27]. The median pH was 7.4 with an IQR from 7.0–7.8, within the desired range. Historic values ranged between 6.0–10.8 (Stafford and Horne 2004). During the GOGA Stables Study (1999 to 2005), 266 pH measurements were made with a median value of 7.5 with an IQR from 7.1–7.7 (Figures 59 and 60); values rarely fell outside the pH range of 6.5–8.5.

[27] D. Fong, National Park Service, Golden Gate National Recreation Area, CA, pers. comm..

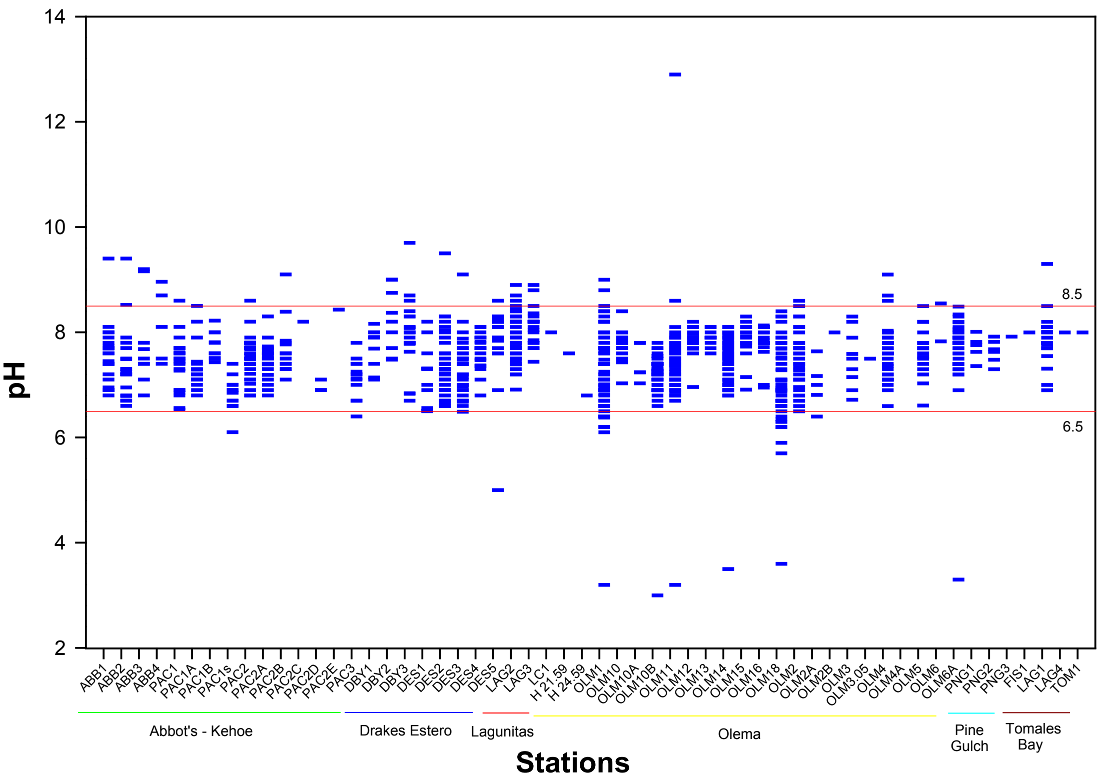

Figure 58. pH for Point Reyes National Seashore and northern Golden Gate National Recreation Area (1999 to 2005). RWQCB water quality objective range from pH 6.5–8.5 outlined in red. pH values below 4 are believed to be due to instrument malfunction.

Conductivity/Specific Conductance

Conductivity, the ability of a solution to pass an electric current, is an indicator of dissolved solids and can be influenced by the geology of an area as well as urban runoff. Ideally, streams should have conductivity between 150–500 µS/cm to support diverse aquatic life (Behar 1997). Conductivity in rivers is mainly affected by the geology of the area through which the water flows (Hem 1985, Behar 1997). Near the ocean, conductivity is influenced by saltwater intrusion and tidal fluxes, making it a less useful parameter for detecting pollution. Generally, very high conductivity levels or an increase in conductivity in freshwater streams indicates pollution upstream, such as inflow from sewage (treated or raw) or runoff from highways. The conductivity of rivers generally ranges between 50–1,500 µS/cm and industrial water can be as high as 10,000 µS/cm (Behar 1997). At about 1,700 µS/cm, the salt levels become lethal in freshwater fish; streams with levels greater than 850 µS/cm are impacted[28]. Sites with mean conductivity above 850 µS/cm were considered impacted by land use activity and sites with conductivity values of 500–850 µS/cm were considered likely impacted by existing land use activities. Conductivity varies across water temperatures; specific conductance is conductivity adjusted to 25°C (77ºF). Results are commonly reported as specific conductance to compare results across stations or sampling times with varied water temperatures. The Basin Plan (CRWQCB 2007a) does not have objectives for specific conductance, but states that

[28] M. Rugg, California Department of Fish & Game, pers. comm., 2000.

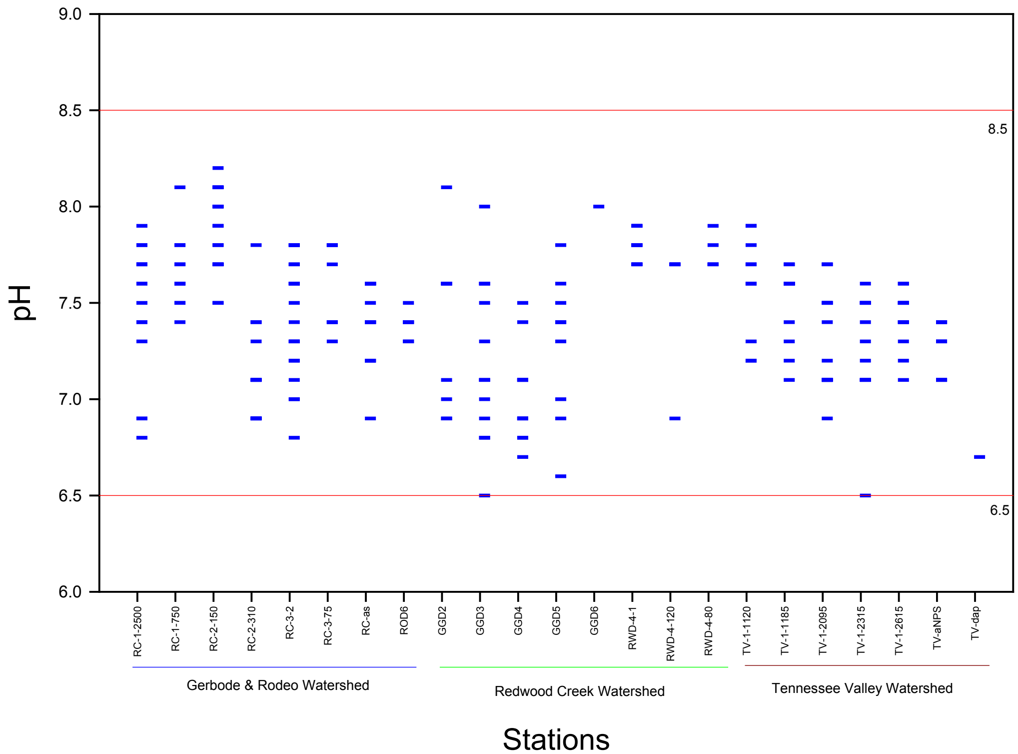

Figure 59. pH for Golden Gate National Recreation Area (GOGA) from 1999 to 2005 during the GOGA Stables Study.

"controllable water quality factors shall not increase the total dissolved solids or salinity of waters of the state so as to adversely affect beneficial uses, particularly fish migration and estuarine habitat."

Specific conductance was measured in the field with hand-held YSI-30 and YSI-85 meters. Most stream monitoring stations measured within PORE and GOGA had specific conductance values within the range of 20–400 µS/cm, with a few values between 600–8,000 µS/cm where seawater tidal influence or high pollution exists.

PORE: In PORE and northern GOGA, median specific conductance measured for 1,014 samples from 1999 to 2005 is 278 µS/cm with an IQR from 181–370 µS/cm. Figure 61 shows the specific conductance maxima at PORE monitoring locations and compares values to 850 µS/cm and 1,700 µS/cm. Values higher than 1,700, indicating severe pollution, occurred at dairy locations, including North Kehoe Creek (PAC2A), at the J Ranch and K Ranch property line (PAC2B), the L Ranch Impact Yard (PAC1B), the A and B Ranches (DBY3, DBY2) and the McClure's dairy swale (ABB3). High conductivity likely due to saltwater influence was also noted at Abbotts Lagoon (ABB4), and the tide gates at the Fish Hatchery (FIS1) and Lagunitas (LAG4) at the north end of the levee.

GOGA: In the GOGA Stables Study conducted from 1999 to 2005, median specific conductance measured for 279 samples is 195 µS/cm with an IQR from 152–272 µS/cm. Samples did not exceed the 850 µS/cm criteria (Figure 62).

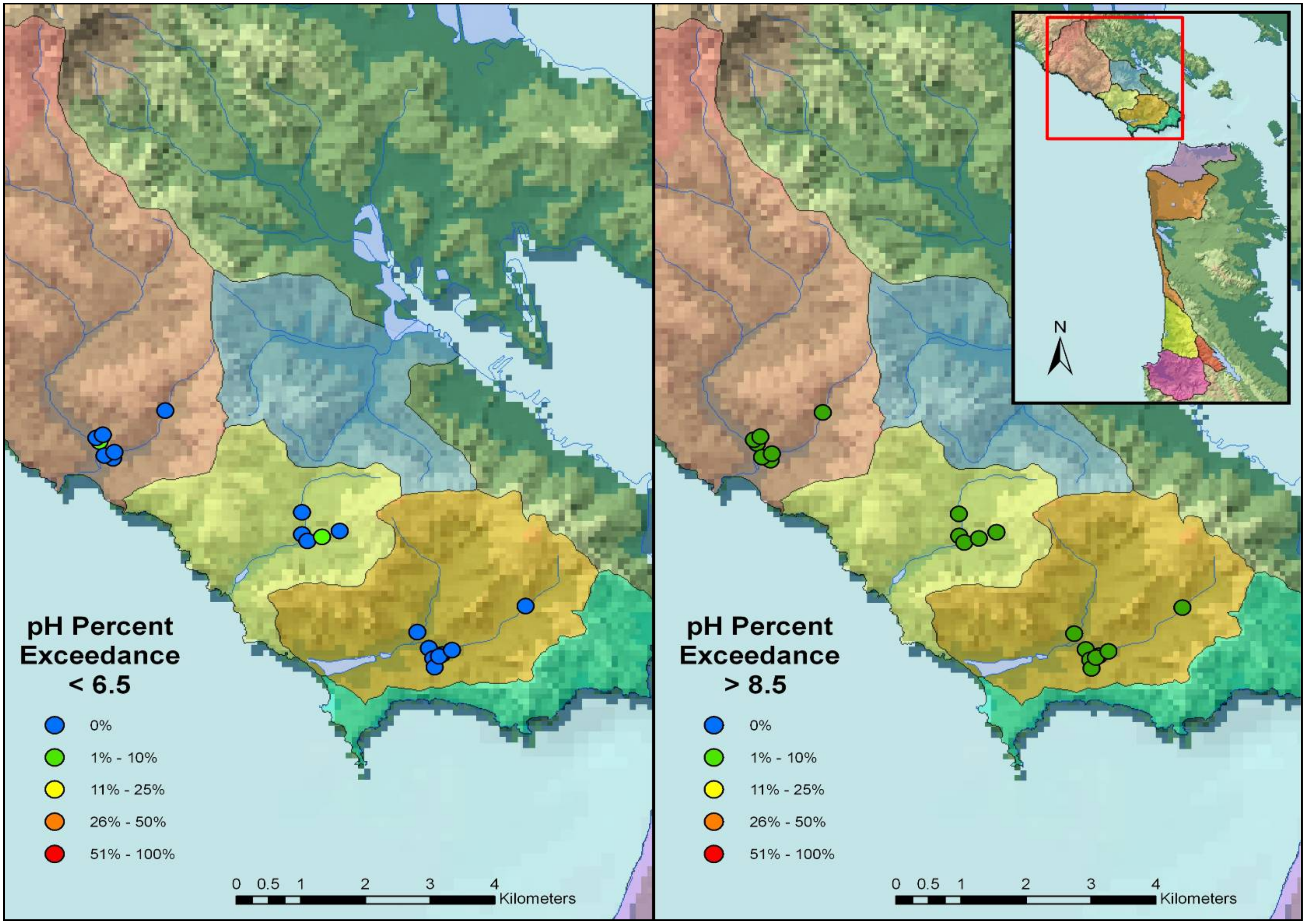

Figure 60. Golden Gate National Recreation Area watersheds with water sampling locations and percent of samples measured between 1999 and 2005 that were above or below the pH water quality objective range from pH 6.5 to 8.5.

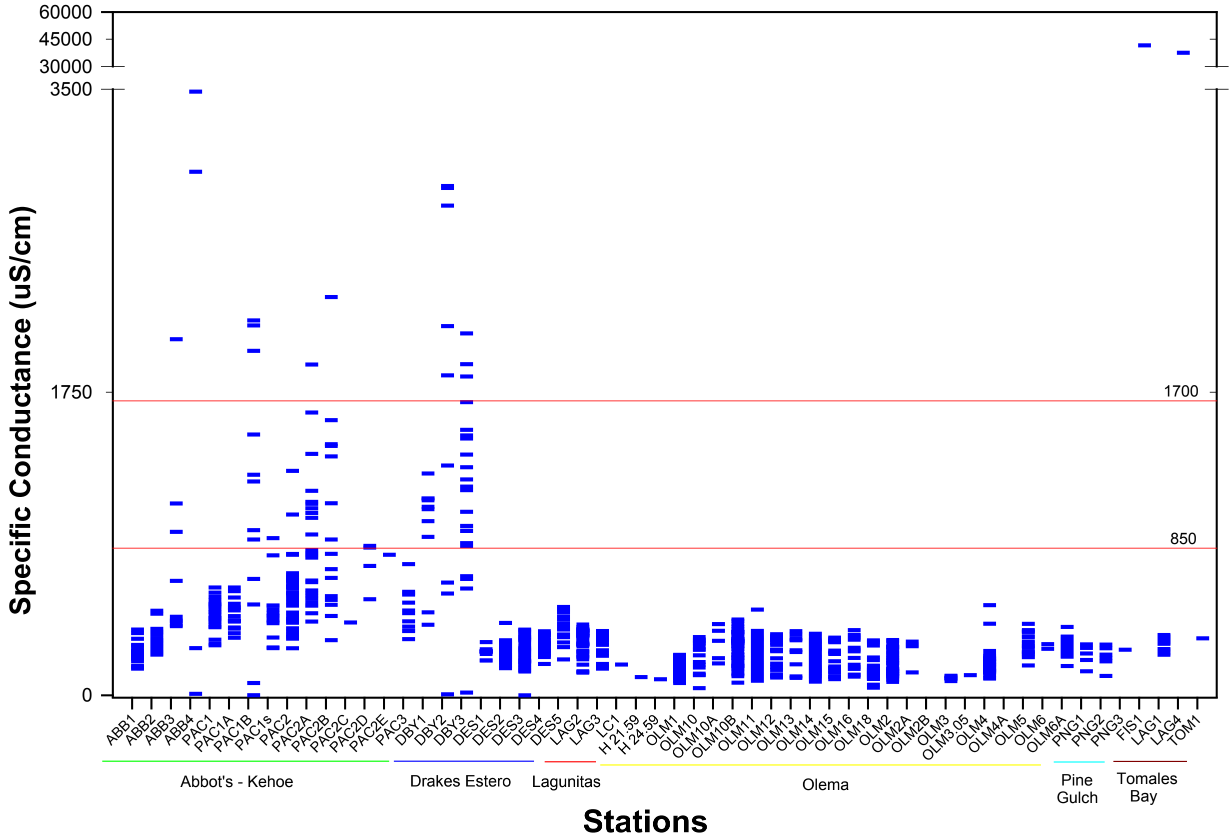

Figure 61. Scatter plot of specific conductance for Point Reyes National Seashore and northern Golden Gate National Recreation Area samples taken from 1999 to 2005, illustrate the samples which are impacted (>850 μS/cm) or toxic to fish (>1,700 μS/ cm). High values are exclusively found at estuarine (ABB4, TOM1) and dairy sites, indicating that direct impacts to freshwater fish are limited.

Turbidity/Total Suspended Solids (TSS)

Peak turbidity and TSS are common during floods and during high winter flows. TSS can also come from algal and bacterial growth. Increased levels of TSS often indicate increased levels of particle-associated contaminants in depositional areas and can inhibit fish production. TSS was not consistently measured so this analysis is confined to turbidity. Turbidity, an indirect measure of suspended solids is measured with a portable turbidity meter in Nephelometric Turbidity Units (NTU). SFRWQCB criteria levels for TSS objective are not to impair beneficial uses (CRWQCB 2007a). After 1999, the EPA came out with new guidance documents for nutrient criteria development (US EPA 2000a, 2000b), including total nitrogen, total phosphorous, chlorophyll *a* and turbidity. The turbidity criterion is 1.2 NTU, which is significantly more stringent than the criteria of 50 NTU used to screen Legacy STORET data (NPS WRD 2003, 2005); however, because these are draft criteria, we used the WRD screening level in the analysis.

PORE: High turbidity was detected in Olema Creek (but there was only one measurement) prior to 1999 (NPS WRD 2003). A turbidity of 180 NTU was measured, which exceeded the WRD screening criteria of 50 NTU (NPS WRD 2003).

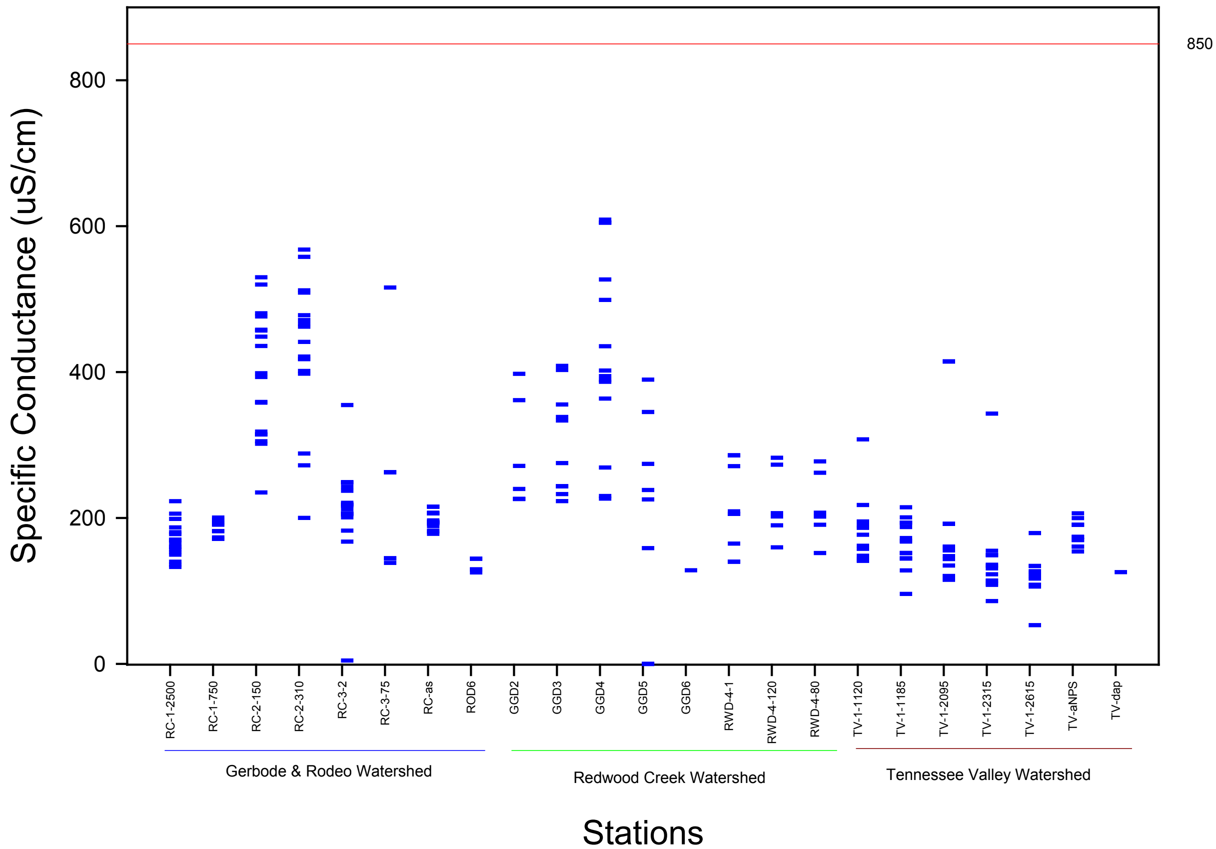

Figure 62. The scatter plot of specific conductance results for Golden Gate National Recreation Area samples taken from 1999 to 2005, illustrate that no samples were (>850 μS /cm) or at a range considered toxic to fish (>1700 μS /cm).

In PORE and northern GOGA, 64 turbidity measurements were made from 1999 2005 (Figure 63). The median is 3.82 NTU with an IQR from 0.77–24.03 NTU. The mean value was 68.82. Almost one-fourth of the measurements exceeded the WRD screening criteria of 50 NTU and over half the samples exceeded EPA guidance of 1.2 NTU for pristine conditions, indicating that high turbidity may be a problem in some locations. It should be emphasized that much of the sampling occurred during or immediately following storm events to capture the worst conditions. There are a paucity of measurements compared to other parameters, but some sites had extremely high turbidity measurements, including sites along the mainstem and tributaries of Olema. OLM 11 at Bear Valley Bridge exhibited the highest measurements (887 NTU), followed by South Kehoe (PAC1), Five Brooks (OLM14) and Lower Olema Creek (OLM10B). B Ranch (DBY2) and Creamery Creek (DES1) were also fairly high.

GOGA: Turbidity concentrations were measured 1,448 times at 80 monitoring stations from 1972 through 1998. Sixty-six observations at 30 stations (5.5% of observations and 37.5% of stations) equaled or exceeded the WRD screening criterion of 50 NTU from 1973 through 1998 (NPS WRD 2005). The highest concentration of 950 Formazin Turbidity Units was reported in Pilarcitos Creek (GOGA 0011) in January 1975. Recent measurements for turbidity are not available. Turbidity was not measured as part of the GOGA Stables Study.

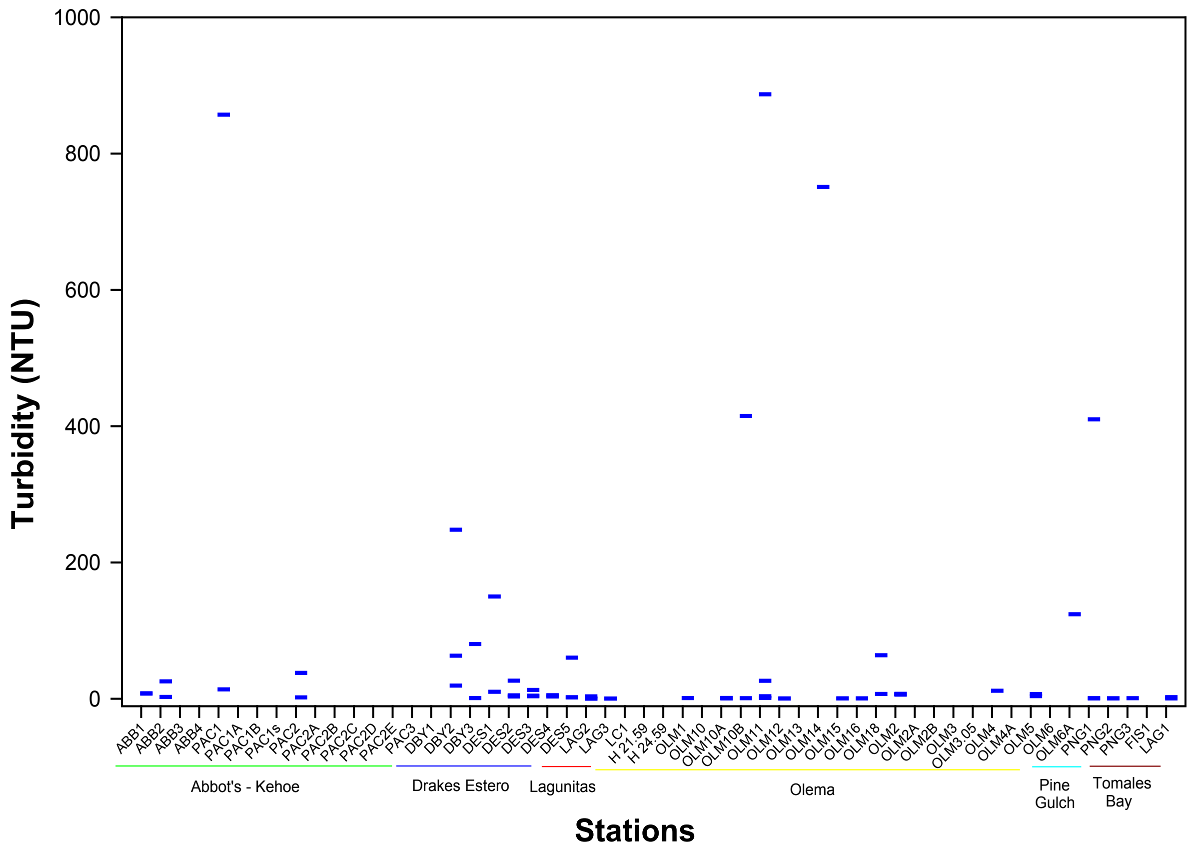

Figure 63. The scatter plot of turbidity measurements in Point Reyes National Seashore and northern Golden Gate National Recreation Area for samples taken from 1999 to 2005. Turbidity sampling was sporadic, but turbidity was high in some instances.

Dissolved Oxygen

Oxygen in the water is depleted by respiration of fish, algae, bacteria and other organisms. Oxygen is also used in the oxidation of wastes, including ammonia and organic matter (Rittman and McCarty 2001). Dissolved oxygen (DO) is often a concern in the summer and fall as temperature rises, water flow declines and leaf fall adds oxygen demand. The RWQCB objectives for DO in inland (fresh) waters are 7.0 mg/L (ppm) or above for cold water habitat and 5.0 mg/L (ppm) or above for warm water habitat (CRWQCB 2007a). Estuaries can naturally have DO levels below 5 mg/L (ppm) and to date no standard has been set by the US EPA or the SFRWQCB. Almost all fish kills in natural waters are associated with DO <2 mg/L (ppm) (Stafford and Horne 2004. Salmonids show signs of initial distress symptoms at 6 mg/L (ppm) of DO (Reiser and Bjornn 1979).

PORE: An analysis of Legacy STORET data (397 observations from 62 stations) prior to 1999 indicated that less than 1% of the observations had DO levels below 4.0 mg/L (ppm) from 1959 through 1991. The low measurements were 0.4 mg/L (ppm) in Walker Creek at the State Route 1 Bridge (PORE0216) in January 1979 and 3.1 mg/L (ppm) in San Geronimo Creek downstream of Woodacre (PORE0044) in May 1991.

From 1999 to 2005, 968 measurements had a median value of 9.3 mg/L (ppm) and an IQR from 7.4–10.6 mg/L (ppm). Over 75% of the samples are in a comfortable range for aquatic life (>7.0 mg/L) (ppm) and 90% were >5 mg/L (ppm), the less stringent warm-water criterion. Figure 64 illustrates that a fairly significant number of samples fall below the optimum range. Extremely low DO conditions occur in the Kehoe/Abbotts watershed at PAC1 sites, Drake's Estero/Bay at A, B and C ranches (DBY1, 2 and 3), and in the tributaries draining to Drakes Estero. In the upper portion of the Olema watershed, primarily at ranch and horse stable sites, there were a significant number of exceedances. The map in Figure 65 illustrates the percent of samples that exceed standards for the cold and warm water DO objective for specific sites. Generally the percent of samples exceeding standards is lower than 50%, except for PAC1 and OLM18; however, five cold water sites and two warm water sites had low DO levels for over a quarter of the measured samples.

Dissolved oxygen may be lower with warmer water and under intermittent flow conditions. Upper Olema Creek (OLM18) and some tributaries (OLM4) are intermittent. Hence, samples were representative of individual pool conditions. Synoptic samples of John West Fork under intermittent conditions showed that conditions within individual isolated pools were stratified (temperature and DO), and that DO and temperature from pool to pool were distinct.

GOGA: DO concentrations were measured 4,658 times at 131 monitoring stations from 1963 through 1998. From 1972 through 1998, 5% of the observations and 15% of stations had DO measurements that were less than or equal to the 5 mg/L (ppm) objective. Approximately 60% of the observations less than or equal to 5 mg/L (ppm) were reported within GOGA legislative boundaries in the southern portion of the study area during depth sampling at four reservoir stations (GOGA 0021, GOGA 0043, GOGA 0051, GOGA 0077) from 1996 through 1998.

In the GOGA Stables Study conducted from 1999 to 2005, DO measured for 279 samples is 10.5 mg/L (ppm) with an IQR from 9.4–11.4 mg/L (ppm). Samples from the Golden Gate Dairy in the Redwood Creek watershed (GGD4) and samples from Rodeo Creek (RC-2-310) fell below the DO criteria of 7 mg/L (ppm) for coldwater (Figures 66 and 67).

Nitrogen: Total Nitrogen, Ammonia, Nitrate, Nitrite

Nitrogen is essential to biotic production and, in aquatic systems, exists in various forms – nitrogen gas, nitrate (NO_3^-), nitrite (NO_2^-), reactive ammonia (NH_4^+), urea and dissolved organic compounds. The primary anthropogenic sources of nitrogen are sewage, fertilizers and barnyard wastes. Too much nitrogen leads to excessive algal blooms, low dissolved oxygen and ultimately fish kills. Sewage and barnyard wastes have nitrogen primarily as ammonia; fertilizer runoff has nitrogen primarily as nitrate. Even moderate environmental disturbances such as farming and logging release nitrate into solution (Goldman and Horne 1983).

Nitrate is very soluble and is flushed out of soils relatively quickly; organic nitrogen and ammonia are associated with particles and surface runoff. Storm events can result in high levels of nitrogen compounds in surface waters (Goldman and Horne 1983). Nitrogen compounds accumulate in depositional (sink) areas, such as ponds or lagoons. In high nitrate estuaries, a large part of the nitrogen load is removed by benthic denitrification, which reduces eutrophication. Nitrous oxide (N_2O), a product of denitrification, is a major greenhouse gas; high nitrate estuaries may be an important source of N_2O to the atmosphere (Robinson et al. 1998).

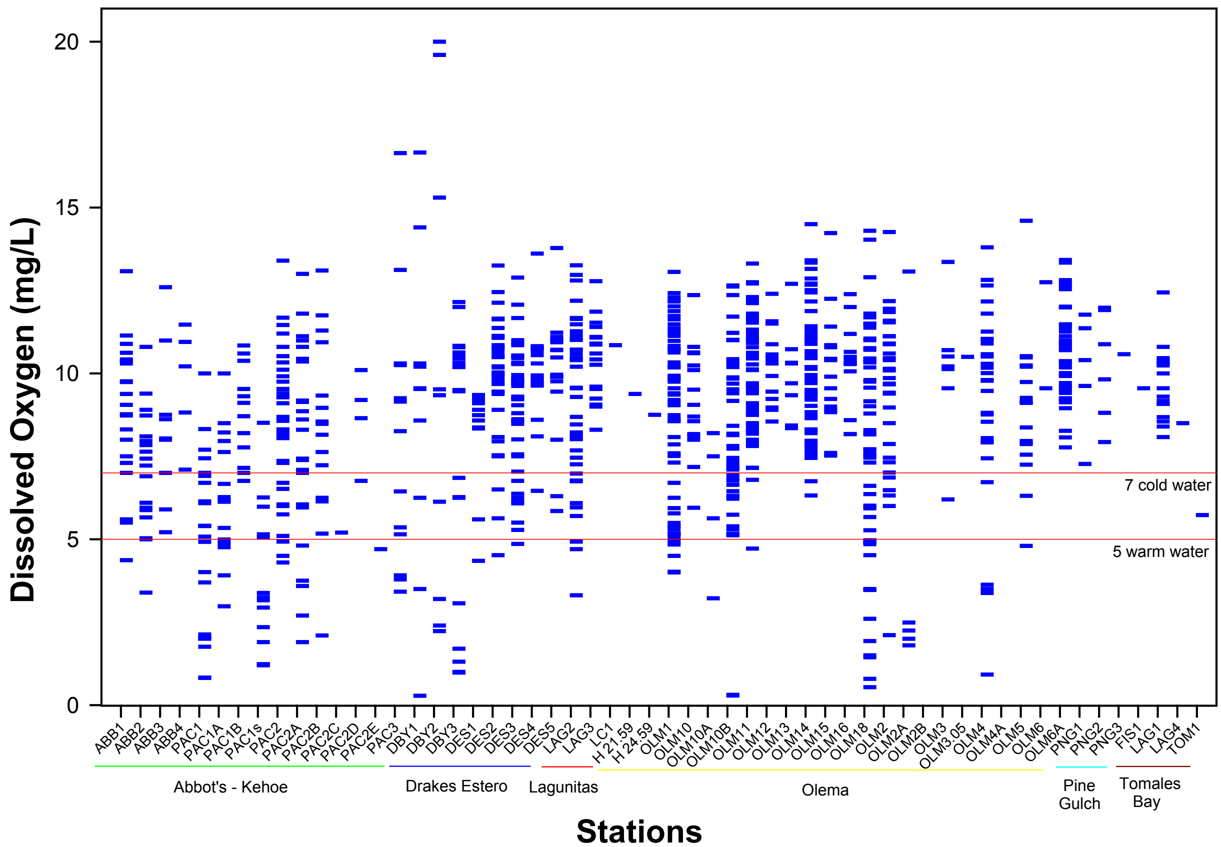

Figure 64. The scatter plot of dissolved oxygen results for Point Reyes National Seashore and northern Golden Gate National Recreation Area samples taken from 1999 to 2005 illustrates the number of samples below the 5 mg/L (ppm) warm water standard and the 7 mg/L (ppm) coldwater standard.

The drinking water standard is 10 mg of nitrogen/L (mg-N/L) for nitrate and 1 mg-N/L for nitrite, which is too high to be protective of many ecosystems (Stafford and Horne 2004). The US EPA developed guidance documents for nutrient criteria development (US EPA 2000a,b) including total nitrogen, total phosphorous, chlorophyll *a* and turbidity. US EPA's ecoregional nutrient criteria address cultural eutrophication – the adverse effects of excess nutrient inputs; however, there are insufficient data to apply the criteria for total nitrogen.

Efforts are underway to revise nutrient criteria in California based on specific habitat measures (Tetra Tech, Inc. 2006). The effort expands on the more traditional method that relies on measures of exposure alone (e.g., nutrient concentration targets); because the amount of nutrients that a water body can assimilate without impairment of uses varies widely, depending on a large number of cofactors. The theory is that the "intermediate measures" might be more easily generalized. For example, it may be possible to agree that a given density of periphyton biomass is injurious to coldwater fisheries, or a given frequency of blue-green algal blooms impacts a municipal supply use, even if the nutrient concentration that will cause that result varies widely from stream to stream (Tetra Tech, Inc. 2006). Impediments to the use of "intermediate measures" are that they are not routinely measured in park systems and they require models to predict nutrient loads appropriate without site-specific analysis.

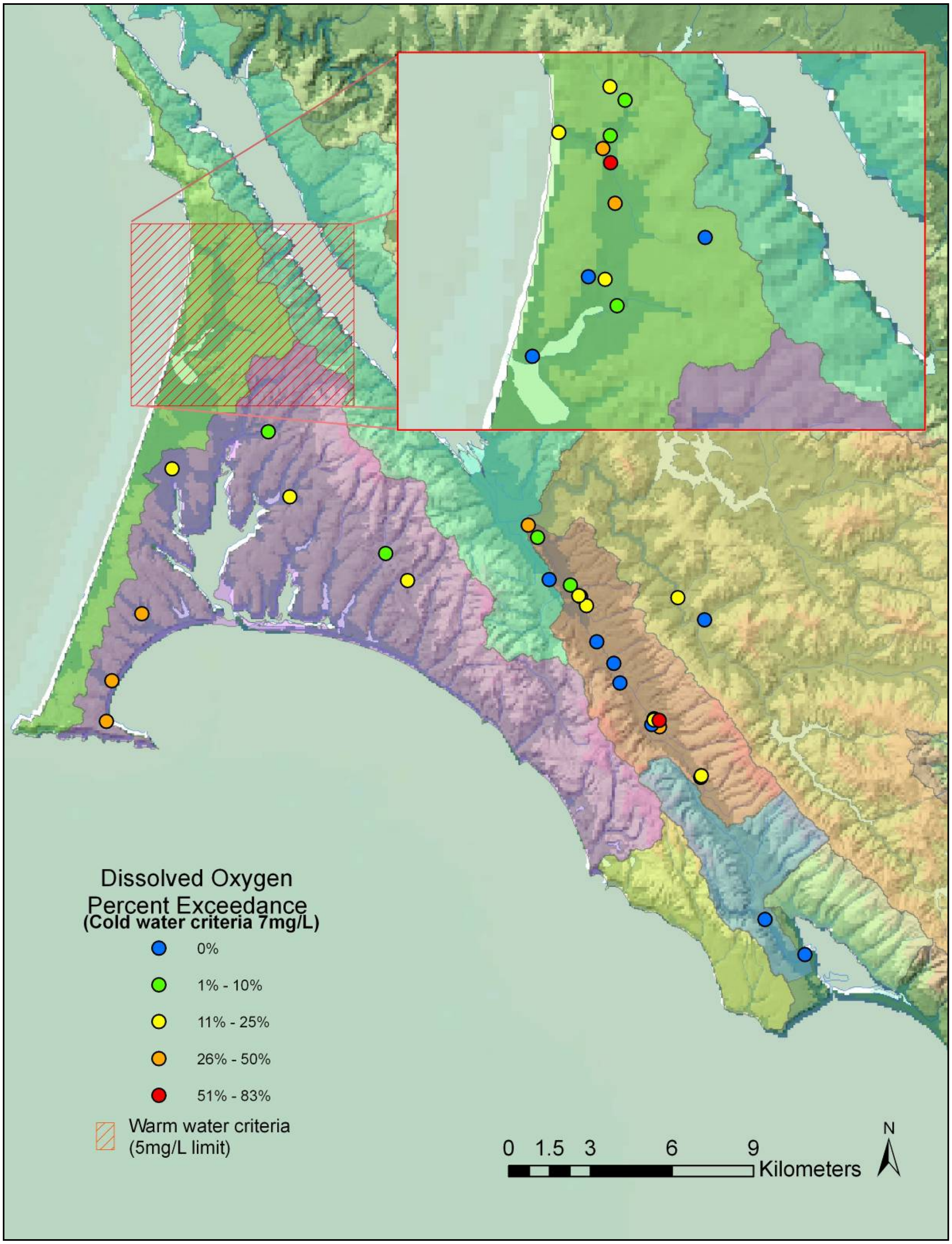

Figure 65. The percent of samples at each water quality sampling location in Point Reyes National Seashore and northern Golden Gate National Recreation Area watersheds where dissolved oxygen minima were below 7 mg/L (ppm) (for cold water sites) or below 5 mg/L (ppm) (for warm water sites).

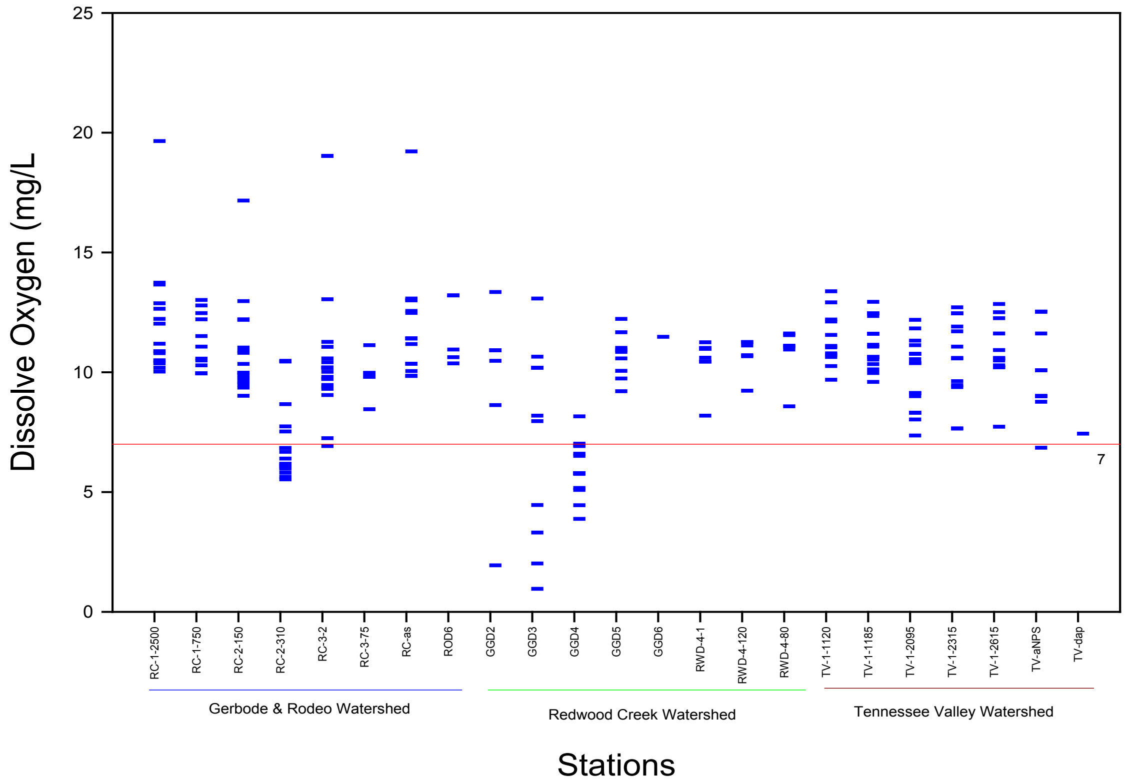

Figure 66. The scatter plot of dissolved oxygen results for the Golden Gate National Recreation Area Stables Study (1999 to 2005), illustrates the number of samples that are below the 7 mg/L coldwater standard. The lowest values occurred near the Golden Gate Dairy (GGD2 and 3).

After consultation with the sources above and several experts, we settled on an objective of 1 mg/L N as nitrate as an initial screening criterion and provide information on nitrites as background information**.** We also used the 10 mg-N/L level as an indication of high nitrate contamination. In many of the nutrient samples, over 75% of nitrite and reactive ammonia, fell below the limits of detection that led us to exclude these analyses.

In aquatic systems, ammonia is generally present in its ionized or reactive form (NH_4^+). A small fraction occurs in the un-ionized form (NH_3), which is toxic to aquatic species. Algal blooms lead to low DO levels and increases in pH, which increases ammonia toxicity. The US EPA's criteria for free ammonia toxicity are presented in terms of pH and temperature for total ammonia and un-ionized ammonia (NH_3) as 1-hr values and 4-day averages (i.e., not one number). The US EPA recommends that these levels should not be exceeded more than once in three years, which would enable a system to recover from the stress caused by ammonia pollution. The Basin Plan states that receiving waters should not exceed an annual median of 0.025 mg-N/L or a maximum of 0.16 mg-N/L of un-ionized ammonia to protect the migratory corridor in the Central Bay and 0.4 mg-N/L for the Lower San Francisco Bay (CRWQCB 2007a). This objective was used as a guide for evaluating possible lethal conditions.

PORE: Nitrite concentrations (including total N, dissolved and total as NO_2) were measured 198 times at 40 monitoring stations from 1978 through 1998. Of the few exceedances noted, nearly all were located in GOGA near Easkoot Creek.

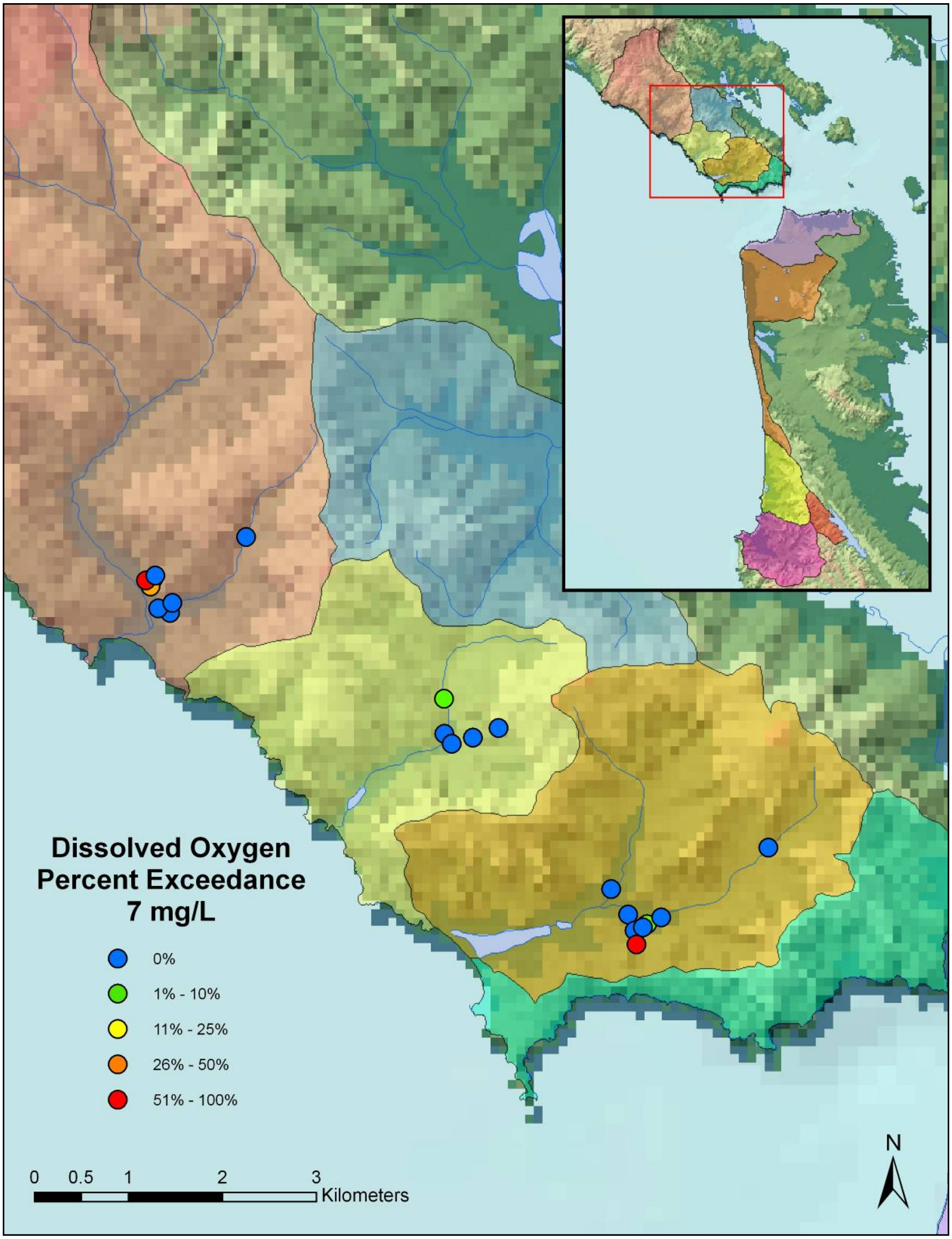

Figure 67. The percent of samples at each water quality sampling location in Golden Gate National Recreation Area watersheds where the dissolved oxygen minima were below 7 mg/L (ppm).

In PORE, nitrite was measured 148 times from 1999 to 2005; however, over 75% of the samples were below the detection limits of 0.01 mg/L. The samples above the detection limit were between 0.01–1.10 mg/L. The highest values were in the Pacific Coast watersheds in Kehoe Creek sites, PAC 1, PAC2, PAC2B and in the Drakes Estero watershed at sites near A and B Ranches, DBY2 and DBY3 below dairies. OLM 11 was somewhat elevated. Due to the paucity of results with values above the detection limit, we did not graph or map nitrite exceedance; the exceedance noted tends to mirror the exceedance noted for nitrate.

In PORE**,** nitrate (as NO_3^-) was measured 463 times from 1999 to 2005 with a median value of 0.52 mg/L, with an IQR from 0.2–1.4 mg/L. A majority of the samples fell well below 10 mg/L (Figure 68); however, several samples exceed this level (Table 26). Over 50% of the samples exceeded 1 mg/L **(**Figure 68), which is evidence of nutrient enrichment[29]. The highest percentage of exceedances occurred in the Kehoe/Abbotts watershed, consistent with a previous analysis (Ketcham 2001). Samples at the L Ranch impact yard (PAC 1B) had two extremely high concentrations (400 and 600 mg/L N), indicating high levels of waste loading (Figures 68 and 69). These results are uncommonly high for PORE and are a result of the timing of the sampling event during high storm runoff conditions and the location of the monitoring station, which receives runoff from a densely populated field of grazing cattle. Between 1999 and 2005, over 34% of the samples were below the detection limits of 0.2 mg/L for nitrate (as NO_3^-).

Table 26. Point Reyes National Seashore and northern Golden Gate National Recreation Area sites with high levels of nitrate (>10 mg/L). These are not drinking water sites, but are areas with high nitrate levels.

Site*	Location Name	Watershed
PAC1A	McClure pond draining to S. Kehoe	Abbotts-Kehoe
PAC2	North Kehoe	Abbotts-Kehoe
PAC2A	North Kehoe Ranch (farm)	Abbotts-Kehoe
DBY3	A Ranch Perennial	Drakes Bay/Drakes Estero
ABB2	McClures Ranch	Abbotts-Kehoe
PAC1	South Kehoe	Abbotts-Kehoe
OLM5	Vedanta Creek	Olema
ABB3	McClures Dairy Swale	Abbotts-Kehoe

In PORE, Ammonia has been monitored as reactive ammonia (NH_4^+) fairly consistently (N=390) and as un-ionized ammonia (NH_3) sporadically (N=29) from 1999 to 2005. The scatter plots depict reactive ammonia concentrations (Figure 70) from 1999 to 2005. Over 80% of the samples tested for reactive ammonia were below the detection limits. For reactive ammonia, the median value was 0.2 mg-N/L with an IQR from 0.2–0.3 mg-N/L. Nearly 10% of the samples were above 0.6 mg-N/L. High measurements were found in Kehoe/Abbotts Lagoon, A and B Ranches. There are no agreed upon standards for reactive ammonium.

Almost 70% of the samples tested for reactive ammonia (NH_4) from 1999 to 2005 were below the detection limits. Extremely high measurements were found in McClure pond draining to S. Kehoe (PAC1A) and the McClure Dairy Swale (ABB3). Measurements above the toxic threshold and the Basin Plan objective of 0.16mg/L (un-ionized ammonia) were found in North

[29] C. Creager, North Coast California Regional Water Quality Control Board, Santa Rosa, CA pers. comm., 2006.

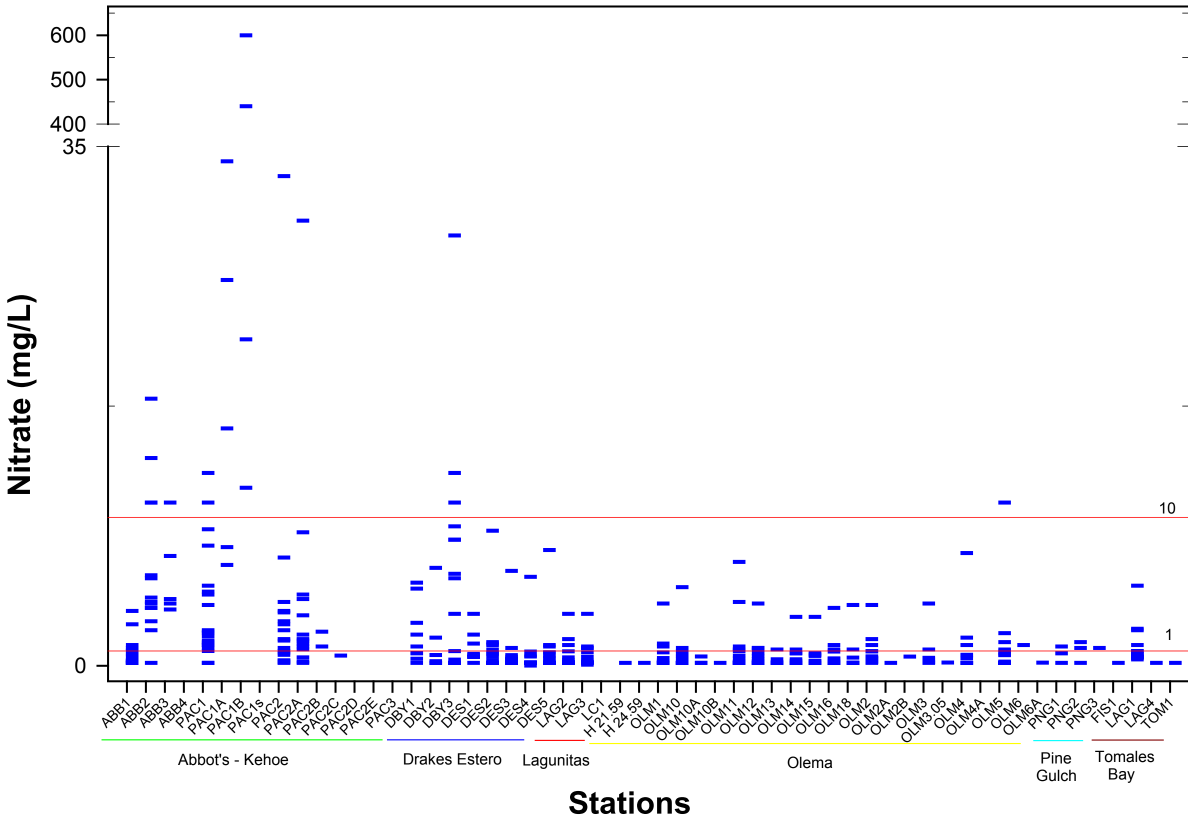

Figure 68. The scatter plot of nitrate results (as N) for Point Reyes National Seashore and northern Golden Gate National Recreation Area samples taken from 1999 to 2005 compares values to 1 mg/L (ppm) and 10 mg/L (ppm) nitrate levels. Note: Drakes Estero refers to Drakes Bay and Drakes Estero sites on this scatter plot and all of the following scatterplots.

and South Kehoe, the L Ranch impact yard and A and B Ranches in Drakes Bay. There were too few measurements to show exceedances. The Basin Plan states that receiving waters should not exceed an annual median of 0.025 mg-N/L or a maximum of 0.16 mg-N/L of un-ionized ammonia to protect the migratory corridor in the Central Bay, and 0.4 mg-N/L for the Lower San Francisco Bay (CRWQCB 2007a). The objective was used to evaluate possible lethal conditions.

GOGA: From 1906 through 1998, nitrate concentrations (dissolved and total as N and dissolved and total as NO_3) were measured 1,363 times at 115 monitoring stations. Of the 1,044 observations, one total NO_3-N concentration of 10.08 mg/L was measured in GOGA in the Presidio of San Francisco in Lobos Creek approximately 200 feet (61 m) inland from the Pacific Ocean (GOGA 0173) exceeded the drinking water criterion of 10 mg/L NO_3-N in August 1995.

The GOGA Stables Study (1999 to 2005) found sites that exceeded 1 mg/L (ppm) nitrate standard (Figure 71). The Redwood Creek watershed (RWD-4-1, 80, 120) and Tennessee Valley Creek (TV-1-1120) had the highest levels (12% and 20% mean exceedance, respectively); all samples were below the 10 mg/L (ppm) nitrate drinking water standard. All watersheds had values above 1 mg/L (Figure 72); within mean exceedance of 30%, the Gerbode and Rodeo watersheds (southernmost) had the highest percentage of samples above the objective.

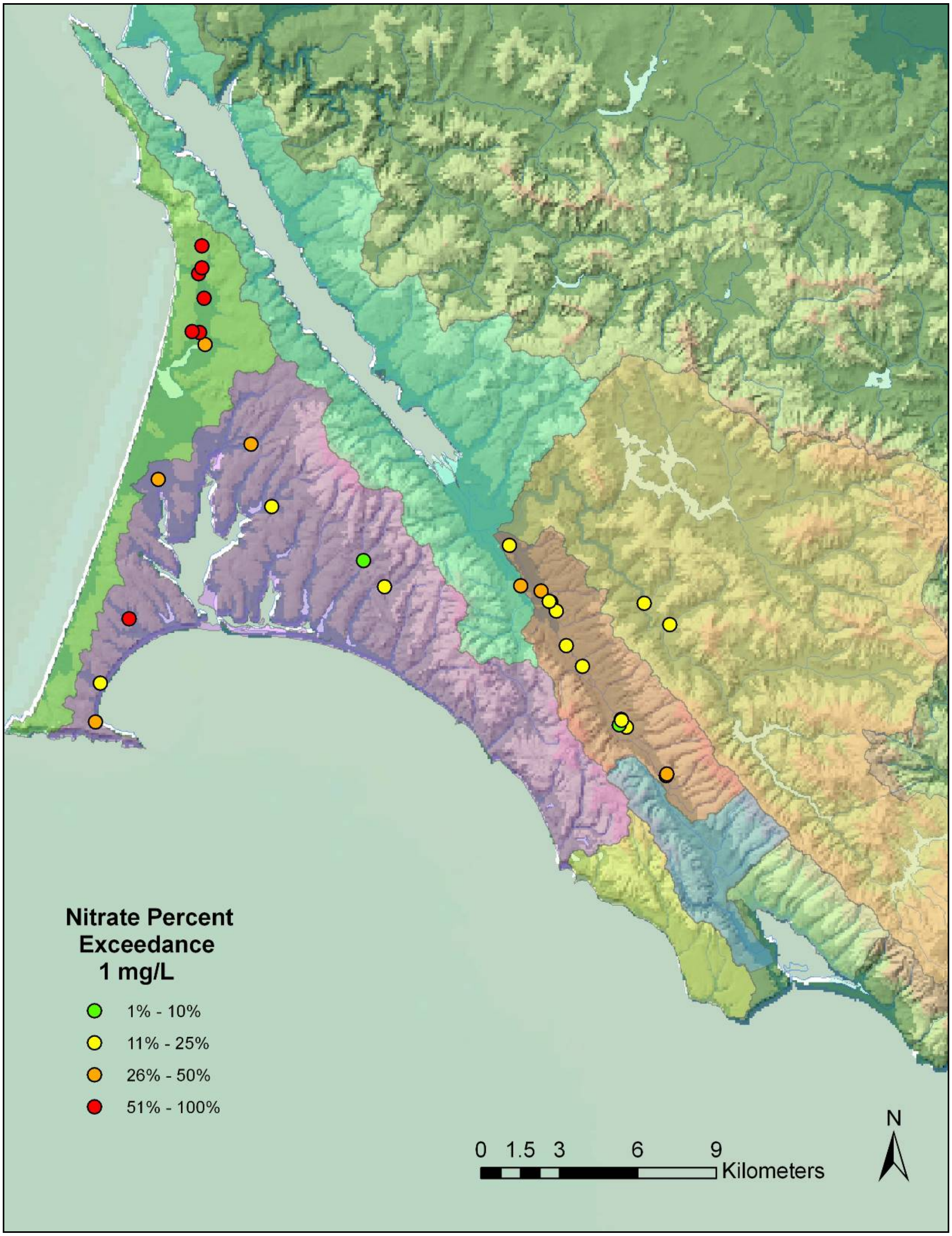

Figure 69. Point Reyes National Seashore and northern Golden Gate National Recreation Area watersheds where the frequency of water quality samples exceed 1 mg/L nitrate between 1999 and 2005.

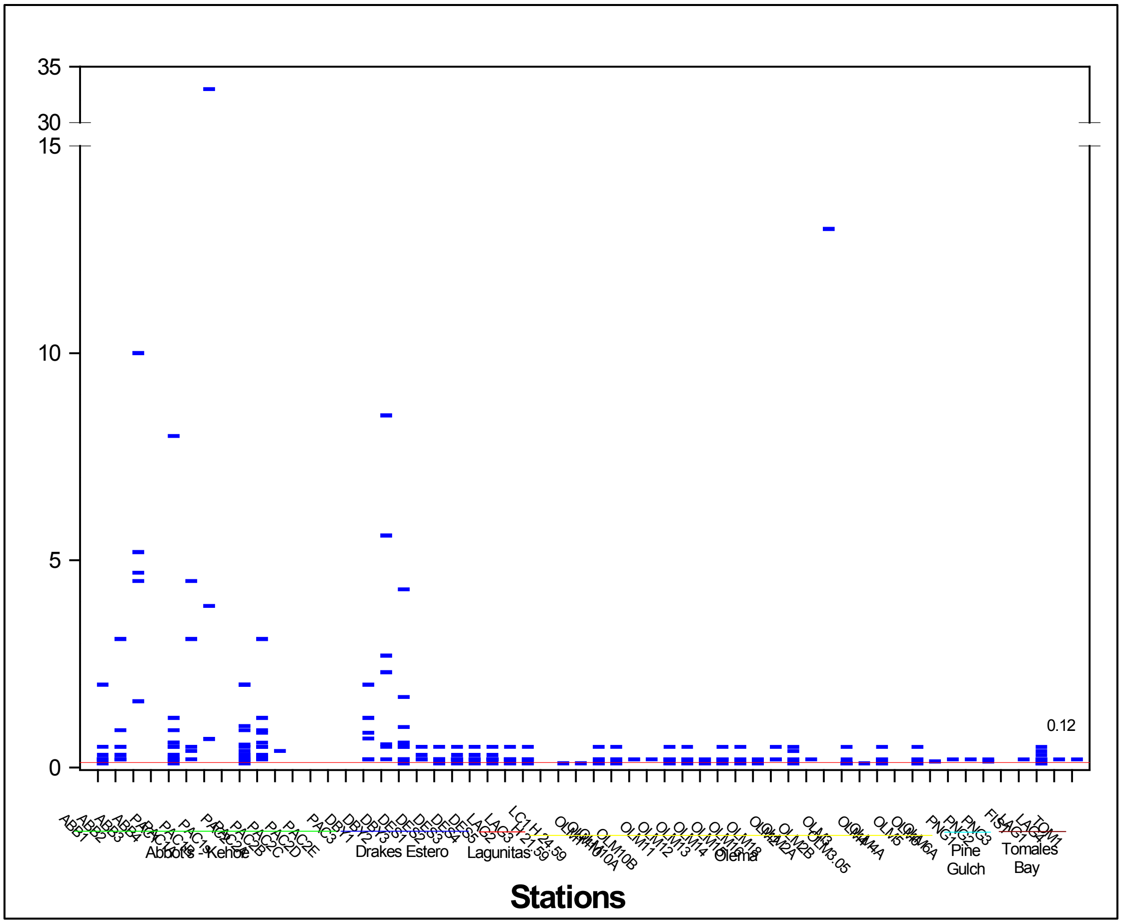

Figure 70. The scatter plot for reactive ammonia (NH_4) is shown for samples collected from 1999 to 2005 in Point Reyes National Seashore and northern Golden Gate National Recreation Area (N=315)

Total ammonia measurements (N=392) were collected during the GOGA Stables Study from 1999 to 2005. The calculated un-ionized ammonia measurements shown exceeded the objective of 0.16 mg/L in the Gerbode and Rodeo watershed and at two sites in the Redwood Creek watershed (Figures 73 and 74), indicating levels potentially toxic to fish.

<u>Phosphorus: Phosphate, Total Phosphorus, Orthophosphate</u>

Like nitrogen, phosphorus (P) is critical to biotic production; however, excessive levels lead to algal blooms and low dissolved oxygen. Sources of phosphorus include soil sediments, fertilizer runoff, animal wastes and detergents. In general most phosphorus is bound to sediment particles and ultimately delivered downstream and to the water bodies such as lagoons and estuaries.

Small oligotrophic stream biota may respond to phosphorus concentrations of 0.01 mg/L or less. In general concentrations greater than 0.05 mg-P/L (milligrams of phosphorus per liter) will have a detrimental impact, unless nitrogen is the limiting nutrient (Behar 1997). The US EPA total P reference value for Aggregate Ecoregion III rivers and streams is 0.02 mg-P/L, with a range of reference conditions from 0.01–0.05 mg-P/L (US EPA 2000c). For Aggregate Ecoregion III lakes and reservoirs, the reference value for phosphorus is 0.017 mg-P/L with a range of

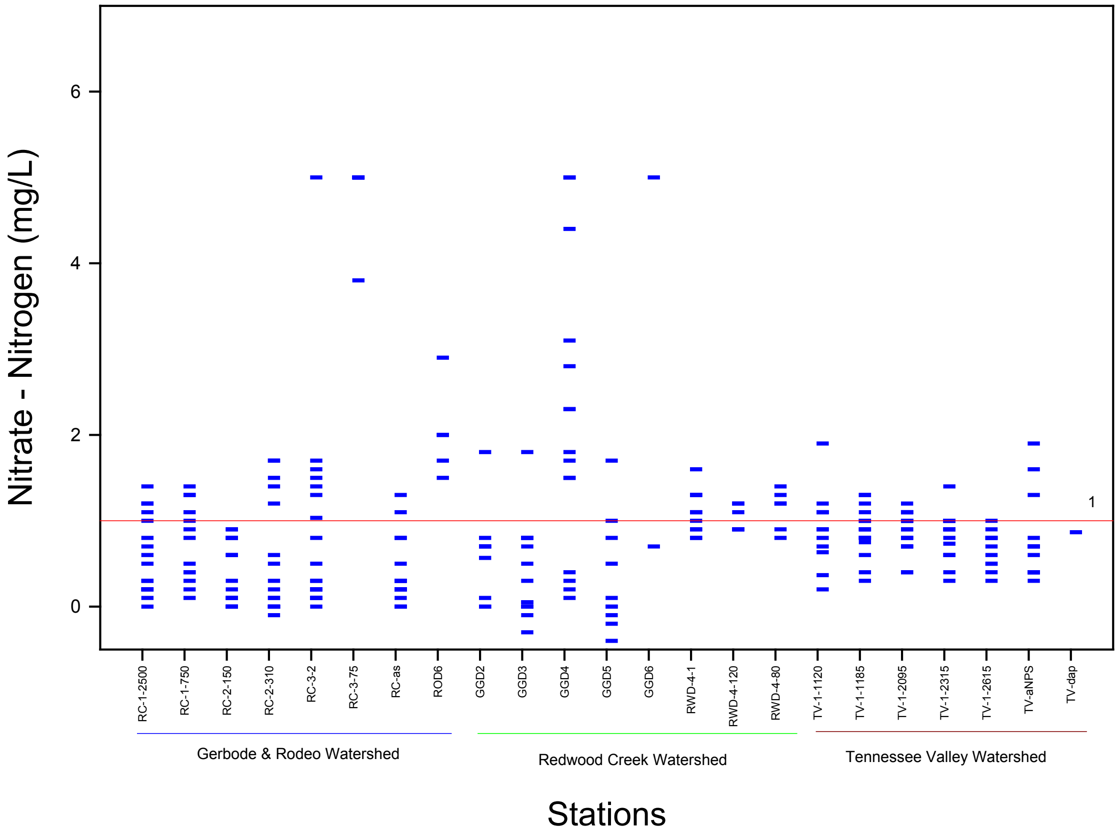

Figure 71. Scatter plot of nitrate for the Golden Gate National Recreation Area Stables Study from 1999 to 2005 compares values to the 1 mg/L nitrate standard.

reference conditions from 0.003–0.172 mg-P/L (US EPA 2000e). In the parks, phosphorus is rarely a limiting nutrient so Stafford and Horne (2004) suggested eliminating it from a standard list of indicators. Phosphorus has not been consistently monitored; nor was it included as an indicator in the SFAN I&M vital signs assessment.

PORE: For pre-1999 conditions, phosphorus was not analyzed in the Horizon Report (NPS WRD 2003). From 1999 to 2005, orthophosphorus was measured 164 times with six results below the detection limit, a median value of 0.22 mg/L and an IQR of 0.13–0.47 mg/L. Our review of the data indicated a few extremely high values, particularly in the Kehoe/Abbotts watershed at PAC1 and PAC2 and the A and B Ranch areas in the Drakes Bay watershed (DBY2 and DBY3).

GOGA: Previous studies have noted high phosphorus concentrations at GOGA stations (NPS 1990). Total phosphorus and orthophosphorus were measured prior to 1999; however, the Horizon report does not summarize the results (NPS WRD 2005). Orthophosphorus is not included in the present analysis.

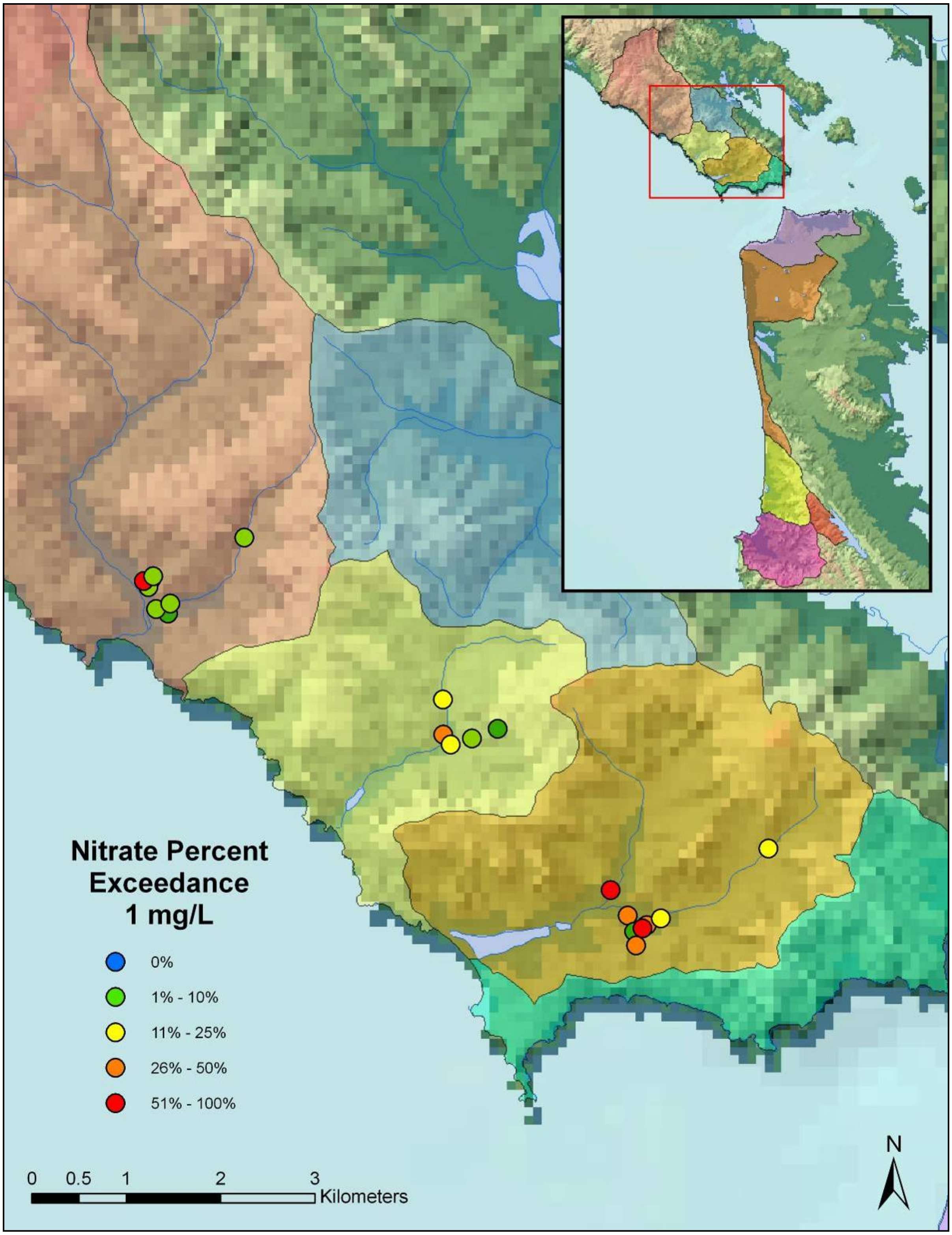

Figure 72. Map of Golden Gate National Recreation Area watersheds illustrates the percentage of water quality samples at each sampling location that exceeded 1 mg/L (ppm) nitrate (as N) objective.

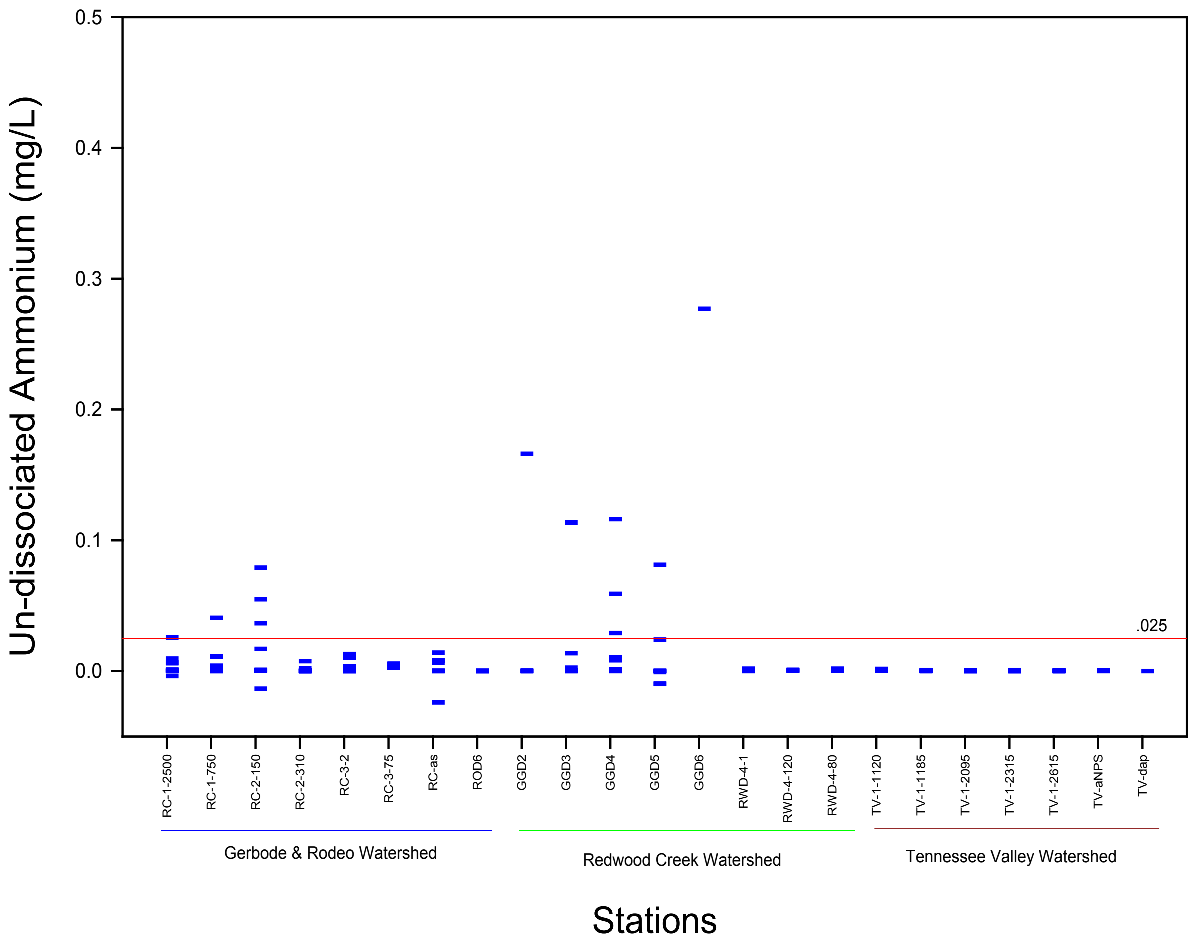

Figure 73. Scatter plot of un-ionized ammonia (NH_3-N) for the Golden Gate National Recreation Area Stables Study from 1999 to 2005 compares values to the 0.16 mg/L (ppm) level. Values measured in Redwood Creek were greater than the guideline.

Pathogens: Fecal Coliform Total Coliform and E. coli bacteria

Fecal contamination can result from ineffective management of human wastes, such as leaking septic systems or untreated wastewater. Fecal contamination also comes from poor management of animal wastes, as well as manure from dairies and ranches. Low levels of fecal contamination also come from wildlife. US EPA numeric objectives for indicator bacteria are listed in Table 27. These objectives are set to be protective of public health and not intended to reflect ecosystem health, although high levels of waste can introduce nitrogen into the water causing eutrophication, which affects overall ecosystem health. In PORE, fecal coliform has been monitored and found useful in pollutant source tracking, since nutrients are so rapidly diluted in streams (Ketcham 2001). Because the samples are not evenly spaced during a 30-day period, we used the single sample objective to evaluate total coliform (10,000 MPN/100 mL) and fecal coliform (400 MPN/100 mL).

PORE: According to the WRD Baseline Inventory and Analysis Report for PORE (NPS WRD 2003) for pre-1999 conditions, the only stations with data exceeding the WRD fecal indicator bacteria (i.e., fecal or total coliform or *E. coli* screening limits for freshwater and marine water

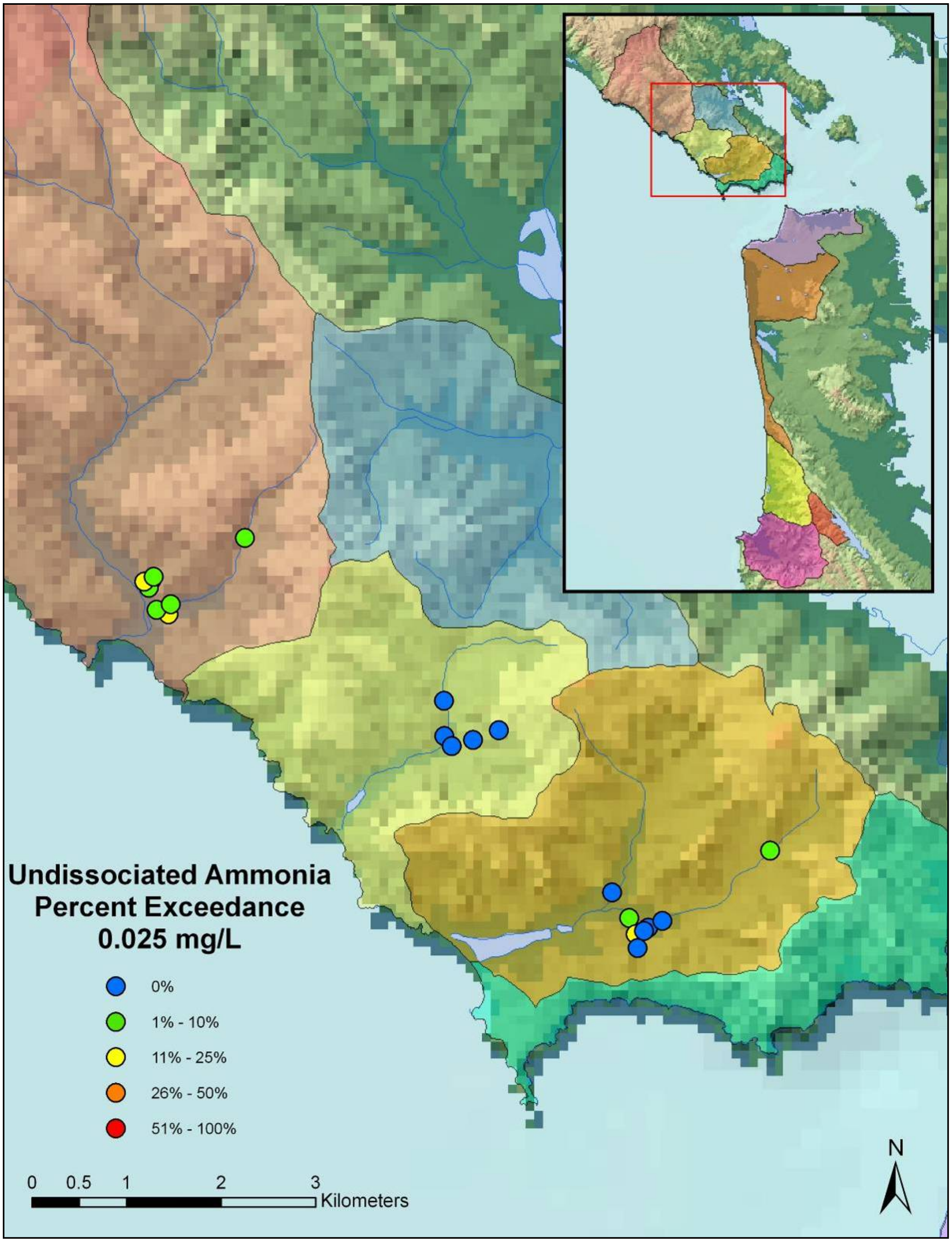

Figure 74. Map of Golden Gate National Recreation Area watersheds illustrates the percentage of water quality samples at each sampling location that exceeded 0.025 mg/L (ppm) of un-ionized (undissociated) ammonia.

Table 27. US Environmental Protection Agency bacteriological criteria for contact recreation (REC1).

Fecal Indicator Bacteria	Bacterial Colonies/100mL (MPN)
Total Coliform	
Single Day Sample	10,000
*30 Day Geometric Mean	1,000
Fecal Coliform	
Single Day Sample	400
*30 Day Geometric Mean	200
*E. Coli***	
Single Day Sample	235
*30 Day Geometric Mean	126
*Enterococcus***	
Single Day Sample	61
*30 Day Geometric Mean	33

* Geometric mean of five consecutive weeks

**The bacteriological tests are considered "ancillary" for the San Francisco Regional Water Quality Control Board; however the US EPA has adopted *E.coli* as the primary test for freshwater recreational uses, and *Enterococcus* testing for marine water recreational uses because they have determined that these tests correlate more closely with contact-related illnesses.

contact recreation) were Home Ranch Creek and East Schooner Creek; however, pre-1999 measurements were fairly limited. One station in the Kehoe watershed had the highest concentration (>24, 000 MPN/100 mL) and exceeded the contact recreation criteria for total coliforms (10,000 MPN/100 mL).

Total coliform was measured 962 times from 1999 to 2005 and depicted a median value of 1,700, with an IQR from 500–9,000 MPN/100 mL, indicating that more than 75% of the samples fell below the maximum water contact recreation criteria for total coliforms (10,000 MPN/100 mL). The scatter plot and map (Figure 75 and 76) indicates that there are a large number of exceedances in the Kehoe/Abbotts and Drakes Estero watersheds. Many sites in these watersheds exceeded the standard more that 50% of the time.

Fecal coliform was measured 923 times from 1999 to 2005 and had a median value of 800 MPN/100 mL and an IQR of 200–3,000 MPN/100 mL, indicating that over 50% of the samples exceeded the contact recreation criteria for fecal coliform (400 MPN/100 mL). The scatter plot and map (Figures 77 and 78) show the large number of exceedances in the Kehoe/Abbotts and Drakes Estero watersheds; exceedances occurred in all watersheds, particularly near dairies.

GOGA: Within GOGA managed lands, Fitzhenry Creek, Black Rock Creek and Easkoot Creek periodically exceeded the contact recreation criteria for total coliforms and fecal coliforms for pre-1999 samples. A review of WRD data plots (including data from 1971, 1978 and 1986–1998) indicated no apparent annual or seasonal variability in fecal or total coliform concentrations. Higher concentrations would be expected in the winter rainy season if runoff was a concern; therefore, other non-point sources (septic systems) or point sources in the Stinson Beach area may be causing the high numbers. The range in medians for Fitzhenry Creek was 2.032–2.732 log MPN/100 mL for total coliforms and 0.389–2.38 log MPN/100 mL for fecal

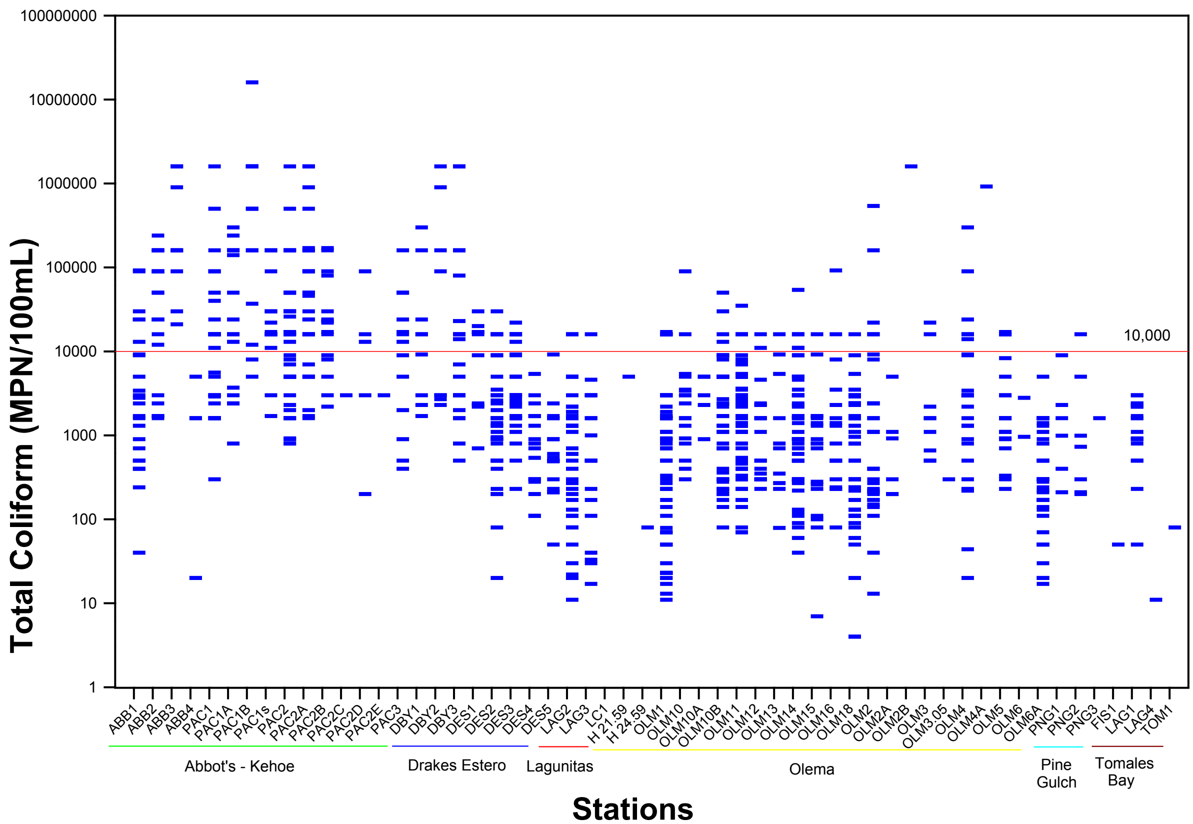

Figure 75. Scatter plot for total coliform for samples collected from 1999 to 2005 in Point Reyes National Seashore and northern Golden Gate National Recreation Area. Each sample plotted on a log scale, is compared to the 10,000 MPN/100 mL water contact total coliform standard.

coliforms. At the Easkoot Creek station within park boundaries the range in medians was 2.38–3.38 log MPN/100 mL for total coliforms and 1.699–2.964 log MPN/100 mL for fecal coliforms. *E. coli* concentrations in El Polin Spring and Lobos Creek exceeded the contact recreation criteria of 126 MPN/100mL (NPS WRD 2005).

Fecal coliform was measured 507 times from 1999 to 2005 during the GOGA Stables Study. Redwood, Tennessee Valley and Rodeo/Gerbode watersheds had 7%, 7% and 17% of the samples, respectively, exceeding the contact recreation criteria for fecal coliform (400 MPN/100 mL). The scatter plot (Figure 79) and map (Figure 80) show exceedances in all watersheds near stables.

<u>Metals</u>

Though some metals exist naturally in aquatic environments, high levels are distinct threats to humans and aquatic life. Each metal has distinct effects and food web transfer properties. In general, metals have not been well monitored in the PORE and northern GOGA park areas, but have been monitored more extensively in watersheds in southern GOGA.

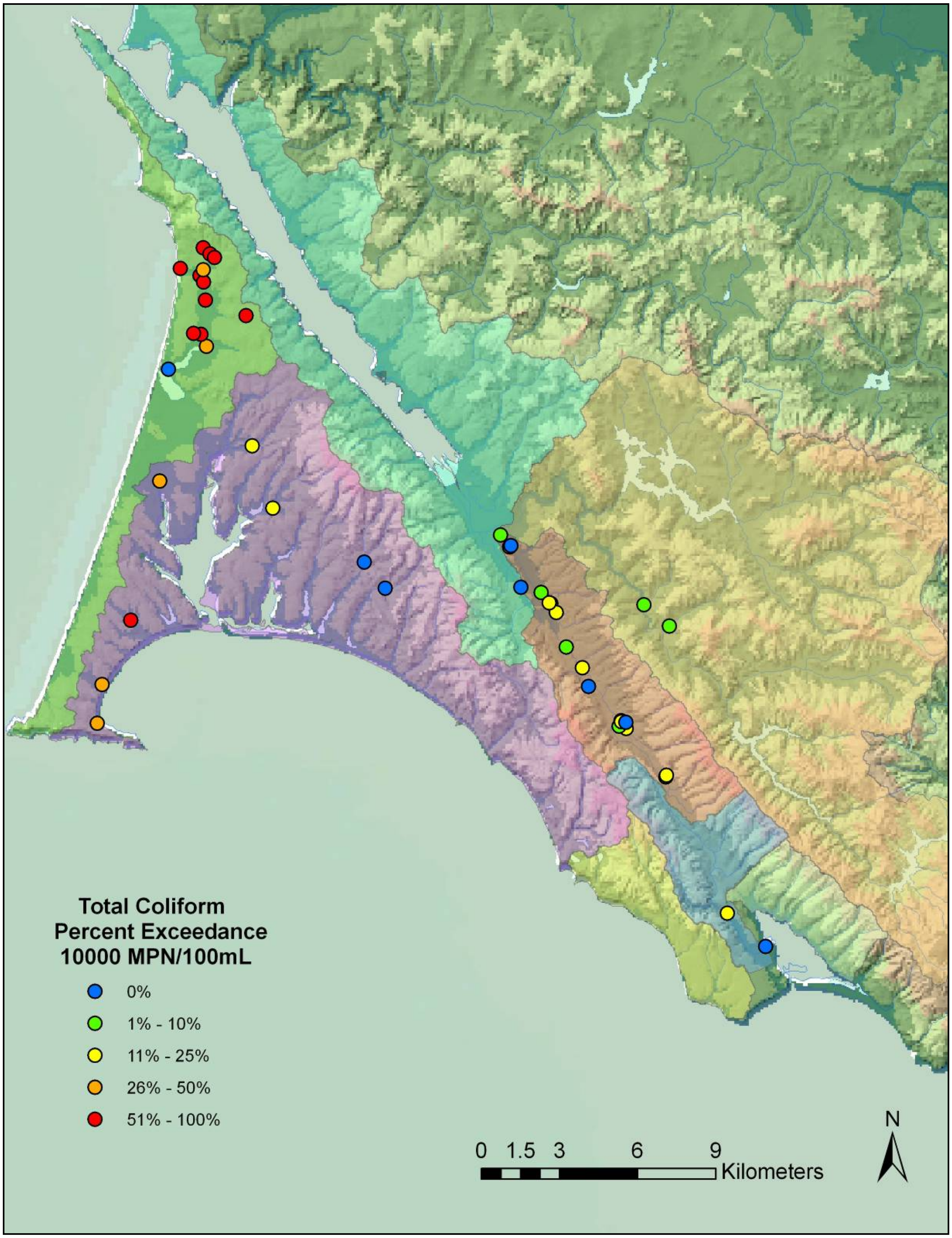

Figure 76. The percent of samples at each water quality sampling location in Point Reyes National Seashore and northern Golden Gate National Recreation Area watersheds that exceeded the total coliform water contact standard for one-time sampling of 10,000 MPN/100 mL.

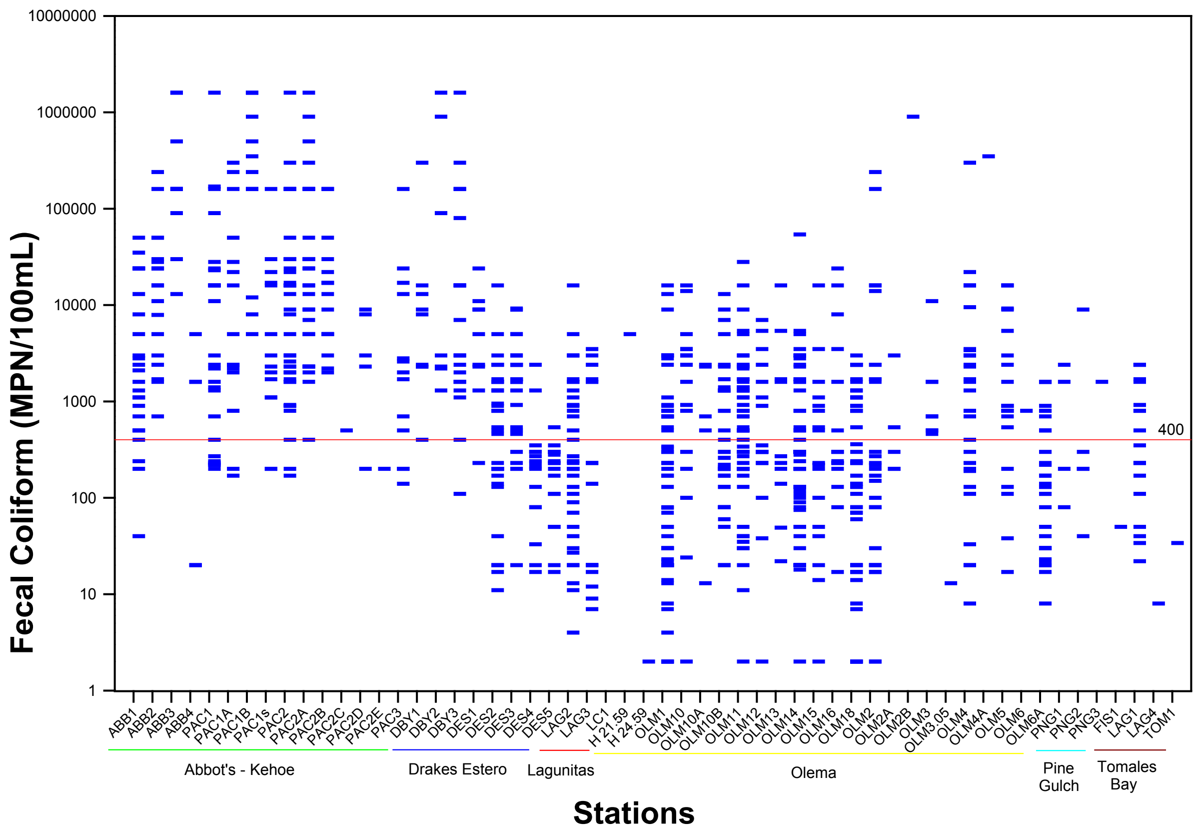

Figure 77. The scatter plot for fecal coliform is shown for samples collected from 1999 to 2005 in PORE and northern Golden Gate National Recreation Area. Each sample plotted on a log scale, is compared to the 400 MPN/100 mL water contact fecal coliform standard.

PORE: The failure of a former (Gambonini) mercury mine tailings pond near Walker Creek led to elevated mercury levels in Walker Creek and Tomales Bay (Johnson et al. 2009). Releases of mercury-contaminated sediment were mostly a product of intense bursts of rain and resulting erosion (Whyte and Kirchner 2000); and in 1999, the US EPA and RWQCB remediated the waste pile and initiated revegetation (CRWQCB 2006). The Lagunitas Delta appears to be another zone of net methylmercury production in Tomales Bay, but less is known about mercury dynamics in the marsh system than for the Walker Creek Delta (Ridolfi et al. 2009).

Marin County issued fish consumption advisories for Tomales Bay in 2004 after methylmercury concentrations in some sportfish exceeded the US EPA tissue criterion for human health. The California Office of Environmental Health Hazard Assessment (2004) reported that commercial shellfish had relatively low concentrations of mercury and did not present a human health risk.

The Point Reyes community water supply comes from groundwater wells adjacent to Lagunitas Creek behind the US Coast Guard housing facility in Point Reyes Station. The NMWD monitors this supply and has encountered high amounts of naturally occurring iron and manganese, which can affect the color of the water and result in staining. Treatment consists of adding an oxidant to precipitate the iron and manganese and then filtering the water through pressure filters which are capable of removing the iron and manganese and any excess oxidant.

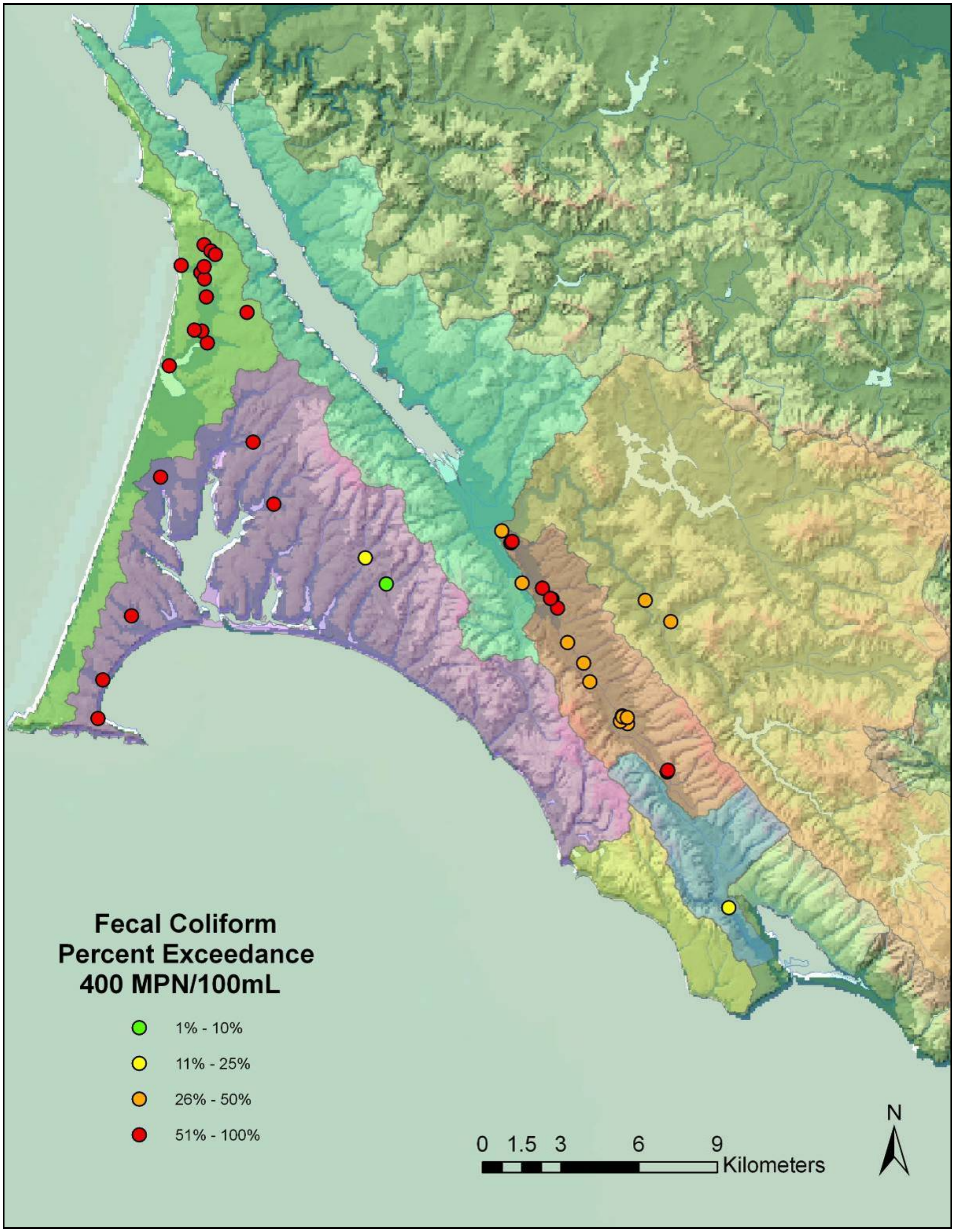

Figure 78. Percent of samples at each water quality sampling location in Point Reyes National Seashore and northern Golden Gate National Recreation Area that exceeded the fecal coliform water contact standard of 400 MPN/100 mL from 1999 to 2005. Many of the samples were collected during storms; after 2003, sampling was performed using a schedule that better represented the seasons.

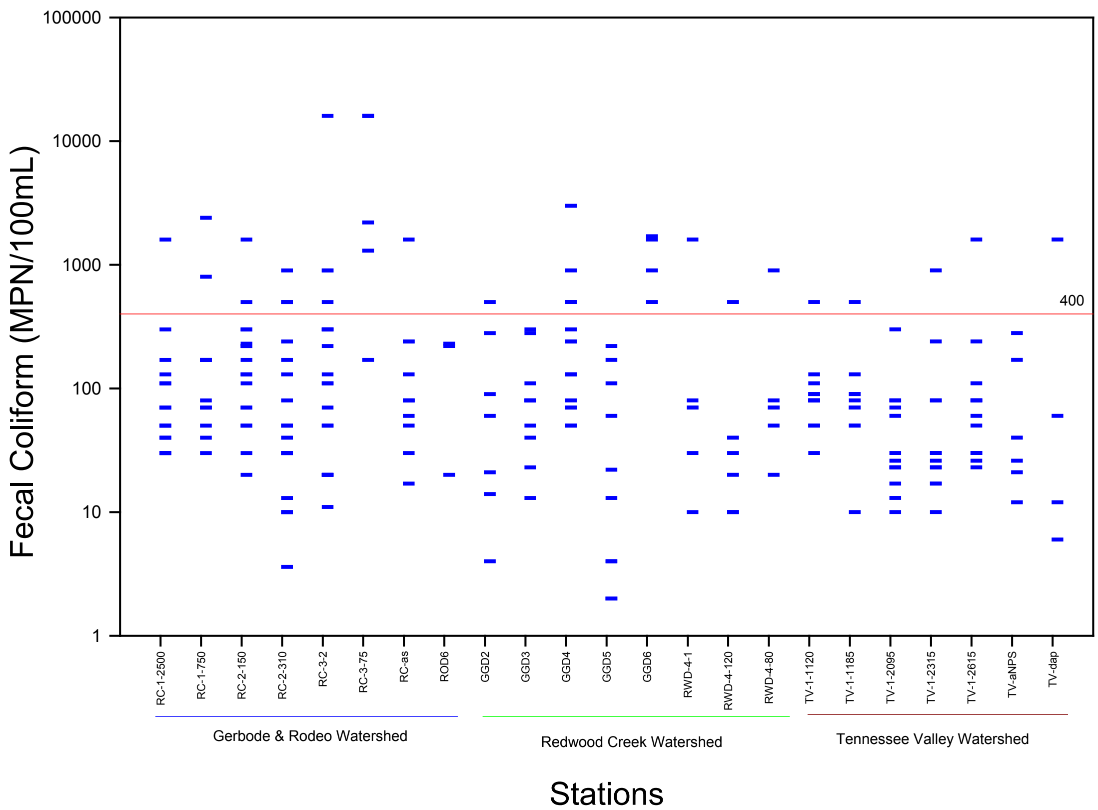

Figure 79. Scatter plot for fecal coliform for samples collected from 1999 to 2005 during the Golden Gate National Recreation Area Stables Study. Each sample plotted on a log scale, is compared to the 400 MPN/100 mL water contact fecal coliform standard.

GOGA: According to the PORE Horizon Report (NPS WRD 2003), before 1999 Easkoot Creek exceeded the US EPA criteria for protection of aquatic life for lead, copper and cadmium. Metals were sampled prior to 1999 at Lobos Creek, Mountain Lake, El Polin Spring (PRES); Redwood Creek (GOGA/MUWO), Green Gulch, Rodeo Lagoon, Gerbode Creek and Tennessee Valley and Calera Creek. Cadmium exceeded acute marine (43 µg/L [ppb]) and freshwater (3.9 µg/L [ppb]) criteria in Rodeo Lagoon. Lobos Creek and Gerbode Valley exceeded the acute freshwater criterion. Copper concentrations in Rodeo Lagoon exceeded the acute freshwater criterion (18 µg/L [ppb]). Lead concentrations exceeded drinking water criterion (15 µg/L [ppb]) in Mountain Lake (south shore) and Redwood Creek below Muir Woods. Mercury concentrations exceeded drinking water criterion (2.0 µg/L [ppb]) in Mountain Lake and Lobos Creek. Two nickel concentrations exceeded the drinking water criterion (100µg/L [ppb]) in El Polin Spring in 1994. Zinc was a concern at several sites including stormwater runoff in the Presidio, Gerbode Valley, Tennessee Valley and Green Gulch (outside park boundaries); 14 concentrations exceeded the acute freshwater criterion (120 µg/L [ppb]) from 1953 to 1996 (NPS WRD 2005). The highest zinc concentration of 3,374 µg/L (ppb) was reported in Lobos Creek in 1996. During the 1999 to 2005 Stables Study, one site, TV-1 1120 in Tennessee Valley exceeded the acute freshwater criterion (18 µg/L [ppb]) for copper.

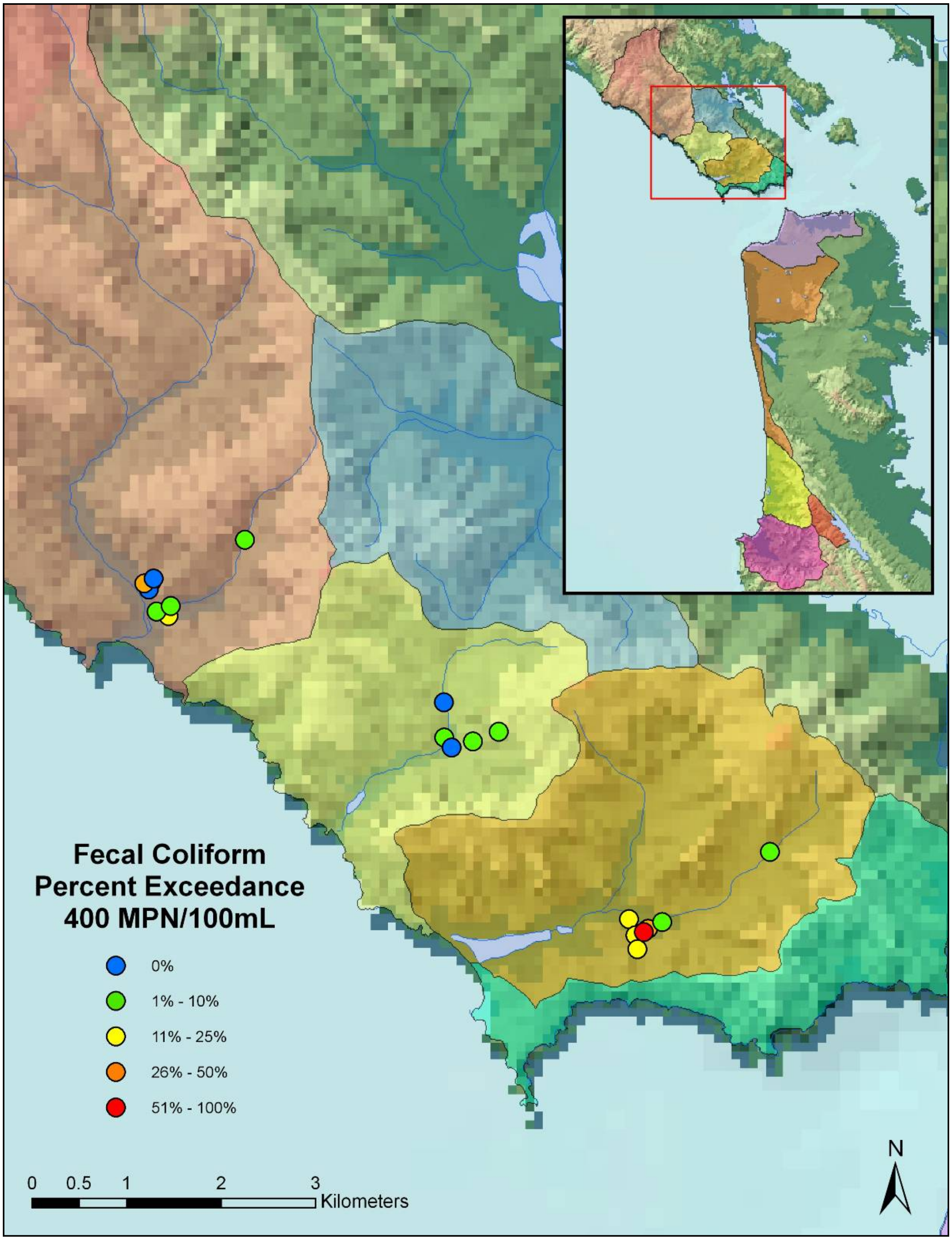

Figure 80. The percent of samples at water quality sampling locations in Golden Gate National Recreation Area that exceeded the fecal coliform water contact standard of 400 MPN/100 mL, 1999 to 2005.

Other Regional Water Quality Monitoring Programs

In addition to NPS-sponsored water quality monitoring programs, there are other local, state and federally sponsored programs that provide information on water quality. The programs that provide fairly large regional datasets within park boundaries are described.

California State Surface Water Ambient Monitoring Program (SWAMP)

In 2000, California approved funding for SWAMP, which allowed for the first time the state and regional boards to perform ambient monitoring to evaluate water bodies for the 305(b) report and the 303(d) list[30]. The goal of SWAMP in San Francisco Bay was to monitor and assess water quality in all of the watersheds in the region to determine if beneficial uses were protected. Between 2001 and 2005, San Francisco Bay Region SWAMP used a rotating basin sampling design to perform year-long surveys of water quality in a number of watersheds. After reviewing the studies, the state concluded more information was needed on (1) long-term trends and annual variability, especially the effects of climate change and other regional and local factors affecting minimally disturbed reference sites; and (2) minimally disturbed ("reference") conditions for benthic macroinvertebrates, nutrients and basic water quality (CRWQCB 2007b). The current emphasis is long-term monitoring of water quality to develop reference conditions and assess the effects of urbanization. Redwood and Pescadero Creeks are two of the six minimally disturbed reference sites selected for monitoring of benthic macroinvertebrate monitoring, periphyton and nutrient levels, basic water quality parameters and stream flow.

General objectives of the current SWAMP program are to:

- Describe water quality conditions and biotic assemblages, and the spatial and temporal variability of those conditions, at minimally disturbed reference sites.
- Perform special short-term monitoring studies to answer questions raised by previous ambient monitoring data on the effects of urbanization on water quality conditions.
- Document pre-project conditions and long-term trends in water quality (e.g., benthic macroinvertebrates, periphyton, basic water quality and aquatic habitat) in response to large-scale urban development.

<u>Watershed-based Monitoring (2001 to 2005)</u>

For the watershed-based monitoring from 2001 to 2005, the 4,000 mi^2 (10,360 km^2) San Francisco Bay Region was divided into 47 "planning watersheds" to implement a rotating basin approach for monitoring and assessment on a scale finer than the seven hydrologic basins. The planning watersheds are 30–200 mi^2 (78 km^2) with most 50–100 mi^2 (129–259 km^2). Past watershed monitoring included creeks in West Marin (Walker and Lagunitas). Watersheds monitored in 2005 included South Coastal Marin and San Francisco creeks, including Pine Gulch, Morses Gulch, McKinnan Gulch, Audubon Canyon, Easkoot Creek, Webb, Redwood, Tennessee Valley and Rodeo Creeks and Bolinas and Rodeo Lagoons. A deterministic study design was used to select stations at confluences (to determine the influence of a tributary), to identify reference conditions in areas of low impact land use, with previous data indicating an impact, to evaluate the impact of particular land uses and to determine if beneficial uses were protected (i.e., water contact).

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[30] Most of this section was excerpted from the San Francisco Bay Region Watershed Management Initiative (CRWQCB 2004).

The technical approach for SFRWQCB activities under SWAMP includes: (1) monitoring fish for contaminants in reservoirs and coastal areas where people catch and consume fish and (2) watershed monitoring to assess water quality impacts and establish reference site conditions (i.e., high quality or "clean"). Coastal Fish Contamination Program funds were used to measure contaminants in fish that people consume in Tomales Bay and the ocean waters. The SFRWQCB implemented most of the SWAMP watershed monitoring with a master contract with the CDFG for bioassessment. SFRWQCB conducts research on watersheds, establishes partnerships within watersheds, does reconnaissance, develops the study design and establishes access. The Regional Board conducts continuous monitoring, bacteriological monitoring and trash assessments.

In 2005, SWAMP released a report that described surveys of reservoirs and coastal areas conducted by the SFRWQCB, in which edible fish were collected and their tissues analyzed for contaminants that may affect human health (SWAMP 2005). The report analyzed fish and shellfish tissues collected from 1998 to 2001 in Tomales Bay, along the San Mateo and San Francisco County coasts; and from fish collected from 2000 to 2002 in 10 other water bodies in the region including Bon Tempe, Nicasio and Soulejule Reservoirs in Marin County.

These studies resulted in the following findings for Tomales Bay and local reservoirs within the San Francisco Bay Region (SWAMP 2005):

- All the reservoirs sampled yielded fish with edible tissue concentrations of mercury that exceed the US EPA water quality criterion of 0.3 ppm (wet weight) and the State Office of Environmental Health Hazard Assessment (OEHHA) screening value (Figure 81).
- Largemouth bass accumulated higher levels of mercury than the other fish species sampled, with concentrations averaging about 3–5 times higher than mercury values in samples from carp, channel catfish and black crappie (Figure 81).
- With the exception of Nicasio Reservoir, all nine of the reservoirs surveyed for pesticides and PCBs had edible fish tissue PCB concentrations above the OEHHA screening value of 20 ppb (wet weight). PCB concentrations were highest in carp, channel catfish and largemouth bass.
- Sufficient mercury data were available from Tomales Bay for OEHHA to set consumption guidelines for California halibut, redtail surfperch, shiner surfperch, jacksmelt, leopard shark, brown smoothhound shark, Pacific angel shark, bat ray and red rock crab (Figure 82). Pile surfperch were included in the advisory, based on data for other surfperches. The OEHHA mercury advisory does not apply to commercial oysters, clams, or mussels from Tomales Bay. Mercury concentrations have been measured in commercially grown Tomales Bay shellfish, and elevated levels have not been found.
- Along the San Mateo coast, two of four crab samples and three of eleven fish samples had mercury concentrations above the OEHHA screening value. One walleye surfperch sample exceeded the screening value for PCBs.
- Salmon composites from the San Francisco coast and the Farallon Islands did not exceed any screening values.

For more information on the SWAMP program sampling workplan, studies, and available reports, please visit their website at www.waterboards.ca.gov/sanfranciscobay.

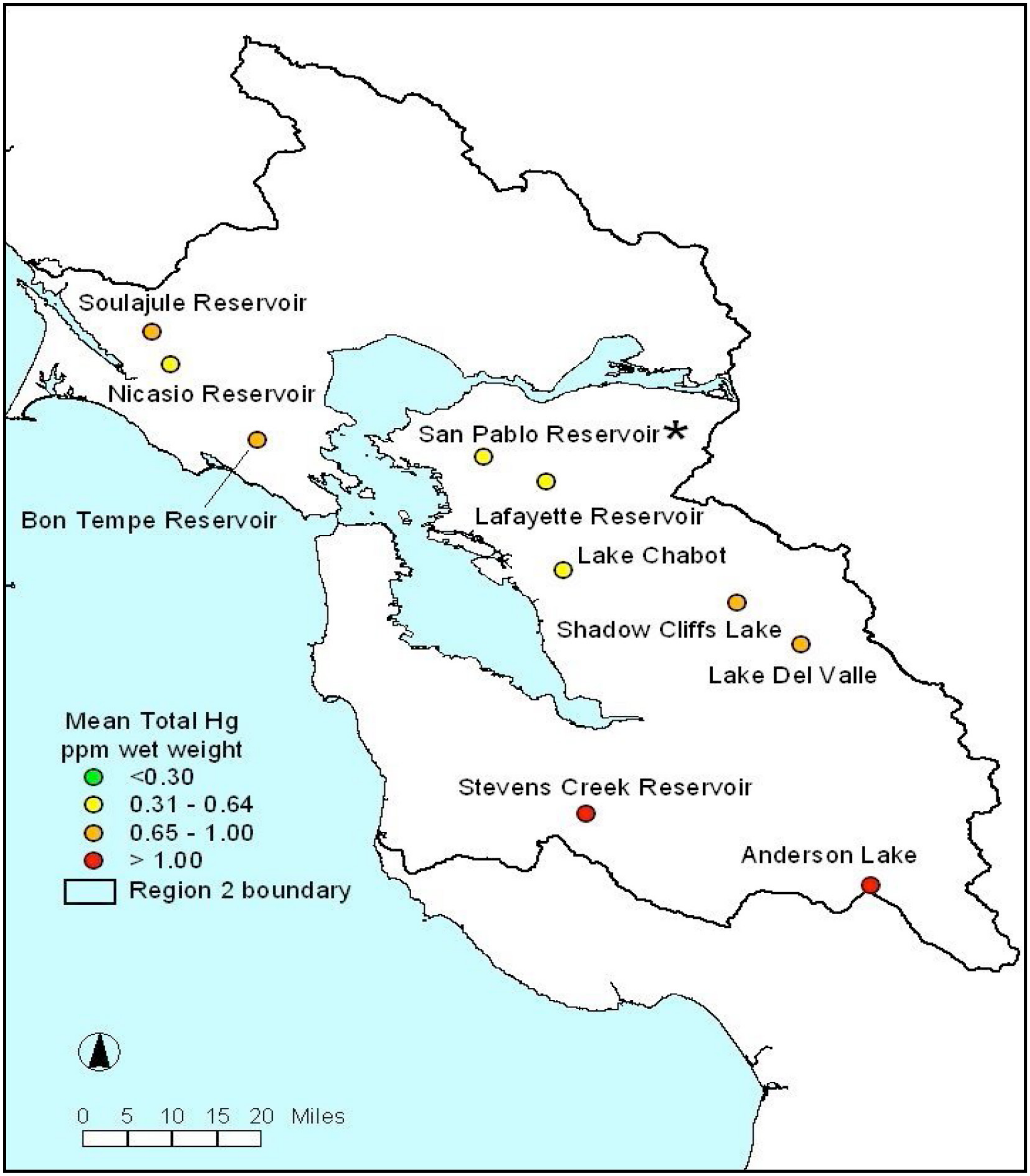

Figure 81. Mercury concentrations in largemouth bass (*Micropterus salmoides*) for the nine reservoirs sampled by the San Francisco Bay Region Water Quality Control Board. The reservoirs are all outside of park boundaries but within Marin County, providing an idea of pollutant sources in the vicinity (SWAMP 2005).

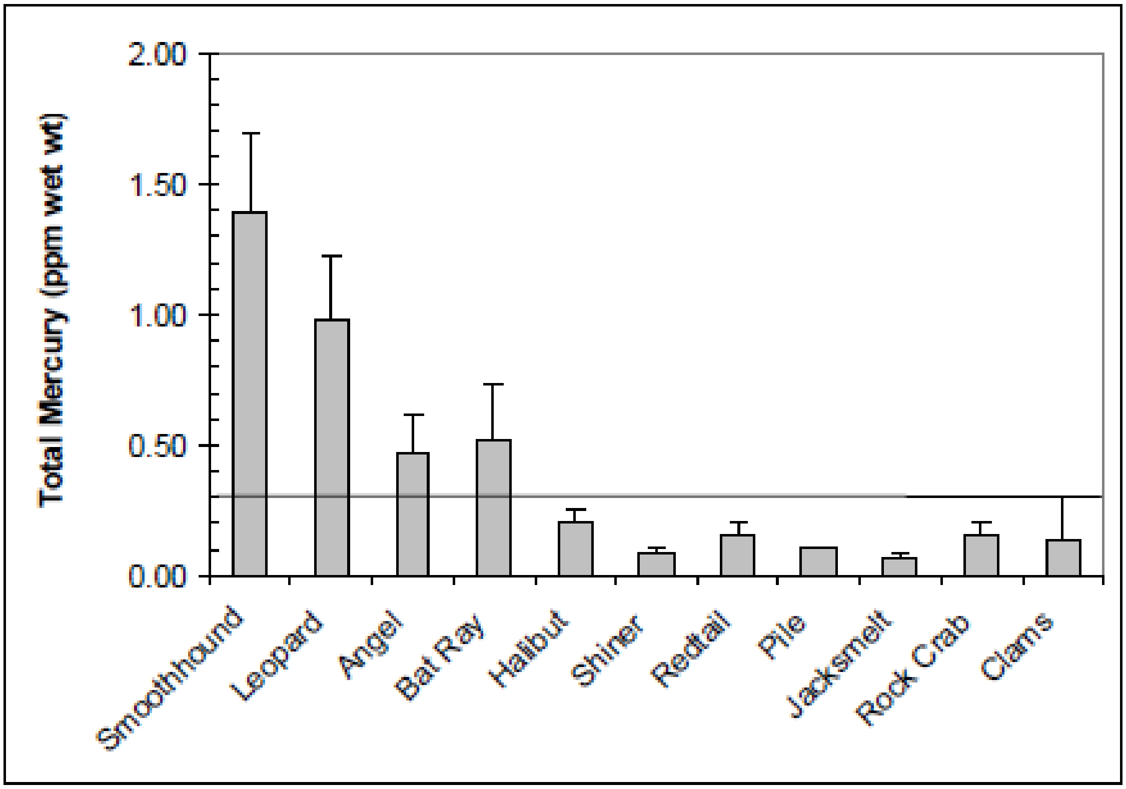

Figure 82. Mean mercury concentrations (±sd) in fish and shellfish species collected from Tomales Bay. Line indicates Office of Environmental Health Hazard Assessment Mercury Screening Value of 0.3 ppm wet weight (SWAMP 2005).

<u>Beach Water Quality</u>
In accordance with California state (California Health and Safety Code section 115910), individual counties are required to monitor ocean water at public beaches and water contact sports areas. The amount of indicator bacteria in runoff, and consequently in the surfzone, is the best indication of whether a beach is safe for recreational contact. Samples are analyzed for bacteriological "indicator" organisms, total coliform, *E. coli* (freshwater) and enterococcus (marine water and freshwater). Elevated concentrations of these organisms are suggestive of contamination by human sewage and other wastes which may result in human disease. Their presence indicates the potential for water contamination with other pathogenic microorganisms, such as bacteria, viruses and protozoa that do pose a health risk to humans.

Most sample locations are selected by monitoring, health and regulatory agencies to specifically target popular beaches and/or those beaches frequently affected by runoff. Water quality samples are collected by the county, city and NPS at a minimum of once a week from April through October, which is required under the California Beach Bathing Water Quality Standards (AB411) or the US EPA National Beach Guidance and Performance Criteria for Recreational Waters (US EPA BEACH program). Some agencies conduct year-round sampling, while others scale back their monitoring programs from November through March.

Shoreline bacteria monitoring is routinely conducted at numerous beaches (freshwater and marine) in the parks. There are seven recognized beaches within the parklands: Stinson Beach, Muir Beach, Tennessee Beach, Rodeo Beach, Horseshoe Cove (Fort Baker), Ocean Beach and Aquatic Park (Cooprider 2004). Additional recreational areas, Baker Beach and Crissy Beach, are located within the boundaries of PRES. Most beaches do not exceed water quality objectives for the monitoring periods (Figures 83, 84 and 85). The figures show the percent of samples taken from 2002 to 2005 by Marin, San Francisco, San Mateo counties and the City of San Francisco that exceeded standards. Chicken Ranch Beach on Tomales Bay and Kehoe Lagoon at Kehoe Beach exhibited the highest number of exceedances for all indicators. Bacterial indicator exceedances are were frequently associated with wet weather from combined sewer discharges, runoff from agricultural areas or for unknown causes.

California Mussel Watch and Toxic Substances Monitoring Programs

In 1976, the California initiated the State Mussel Watch and State Toxic Substances Monitoring Programs to assess the concentration of pollutants in the tissue of aquatic organisms. Tissue levels reflect exposure over much longer periods than instantaneous water column samples and provide an estimate for exposure of people, fish and wildlife to pollutants in the food chain. Both programs ended in 2003, but the data are still used by the state and regional boards to identify waters impacted by pollutants.

The Toxic Substances Monitoring Program used fish and other aquatic organisms from fresh, estuarine and marine waters to monitor pollutant levels (trace elements, pesticides and PCBs) in targeted water bodies with known or suspected impaired water quality. Samples were taken within the parks in Lake Merced and Tomales Bays.

The Mussel Watch Program used resident and transplanted bivalves to monitor pollutant levels at coastal reference stations and bays and estuaries to confirm toxic substance pollution (Table 28 and Figure 86). Periodic monitoring of bivalve tissue by NOAA's National Mussel Watch and international surveys complements information from the State Mussel Watch Program.

NOAA Mussel Watch Program (1986 to present)

Since 1986 the NOAA National Status and Trends Program Mussel Watch has monitored concentrations of trace chemicals in the coastal United States by sampling mussels, oysters and sediment. (O'Connor 1998). Initially, the NOAA Mussel Watch Project based its suite of measured contaminants on an earlier US EPA Mussel Watch Program and reoccupied 50 sites from that program. NOAA Mussel Watch sites are representative of large coastal areas and to avoid small-scale patches of contamination, or "hot spots." For this reason, the data can be used to compare contaminant concentrations across space and time to determine which coastal regions are at greatest risk in terms of environmental quality. The Mussel Watch Program determines concentrations of PAHs, PCB congeners, several pesticides, butyltins and certain toxic elements in sediment and bivalve samples from the US coastal waters. The data are used to determine the extent and temporal trends of chemical contamination on a nationwide basis and identifying which coastal areas are at greater risk in terms of environmental quality.

Across the nation, over 280 US coastal and estuarine sites are sampled for bivalves biennially and for sediments once every decade. Two NOAA Mussel Watch monitoring stations are located near the parks: Sacramento Landing in Tomales Bay (Figures 87 and 88) and East Landing in the Farallon Islands. Bivalve and sediment samples are collected from three stations at each site (stations are generally within 100 m [328 ft] of a site center). Tissue contaminant concentrations

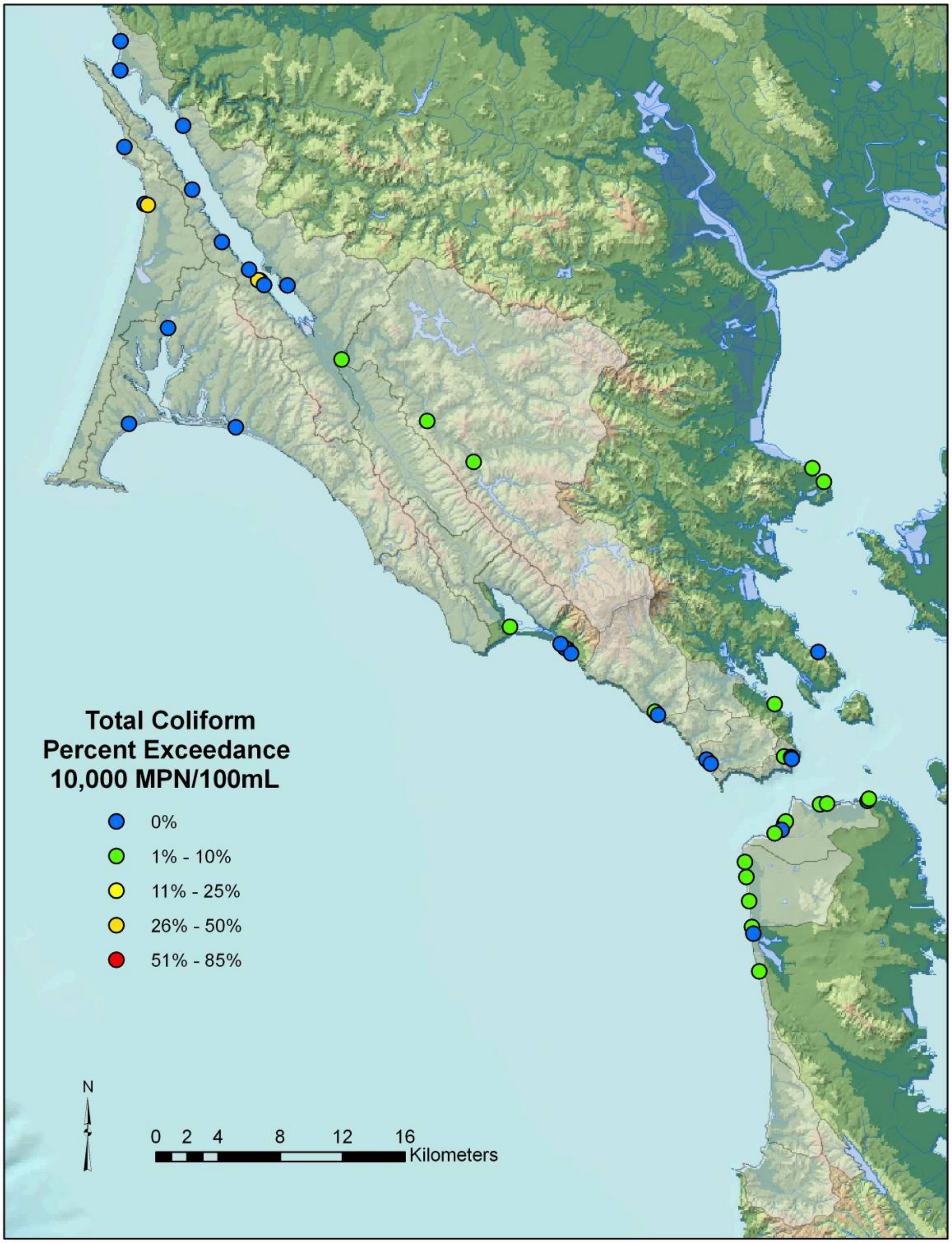

Figure 83. Beach water quality sampling sites in Point Reyes National Seashore and Golden Gate National Recreation Area and the percent of samples at each location that exceeded the total coliform water contact standard of 10,000 MPN/100mL from 2002 to 2005.

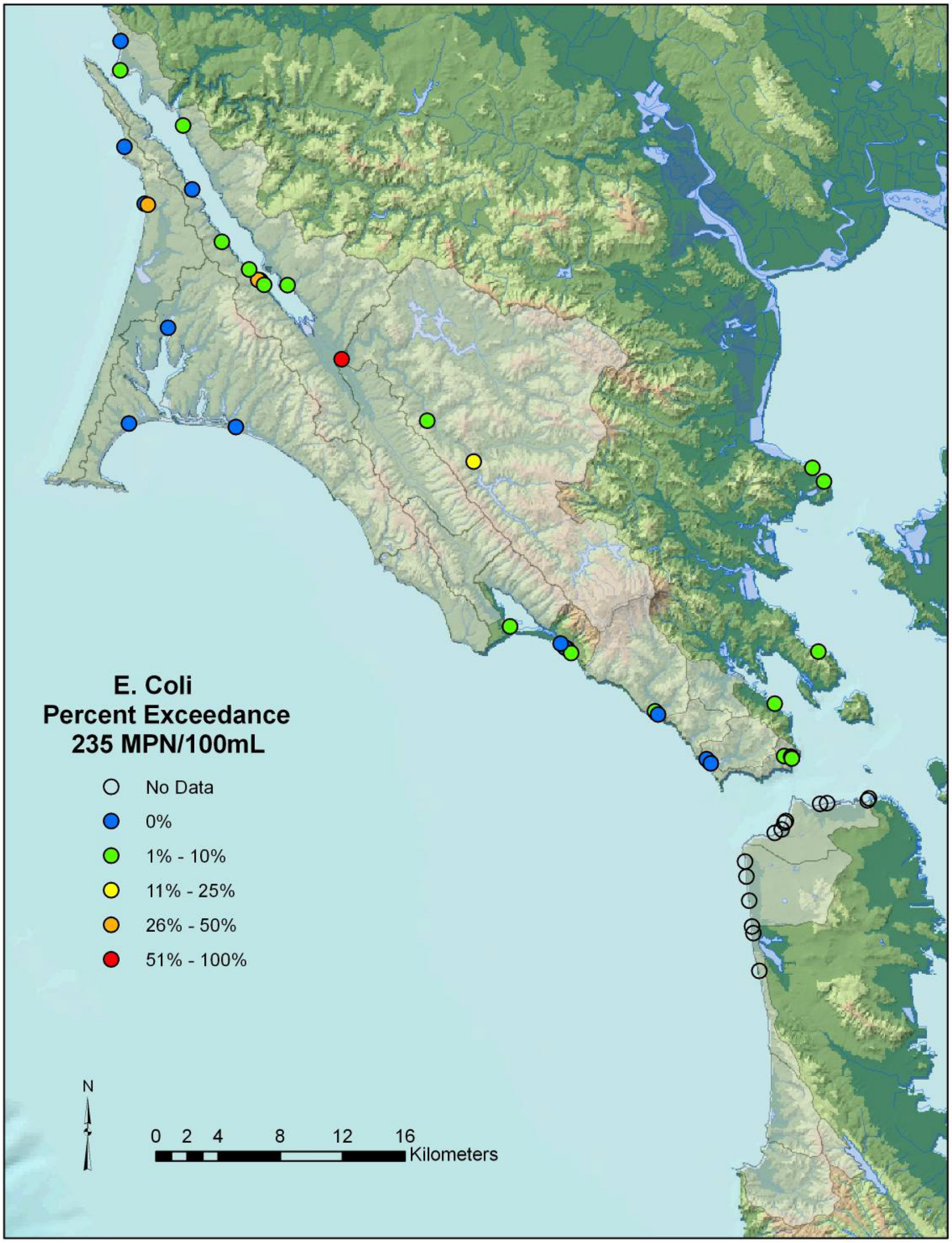

Figure 84. Beach water quality sampling sites in Point Reyes National Seashore and Golden Gate National Recreation Area and the percent of samples that exceeded the *E. coli* water contact standard of 235 MPN/100mL from 2002 to 2005.

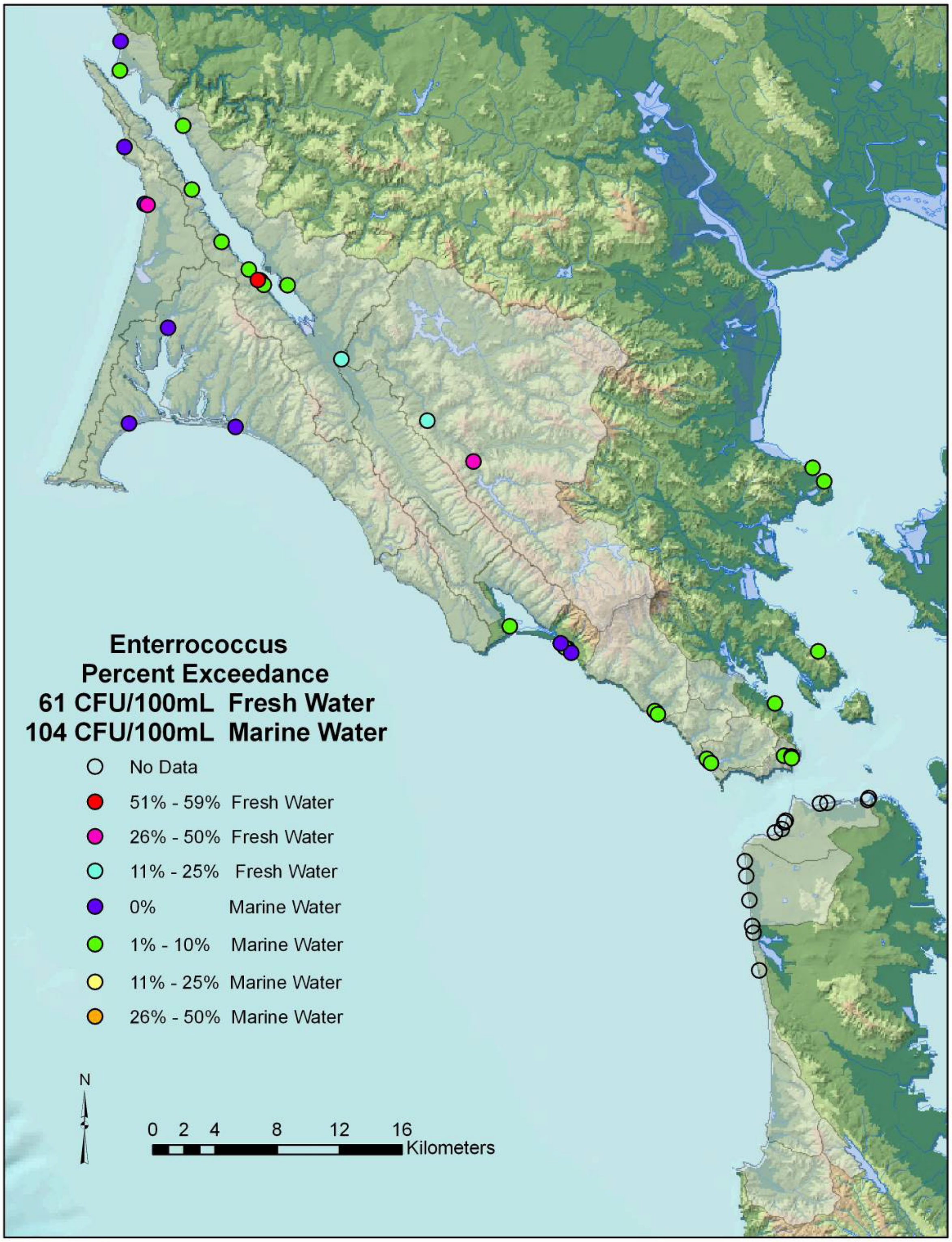

Figure 85. Beach water quality sampling sites in Point Reyes National Seashore and Golden Gate National Recreation Area and the percent of samples that exceeded the *Enterrococcus* fresh water and marine standards from 2002 to 2005.

Table 28. California Mussel Watch monitoring stations near Point Reyes National Seashore and Golden Gate National Recreation Area.

Station Code	Station Name	Sampling History
203.0	Tomales Bay / Shell Beach	1979–1982, 1991–1992, 1997 to 2000
203.1	Tomales Bay / Vincent Landing	1997 to 2000
203.2	Tomales Bay / Walker Ck Mouth #5	1999 to 2000
203.3	Tomales Bay / Walker Ck Mouth #1	1997 to 2000
203.4	Tomales Bay / Walker Ck Mouth #4	1998 to 2000
203.5	Tomales Bay / Walker Ck Mouth #2	1997 to 2000
203.7	Tomales Bay / Walker Ck Mouth #3	1997, 1999 to 2000
203.8	Tomales Bay / Marshall	1998 to 2000
203.9	Tomales Bay / Nicks Cove	1997–1998
204.1	Tomales Bay / HP	2000
204.2	Tomales Bay / Hog Island	2000
204.3	Tomales Bay / Hamlet	1999 to 2000
204.4	Tomales Bay / Audubon	1999 to 2000
204.5	Tomales Bay / McDonald	2000
207.0	Point Reyes	1978–1979, 1991
208.0	Bolinas	1980–1981
211.1	Lagunitas Creek / Bridge #1	1997
211.3	Lagunitas Creek / Bridge #2	1997
306.0	San Francisco Bay / Fort Baker	1981, 1983, 1991–1993, 1999 to 2000
306.5	Alcatraz Island	1989
307.8	San Francisco Outfall	1989
330.0	Duxbury Reef	1980–1981
331.0	Muir Beach	1980
332.0	Point Bonita	1980
333.0	Farallon Islands	1978–1980
334.0	Cliff House	1980
335.0	Pacifica	1980
336.0	J. Fitzgerald	1978–1981, 1991, 1998 to 2000
399.2	Pescadero Creek	1988–1989

are measured in several bivalves, including the foolish mussel (*Mytilus trossulus*), the Mediterranean mussel (*M. galoprovincialis*) and the California mussel (*M. californianus*). The bivalves are collected from intertidal to shallow subtidal zones, brushed clean and shipped on ice to the analytical laboratory. Sediments are collected using a grab sampler and the top 1 cm (0.4 in) is removed for analysis. The bivalve composite samples and sediment samples are analyzed for organic and metal contaminants.

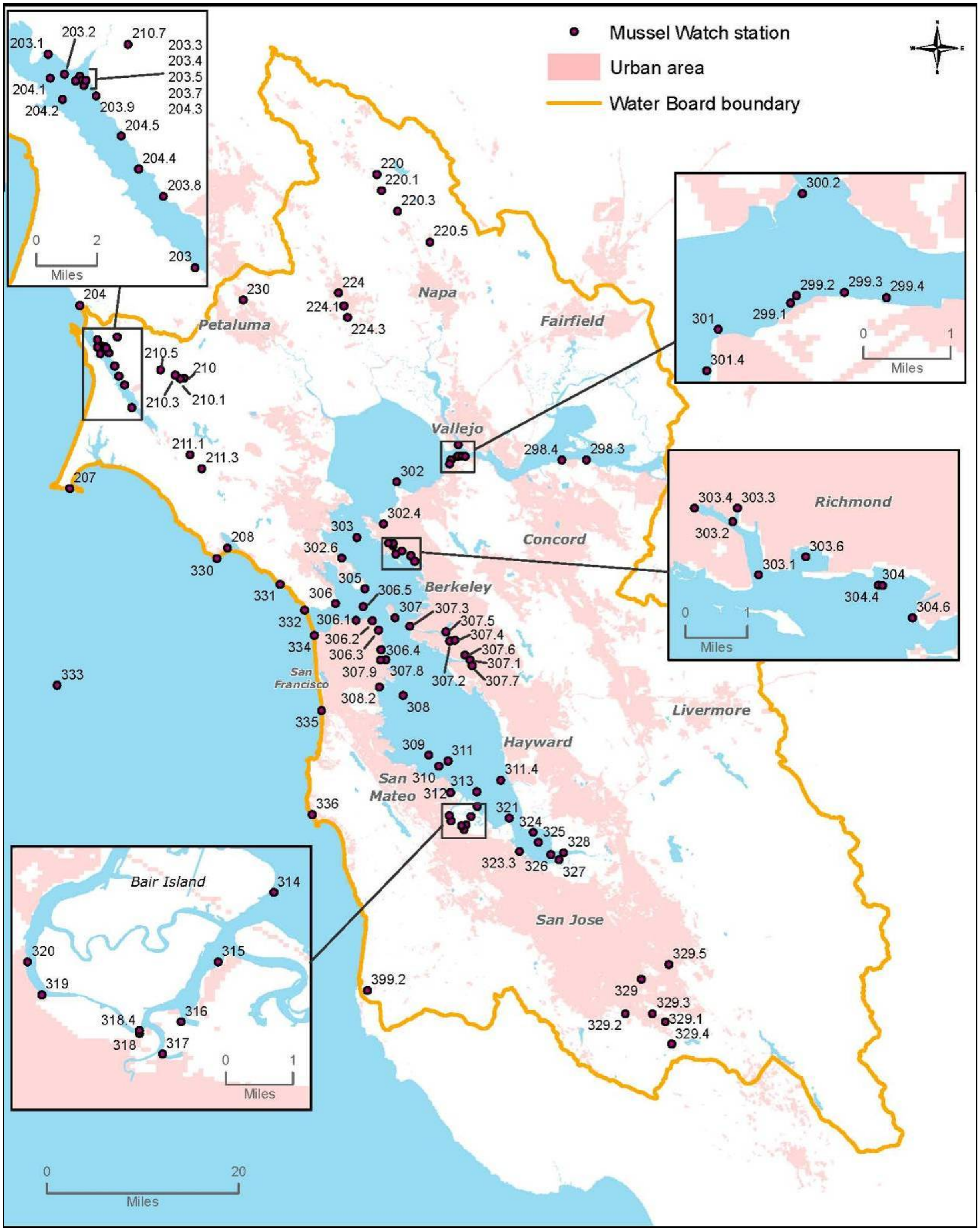

Figure 86. California Mussel Watch stations in the San Francisco Bay region (CRWQCB 2007a).

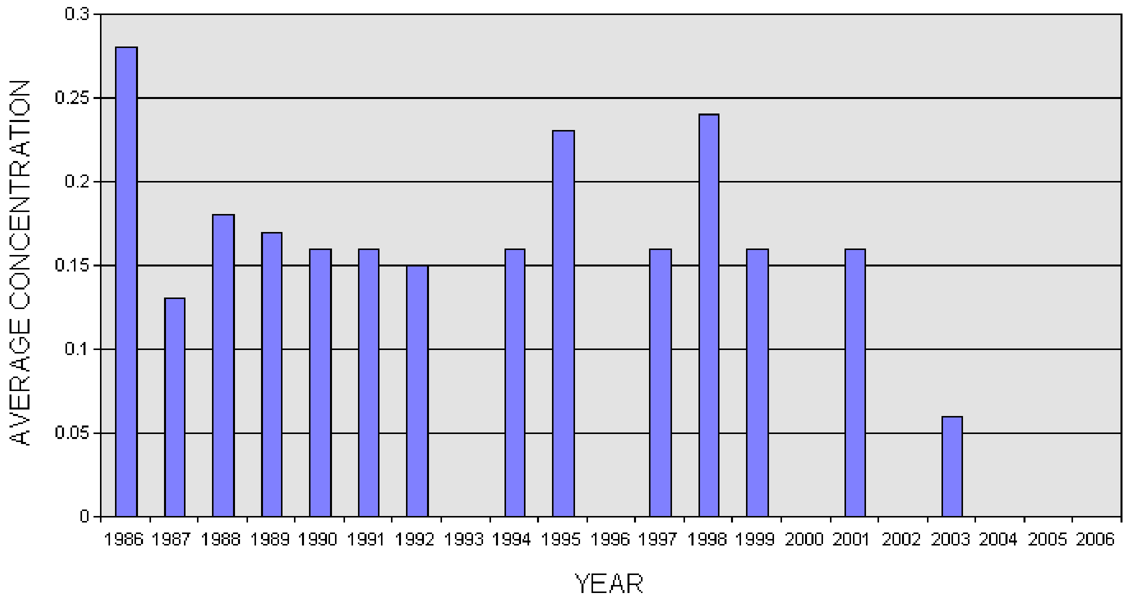

Figure 87. Mercury concentrations (ppm) in bivalve tissue at Sacramento Landing in Tomales Bay (NOAA mussel watch program data).

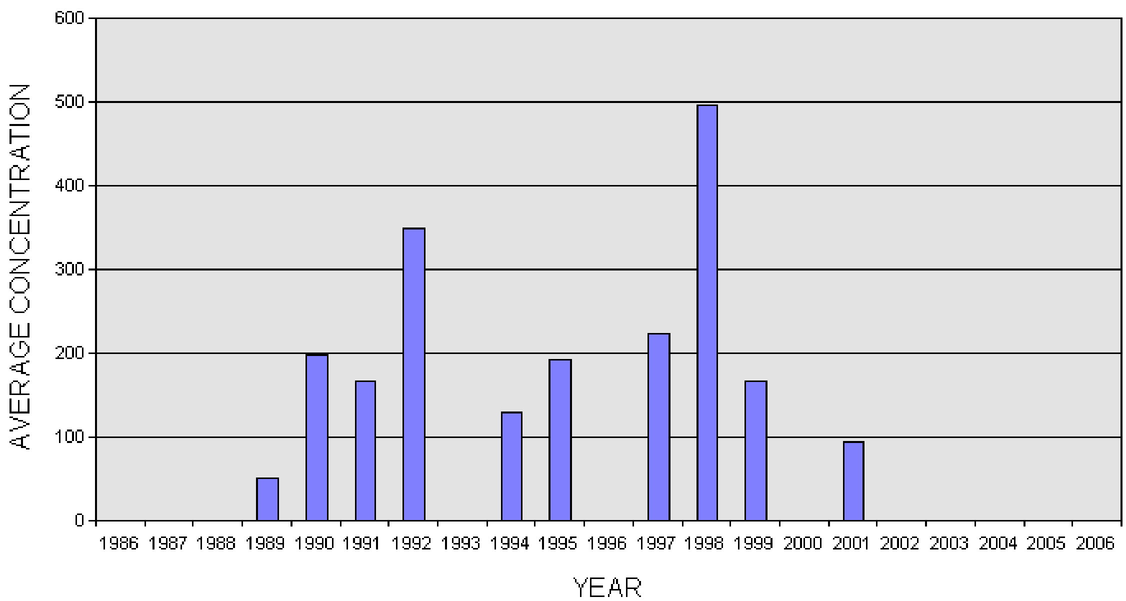

Figure 88. Petroleum aromatic hydrocarbon concentrations (ppb) in bivalve tissue at Sacramento Landing in Tomales Bay in samples taken from 1986 to 2006 (NOAA mussel watch program data).

Western EMAP: Estuaries and Offshore Coastal Monitoring

In 1999, the US EPA created the Environmental Monitoring and Assessment Program (EMAP) to develop tools to assess the status and trends of ecological resources. The objective of the EMAP-West Study is to assess the ecological condition of estuarine and offshore waters of the Pacific Coast States. EMAP and US EPA Region 9 are working with CDFG, Moss Landing Marine Laboratories, San Francisco Estuary Institute and the Southern California Coastal Water Research Project (SCCWRP) to develop California's coastal monitoring strategy.

The EMAP assessment used a probabilistic design and, in 1999, sampled 210 locations in small estuarine systems (80 in California) for dissolved oxygen, light penetration, sediment toxicity, sediment contaminants, tissue residues, fish community parameters and benthic communities. In 2000, US EPA sampled stations in San Francisco Bay and in 2002, wetland stations were sampled. In summer 2003, NOAA, US EPA and partnering West Coast states (WA, OR, CA) combined efforts to conduct a joint survey of ecological condition of aquatic resources in near-coastal waters along the US western continental shelf. In 2004 and 2005, EMAP surveys were focused on supporting the National Coastal Monitoring Assessment. The results of the coastal EMAP are a major component of the National Coastal Condition Assessments reports.

The environmental condition indicators sampled in the estuarine survey include measures of: 1) general habitat condition (depth, salinity, temperature, pH, total suspended solids and sediment characteristics); 2) water quality indicators (chlorophyll a, nutrients); 3) pollutant exposure indicators; and 4) benthic condition indicators (Table 29; Nelson et al. 2005). A number of supplemental indicators were measured by EMAP or by external collaborators during the EMAP Western Coastal survey. An additional sediment toxicity test was conducted for the base California stations using the amphipod *Eohaustorius estuarius* acute toxicity test in order to compare the sensitivity of this species with *Ampelisca abdita*, which is the most commonly used amphipod bioassay species in the EMAP program (Nelson et al. 2005). The EMAP data for the estuarine surveys are now available through SCCWRP (www.sccwrp.org) or through the EMAP National Coastal Database program (http://www.epa.gov/emap/nca/html/data/index.html). The 1999 sampling was conducted at five sites in park estuaries, one site in Tomales Bay and four sites in Drakes Bay. In 2002, sampling was conducted in three sites in Tomales Bay and two sites in Drakes Bay.

The systematic sampling of biological and environmental variables provides an important opportunity to learn more about the spatial patterns of near-coastal aquatic resources and processes controlling their distributions. Synoptic sampling of the indicators listed in the previous section supports an integrative "weight-of-evidence" assessment of condition across the sites and allows examination of associations between presence of stressors and biological responses. The incorporation of EMAP's random probabilistic station design is an important feature. This approach enables unbiased statistical estimates of the spatial extent of the study area having degraded versus non-degraded condition, based on the status of the ecological indicators. This information can be used as a baseline for quantifying long-term trends and how environmental conditions may be changing in relation to human or natural disturbances. Although the samples are one-time events, the regional summaries provide important baseline information to compare to local studies. The problem for park-specific condition is the paucity of samples and consequent lack of inference. Despite sampling limitations, we present unique regional findings for sites in Tomales and Drakes Bays.

Table 29. Habitat, benthic condition and exposure indicators for estuaries in Environmental Monitoring and Assessment Program-West (Nelson et al. 2005).

Habitat Indicators	Benthic Condition Indicators	Exposure Indicators
Salinity Water depth pH Water temperature Total suspended solids Chlorophyll *a* concentration Nutrient concentrations (nitrates, nitrites, ammonia, phosphate) Percent light transmission Secchi depth Percent silt-clay of sediments Percent total organic carbon (TOC) in sediments	Infaunal species composition Infaunal abundance Infaunal species richness and diversity Demersal fish species composition Demersal fish abundance Demersal fish species richness and diversity External pathological anomalies in fish	Dissolved oxygen concentration (DO) Sediment contaminants Fish tissue contaminants Sediment toxicity (*Ampelisca abdita* acute toxicity test)

Following are 1999 EMAP-West findings specific to park sites (from Nelson et al. 2005):

- **Chromium** was detected at all 47 California small estuary stations and averaged 143.3 µg/g (ppm) with a maximum concentration of 927 µg/g (ppm) in Drakes Bay. The only other site in the California small estuary stations greater than 400 µg/g (ppm) was the 907 µg/g (ppm) value in Morro Bay. Fifty percent of the area of the California small estuaries had concentrations less than 102.7 µg/g (ppm) and 90% of the area had concentrations less than 368.3 µg/g (ppm).
- **Benthic density** across all of the California small estuaries and Northern California rivers averaged 2,621 individuals/ 0.1 m^2 (2,435/ft^2) and ranged from 7–41,582 individuals/0.1 m^2 (7–38,681/ft^2). Average benthic densities were substantially higher in the Northern California sites than in the rest of the state, 5,606 individuals/0.1 m^2 (5,208/ft^2) in Northern California rivers compared to 1,033 individuals/0.1 m^2 (960/ft^2) in the California small estuary stations. The highest densities occurred in three Northern California stations, two in Smith River and one in Little River. In California small estuary stations, the minimum density of 12 individuals/0.1 m^2 (11/ft^2) occurred in Tomales Bay.
- **Benthic species richness** ranged from 1–95 species/0.1 m^2 (11/ft^2), and averaged 38.1 species/0.1 m^2 (35/ft^2) in the small estuaries. Of the three samples with more than 80 species/0.1 m^2 (74/ft^2), two occurred in Drakes Bay and the third occurred in King Harbor in Southern California. All three of the stations had salinities of 32–33‰.
- **Fish species richness** averaged 5.57 species/trawl in California small estuaries with a maximum of 17 species in a single trawl in Drakes Bay. There were 37 successful 16-ft (4.9-m) otter trawls in 50 California small estuary stations, but only two successful trawls among the 30 Northern California river stations, largely because of the small size of these rivers. Fifty-seven species of fish were collected in the California small estuaries and no additional species were collected in the Northern California rivers.

California Department of Public Health Fecal Coliform and Shellfish Monitoring

The CDPH (under the CA Department of Health and Human Services Agency) has authority and standards to regulate commercial shellfish growing areas. These standards supersede the standards in Regional Basin Plans. In the San Francisco Bay Region, Basin Plan standards for fecal coliform in shellfish-growing waters cannot exceed a median of 14 MPN/100mL or the 90^{th} percentile cannot exceed 43 MPN/100mL. Although CDPH used a median value in the past, they now use a geometric mean of 14 MPN/100mL. CDPH standards follow criteria developed by the National Shellfish Sanitation Program (NSSP administered by the US Food and Drug Administration (USFDA). The standards use a median or a geometric mean. The NSSP standards are based on acceptable levels of fecal coliform in shellfish and shellfish-growing waters. The NSSP fecal coliform standard for shellfish is a market standard of 230 MPN/100 grams (USFDA 2007). CDPH has developed rainfall closure rules when shellfish cannot be harvested for different areas of Tomales Bay based on the analysis of water column and shellfish data. The closure rules have become site specific as the amount of data have increased and the analysis has become more refined. Rainfall closure rules have also become more stringent. The latest and most stringent rules were issued in 1999 (CRWQCB 2005).

Monthly water quality monitoring for fecal coliforms in Tomales Bay and Drakes Estero is conducted by shellfish growers under the authority of CDPH. Fecal coliform bacteria are monitored in approved commercial shellfish-growing waters during periods open to harvesting. Low fecal coliform bacteria concentrations in approved commercial shellfish growing waters during periods open to harvesting imply a corresponding low bacteriological contamination of the meats of harvested shellfish. Several intensive studies have been conducted on bacteriological water quality in relation to shellfish harvesting in the past**.** These studies include: 1) a shellfish and water quality study was conducted in 1974 by the CA DHS (Sharpe 1974); 2) a shoreline and watershed water quality survey was carried out in 1976–1977 and 1977–1978 by the RWQCB (Jarvis et al. 1978); 3) a sanitary survey was conducted by the USFDA Department of Health and Human Services (Musselman 1980); 4) CDPH conducted a pilot study in the winter of 1994–1995 to test sampling methods and locations for the 1995–1996 study; and 5) in 1995–1996 a State Water Board funded study was conducted by CDPH and the RWQCB, under the auspices of the Tomales Bay Shellfish Technical Advisory Committee (CRWQCB 2000).

California EPA developed environmental indicators through the Environmental Protection Indicators of California Program (CA EPA 2002), one of which is fecal coliform bacteria concentrations in approved commercial shellfish-growing waters. There were no exceedances of the regulatory standard for fecal coliform bacteria in approved shellfish-growing waters from 1996 to 2000. Drakes Estero and Tomales Bays had lower fecal coliform counts than Humboldt and Morro bays (Figure 89). Water quality tends to be worse during periods when shellfish are not harvested and monitoring by CDPH is not conducted. The regulatory standard for approved shellfish growing waters during periods open to harvesting is based on the geometric mean of fecal coliform bacteria of monthly samples taken over the most recent three-year period. When this regulatory standard is exceeded, further restrictions to harvesting are placed on commercial shellfish growers. Ongoing evaluations of three-year geometric means relative assess the effectiveness of these restrictions on improving the bacteriological qualities of approved shellfish growing waters during periods open to harvesting. Ongoing changes in the restrictions will tend to lower the fecal coliform bacteria concentrations and the three-year geometric mean. This measure has been collected consistently for several years to meet regulatory requirements and used to determine trends in the quality of the water used for growing shellfish. Because PSP toxicity is a serious ongoing public health threat that requires year-round attention, the CDPH also implements a prevention program that comprises five elements: 1) a coastal shellfish

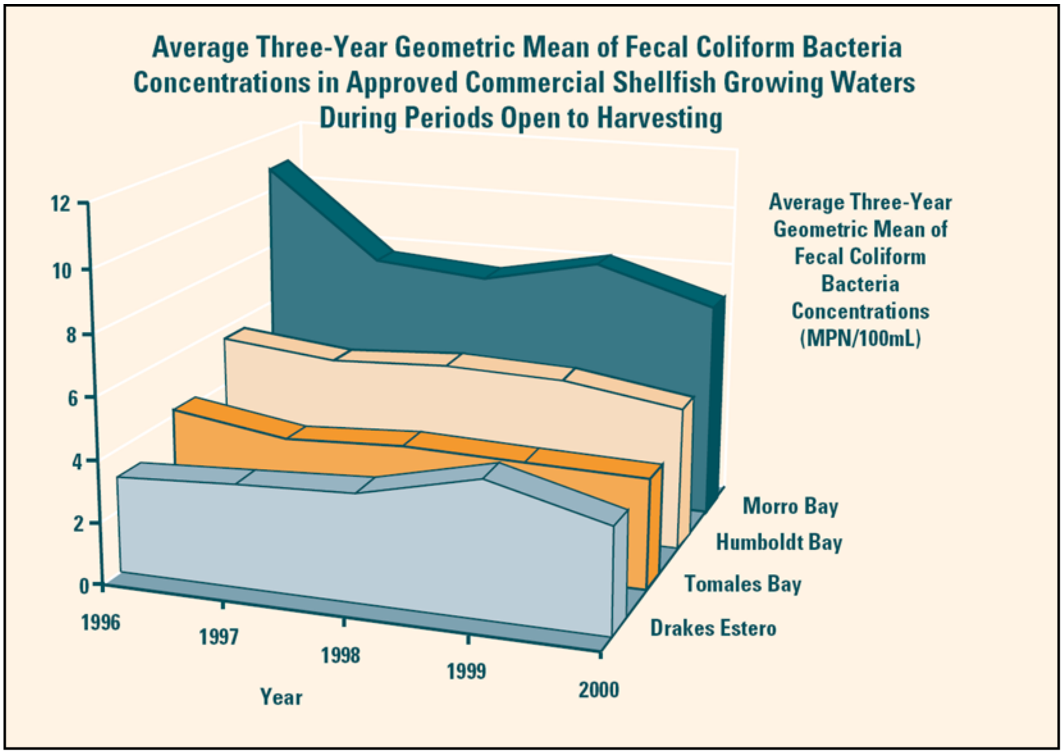

Figure 89. Average three-year geometric mean of fecal coliform bacteria concentrations in approved commercial shellfish growing waters of California. During periods open to harvesting from 1996 to 2000, fecal coliform concentrations were within the regulatory standard of 14 MPN/100 mL (CA EPA 2002).

monitoring program; 2) monitoring of commercial shellfish product; 3) an annual statewide quarantine on sport-harvested mussels (from May 1 through October 31); 4) mandatory reporting of disease cases; and 5) public information and education activities. In response to the occurrence of a new toxin, domoic acid, in the fall of 1991, CDPH added a sixth element to the Marine Biotoxin Monitoring Program: phytoplankton monitoring. This latter monitoring effort was the first volunteer-based phytoplankton monitoring program in the U.S. annual reports describes the shellfish sampling element of the program for PSP toxins and domoic acid and the phytoplankton monitoring results (e.g., Langlois 2008). Summaries are also provided for quarantine and health advisory activities. Locations of shellfish and phytoplankton sampling stations during 2008 are indicated in Figures 90 and 91.

San Francisco Ocean Stormwater and Outfall Monitoring Program

The City and County of San Francisco conduct an ocean monitoring program that has two main components: bacteria monitoring in shoreline waters to provide public health information and determine impacts from shoreline discharges; and offshore monitoring designed to evaluate impacts of treated wastewater on marine sediments and fauna. The monitoring program is a regulatory requirement mandated by the US EPA and the SFRWQCB as a consequence of operating the Southwest Ocean Outfall (SWOO) for the discharge of treated wastewater into the Pacific Ocean offshore of San Francisco. San Francisco watersheds drain to both San Francisco Bay and the Pacific Ocean, as well as to various lakes within the geographic boundaries of the city. During rainstorms, the effects of San Francisco's many hills combined with the high percentage of paved surfaces results in the generation of large volumes of storm water runoff in a

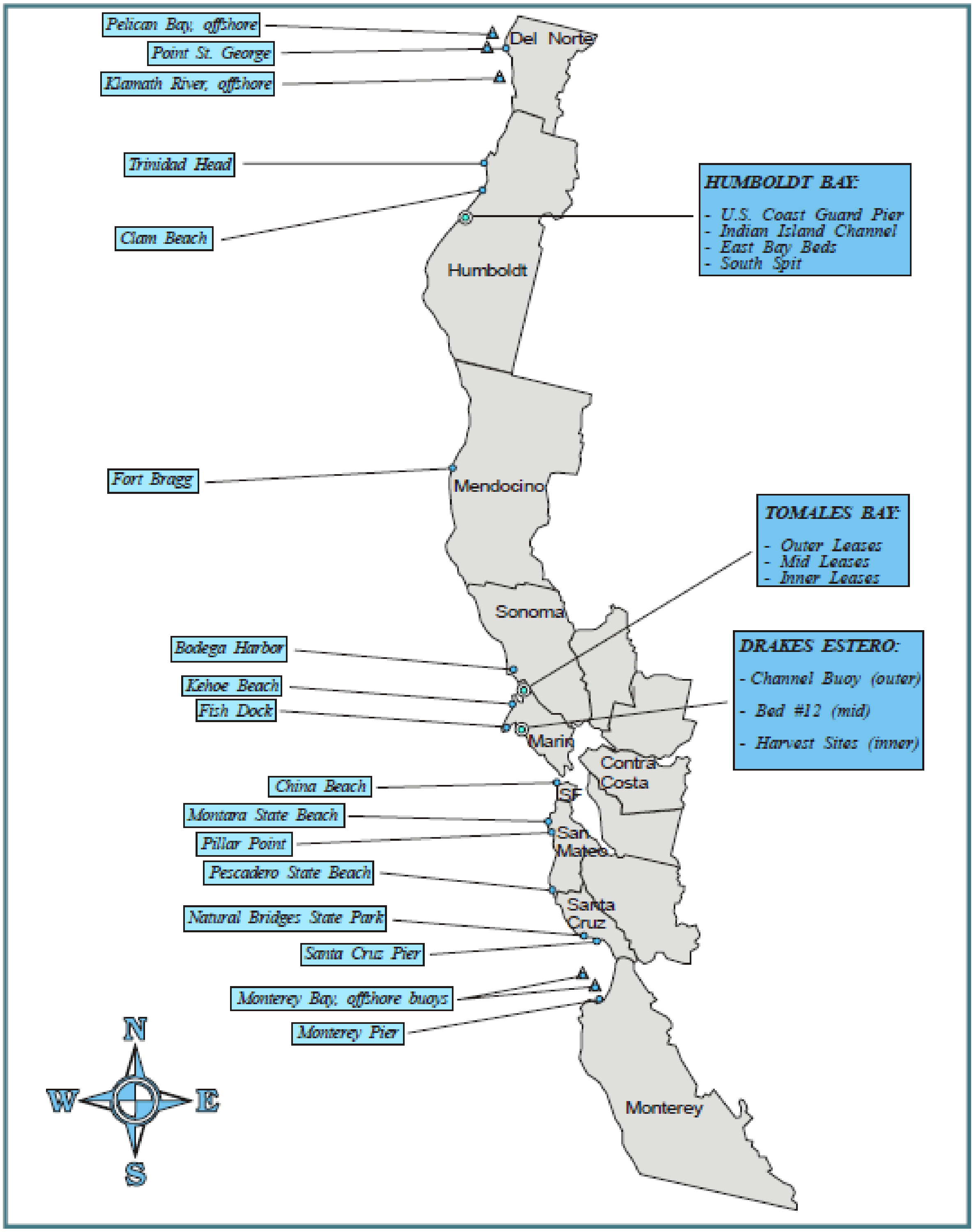

Figure 90. Locations of shellfish sampling stations during 2008 (Del Norte to Monterey counties). Notice the sites in Marin, San Francisco and San Mateo counties along park borders from Kehoe Beach to the Presidio including numerous sites in Tomales Bay and Drakes Bay/Estero (Langlois 2008).

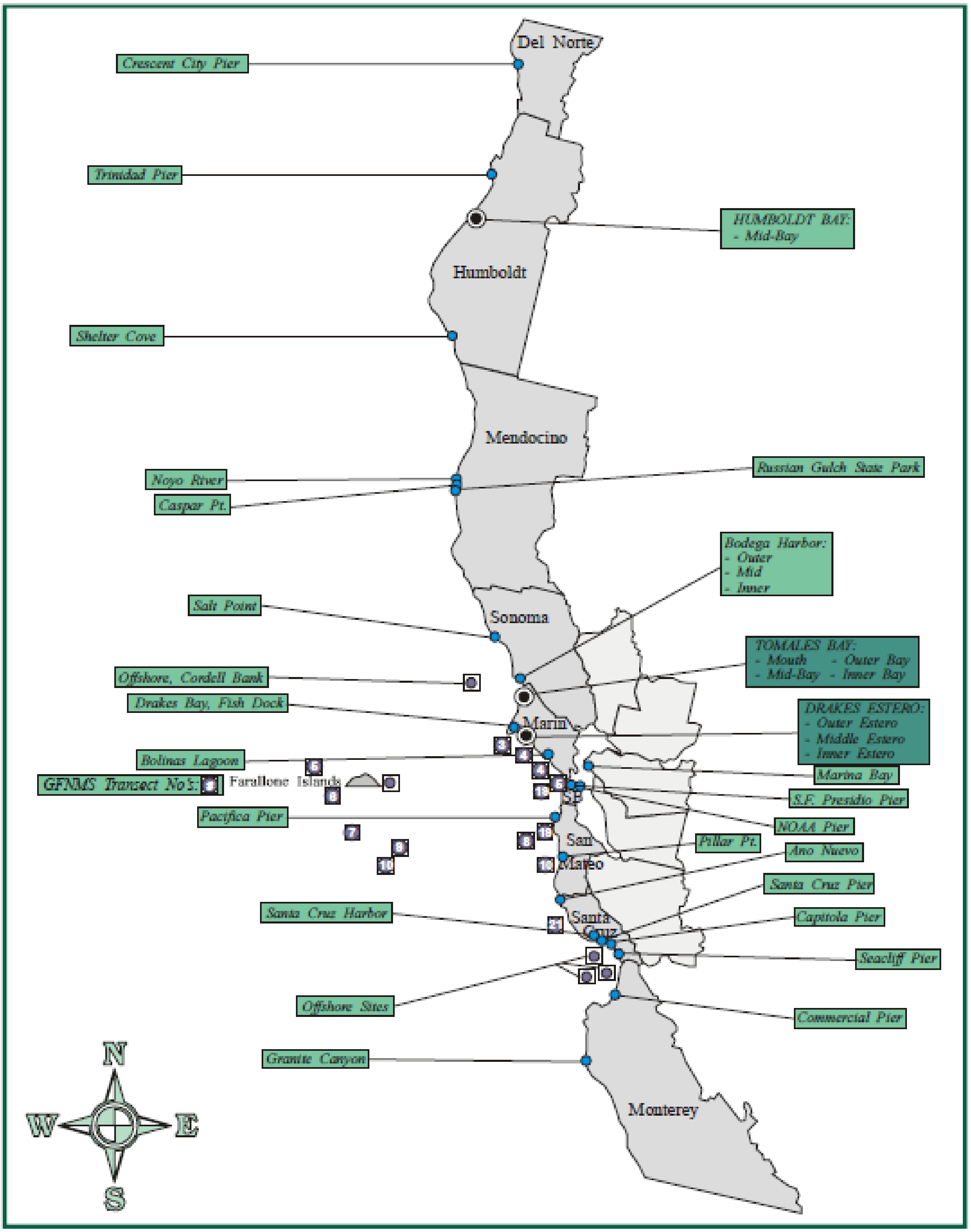

Figure 91. Locations of phytoplankton monitoring stations during 2008 (Del Norte to Monterey counties). Notice the sites in Marin, San Francisco and San Mateo counties along park borders from Kehoe Beach to the Presidio including numerous sites in Tomales Bay and Drakes Bay/Estero (Langlois 2008).

very short time. The city is highly urbanized, with a large central business district. Combined sewers serve the vast majority of the city. Combined sewers collect and transport storm water in the same pipe as sewage, presenting special problems during wet weather when flows increase greatly in volume. Prior to the early 1980s, virtually every rain caused the sewers to overflow at the shoreline, contaminating the beaches and preventing swimming, surfing and board sailing. The city posted health warnings at the shoreline from November through April.

The situation began to turn around in 1981 with the first component of an innovative wastewater system sponsored by San Francisco. In March 1997, San Francisco completed a wastewater facility improvement program making it one of the first cities in the country with combined sewers to complete such a program. San Francisco wastewater facilities in the combined sewer areas of the city capture, store and treat all wet weather flows—sewage and storm water—providing protection to the bay and ocean. San Francisco is unique in the Bay Area in providing treatment for storm water in addition to sewage. Annually, two-thirds of San Francisco's storm water runoff is treated to the secondary treatment standards established by US EPA.

Although San Francisco is served almost exclusively by combined sewers, there have been and continue to be small areas of the city that are served by separate storm sewers. This area will increase as San Francisco assumes jurisdiction over federal government lands and the MS4s the federal government owned and operated. The San Francisco Public Utilities Commission (SFPUC) developed a storm water management plan to address areas of the city served by separate storm and sewer collection systems. Storm water goes into street storm drains and flows to the bay, ocean or local lakes. The storm water management plan describes programs that the SFPUC will implement to minimize storm water pollution in these areas.

Storm water becomes runoff and collects pollutants while passing over landscapes, parking lots, street, gutters and roofs. Recreational and landscaping activities are the primary factors influencing storm water pollutants. The pollutants of concern are sediment, trash, nutrients and pesticides. Water quality in Lake Merced is a concern due to dissolved oxygen and pH not meeting the beneficial use requirements for the lake. In July 2003, the US EPA added Lake Merced to the California 2002 §303(d) list of impaired water bodies due to water quality issues. Lake Merced is a state park located adjacent to GOGA park boundaries (Ocean Beach) that is used by shorebirds and other resources that depend on it as a shallow freshwater resource.

The major areas served by separate storm sewers in the San Francisco urbanized area that affect parklands include the City of San Francisco-owned Lobos Creek (the dead ends of a few municipal streets north from Lake Street drain to the slope above Lobos Creek) and the GOGA-owned area of Alcatraz, Fort Mason and Presidio of San Francisco.

The SWOO Regional Monitoring Program is designed to detect environmental impacts from the discharge of treated combined sewer effluent from the Oceanside Water Pollution Control Plant and Westside Wet Weather Facilities owned and operated by the SFPUC (2006). The facilities and discharges are regulated under the National Pollution Discharge Elimination System (NPDES) provisions of the Clean Water Act through a permit jointly administered by the US EPA, Region 9 and the SFRWQCB. The Oceanside NPDES permit mandates extensive monitoring to assess compliance with broad goals of the Clean Water Act (maintain fishable and swimmable waters) and the California Ocean Plan (prevent degradation of beneficial uses).

Following pre-1996 program analyses and recommendations, the monitoring program adopted a regional perspective in 1997, expanding its monitoring sites to include more references sites (Figure 92) and reducing sampling frequency to one annual sampling event (SFPUC 2006).

The combined sewer system collects and treats sanitary flow, industrial effluent and storm water. All dry weather flows [average 18 million gallons per day (MGD) (68 million L/d)] and wet weather flows up to 43 MGD (163 million L/d) receive secondary treatment. Wet weather flows above 43 MGD receive primary treatment. Flows up to 175 MGD (662 million L/d) are discharged 3.75 miles (6.0 km) offshore in the Pacific Ocean through the SWOO. Flows in excess of 175 MGD result in combined sewer discharges into shoreline waters, including some recreational beaches.

The monitoring requirements varied from 1997 to 2004, but the program always included a Beach and Offshore Monitoring component (SFPUC 2006). The Beach Monitoring Program involves measurements of bacteria concentrations at recreational beaches and notification to the public when State standards are exceeded or when a combined sewer discharge occurs (SFPUC 2006). Pathogen indicators that exceed State standards for water contact recreation are most frequently associated with wet weather, either because of combined sewer discharges or for unknown causes. Combined sewer discharges continue to show a strong relationship with rainfall: years with greater rainfall usually have more discharges, but the intensity of storms is the main determining factor (SFPUC 2006).

The Offshore Monitoring Program involves collection and analysis of physical, chemical and biological indicators to assess and compare the outfall region where impacts may be expected with reference conditions using (SFPUC 2006):

- Sediment quality (physical and chemical): Mean sediment grain size has been similar at the outfall in pre-discharge and discharge periods. Chemistry measures often associated with wastewater discharges were not elevated at the outfall relative to reference Sediment quality (physical and chemical): Mean sediment grain size has been similar at the outfall in pre-discharge and discharge periods. Chemistry measures often associated conditions.
- Benthic infauna community structure: Reference envelope analysis shows that benthic infauna indicators (abundance, diversity, evenness, dominance) at outfall stations are the same as at reference stations.
- Demersal fish and epibenthic invertebrate community structure: Reference envelope, cluster and ordination analyses demonstrate that demersal fish and epibenthic invertebrate community indicators (abundance, diversity, evenness, dominance) are essentially the same at outfall and reference stations.
- Physical anomalies and bioaccumulation of contaminants in organism tissues: Reference envelope analysis demonstrates that sediment metals concentrations at outfall and reference stations do not differ; however, low levels of many chemicals do exist.

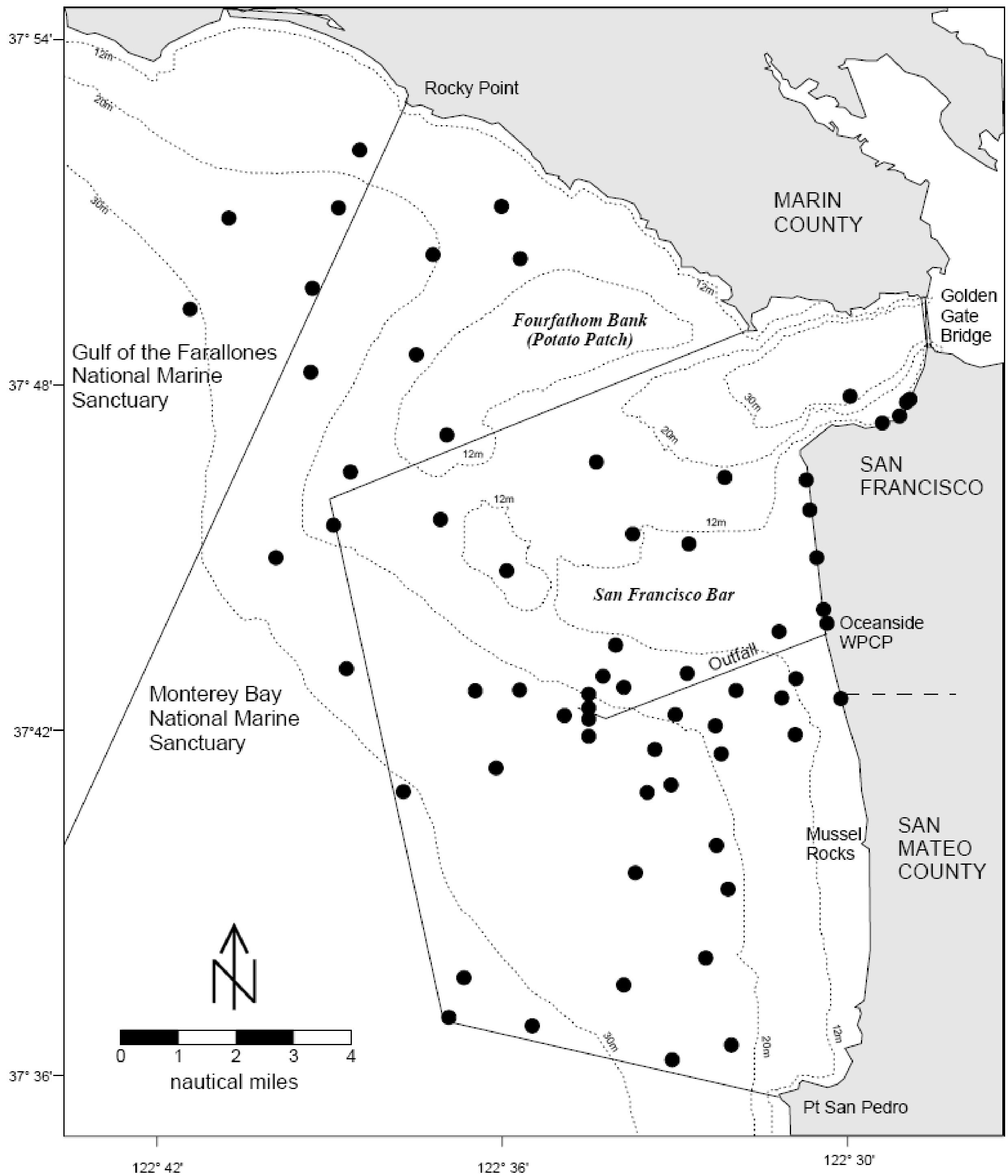

Figure 92. The Southwest Ocean Outfall Regional Monitoring Program study locations (SFPUC Natural Resources Division 2006).

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Appendix 1. Invertebrates of Bays and Estuary: North Central California. I= increasing, D= decreasing, S=Stable, U= Undetermined, L=low (Source: Leet et al. 2001. California's Living Marine Resources: A Status Report).

Scientific Name	Common Name	Commercial Fishery Status	Population Status	Population notes	Range	Habitat
Crangon nigricauda	Blacktail bay shrimp	U	U	abundance increased during years of low river inflow	Alaska to Baja California	found in estuaries and nearshore ocean areas to a depth of at least 90 feet
Saxidomus giganteus	Butter Clam	U	U	present level of harvest can be sustained	Sitka, Alaska to San Francisco	lives at depths 10 to 14 inches in mud or sandy mud of bays, lagoons and estuaries prone to low tides
Crangon franciscorum	California bay shrimp	U	U	Studies indicate that the abundance increases with increased river inflow to the estuary	Alaska to San Diego; most common species in the San Francisco estuary	depths of at least 180 feet
Tresus capax	Fat Gaper	U	U	intertidal and subtidal resource appears to be in a healthy state	Alaska to Scammon's Lagoon, Baja California	fine sand or firm sandy-mud bottoms in bays, estuaries and more sheltered outer coast areas; from intertidal zone to 150 feet
Panope generosa	Geoduck clam	U	U	intertidal clam densities in California would be expected to be considerably less than one clam per square yard	Forrester Island, Alaska to Scammon's Lagoon, Baja California	found from the lower intertidal zone to depths of 360 feet in bays, estuaries, and sloughs, in bottom types ranging from mud to pea-sized gravel, but mostly in unshifting mud or sand
Tresus nuttalli	Pacific Gaper	U	U	intertidal and subtidal resource appears to be in a healthy state	Alaska to Scammon's Lagoon, Baja California	fine sand or firm sandy-mud bottoms in bays, estuaries and more sheltered outer coast areas; from intertidal zone to 150 feet
Siliqua patula	Pacific Razor Clam	L	U	The significant populations in Pismo Beach/Morro Bay, Clam Beach, Crescent City all low	western Alaska to Pismo Beach, California	flat or gently sloping sandy beaches with a moderate to heavy surf
Saxidomus nuttalis	Washington Clam	U	U	present level of harvest can be sustained	Humboldt Bay, California to San Quentin Bay, Baja California	lives at depths of 12 to 18 inches in mud, sandy mud or sand of bays, lagoons and estuaries

Appendix 2. Finfish of Bays and Estuary: North Central California. I= increasing, D= decreasing, S=Stable, U= Undetermined, L=low (Source: Leet et al. 2001. California's Living Marine Resources: A Status Report).

Scientific Name	Common Name	Commercial Fishery Status	Population Status	Population notes	Range	Habitat
Thaleichthys pacificus	Eulachon	U	D	declined drastically	central California to Alaska	outer continental shelf, where they school at depths of 150-750 feet
Hypomesus transpacificus	Delta Smelt	U	L	Listed as threatened in 1993; stringent measures are in place to provide better habitat conditions	endemic only to the Sacramento-San Joaquin estuary	Most of the year resides in the open surface waters of the low salinity portions of the estuary where fresh and salt water mix; migrate to freshwater areas of the estuary that are under tidal influence to spawn from late winter to early summer
Acipenser medirostris	Green Sturgeon	U	U	limited evidence suggests that the overall population may have declined in California- but not in the SF Bay estuary area	Bering Sea to Ensenada, Mexico	spend most of their lives in ocean; adults enter the SF Bay estuary and move up the Sacramento River in early spring to spawn
Spirinchus thaleichthys	Longfin Smelt	U	D	populations in coastal estuaries along the northern coast of California have declined dramatically	Monterey Bay to Alaska	collected in the Sacramento-San Joaquin estuary, Russian River estuary, Humboldt Bay, and the Eel, Klamath, and Smith rivers.
Spirinchus starksi	Night Smelt	U	U	little known about population levels; excessive fishing could cause population to plummet in two or three years	Point Arguello in central California to Alaska	schooling fish, spawn on beaches from January through September
Clupea pallasi	Pacific Herring	U	L	San Francisco Bay's population has not yet recovered from El Nino; abundance fluctuates widely b/c of environmental factors	Baja California to Alaska	coastal zone, waters of the continental shelf

Scientific Name	Common Name	Commercial Fishery Status	Population Status	Population notes	Range	Habitat
Notorynchus cepedianus	Sevengill Shark	U	U	damage to San Francisco Bay could have an adverse effect on population	southeast Alaska to the Gulf of California, with their distribution becoming sporadic south of San Francisco Bay	coastal species that frequently enters bays; prefers rocky reef habitats where kelp beds thrive. the main concentrations appear to be in Humboldt and San Francisco Bays, both of which serve as nursery grounds for newborns and juveniles.
Hexanchus griseus	Sixgill Shark	U	U	no information	Aleutian Islands to southern Baja California	deepwater shark; adults are found along the continental shelf and upper slopes down to at least 8,250 feet deep
Morone saxatilis	Striped Bass	D	D	the decline of the striped bass fishery in the San Francisco Bay estuary between the 1960s and the present is a direct result of a substantial decline in the striped bass population	primarily located in the San Francisco Bay estuary	spawn in fresh water where there is moderate to swift current- common in the section of the San Joaquin River between the Antioch bridge and the mouth of the Middle River or the Sacramento River from Sacramento to Colusa
Hypomesus pretiosus	Surf Smelt	D "fishery may be decreasing"	U	environmental factors like water temp change may dramatically affect population levels; excessive fishing could cause populations to plummet	only common north of San Francisco Bay	spawning smelt congregate in the surf during the day while tide is falling; spend their lives in waters close to the shore
Hypomesus nipponensis	Wakasagi	U	I	expanding its range in central California	Shastina Reservoir, Siskiyou County, in the northern part of the state to San Luis Reservoir and parts of the California Aqueduct in the central part of the state	cold water reservoirs and now appears to survive in estuarine conditions as well as in the warm water reservoirs of the California aqueduct; Species may be a threat to Delta smelt.
Acipenser transmontanus	White Sturgeon	U	U	The population is expected to decline substantially as recruitment almost ceases and growth and mortality reduce the abundance of fish now in the fishable population	from Ensenada, Mexico to the Gulf of Alaska	spawning populations have only been found in large rivers from the Sacramento-San Joaquin system north; most California white sturgeon are found in the SF Bay estuary

Scientific Name	Common Name	Commercial Fishery Status	Population Status	Population notes	Range	Habitat
Allosmerus elongates	Whitebait Smelt	U	U	locally abundant and rarely enter the fisheries	collected sporadically in San Francisco and San Pablo Bays	productive inshore areas and bays

Appendix 3. Nearshore Invertebrates of North Central California. I= increasing, D= decreasing, S=Stable, U= Undetermined, L=low (Source: Leet et al. 2001. California's Living Marine Resources: A Status Report).

Scientific Name	Common Name	Commercial Fishery Status	Population Status	Population notes	Range	Habitat
Haliotis cracherodii	Black abalone	U	U	small populations exist in central and northern California	Oregon to southern Baja California	largely intertidal, extending to a depth of about 20 feet
Cancer antennarius	Brown Rock Crab	U	U	fishing areas intensely exploited over an extended period show a lower catch-per-trap and a reduced size-frequency distribution	northern Washington to central Baja California	waters from the low intertidal zone down to depths of 300 feet or more; prefer rocky or reef type substrate
Parastichopus californicus	California Sea Cucumber (aka Giant Red Sea Cucumber)	U	U	observations at an established reserve in northern California at depths of 150-180 feet revealed densities averaging around 1,000 per acre	Baja California to Alaska	low intertidal to 300 feet
Pandalus danae	Coonstripe Shrimp (aka Dock Shrimp)	U	U	no data	Sitka, Alaska to San Luis Obispo Bay, California	sand or gravel substrates in areas of strong tidal current
Cancer magister	Dungeness Crab	U	U	populations have been fully exploited for 40 years; population fluctuations in northern California fisheries	eastern Aleutian Islands, Alaska to Santa Barbara	sandy to sandy-mud bottoms but may be found on almost any bottom type
Pandalus jordani	Ocean Shrimp	U	U	the population abundance off California is determined by environmental conditions which causes natural fluctuations that are minimally unrelated to fishing	from Unalaska in the Aleutian Islands to off of San Diego, California	remain in well-defined areas or beds from year to year; these areas are associated with green mud and muddy-sand bottoms
Strongylocentrotus purpuratus	Purple Sea Urchin	U	S	larval settlement rates do not indicate a change in larval production	Cedros Island, Baja California, to Alaska	live primarily in shallow water and are the only abundant sea urchin in intertidal areas along the California coast
Haliotis rufescens	Red Abalone	U	U	In northern California, red abalone stocks continue to provide abalone to an important	Oregon to southern Baja California	intertidal and shallow subtidal in northern and central California . Also note that they have been reported to

Scientific Name	Common Name	Commercial Fishery Status	Population Status	Population notes	Range	Habitat
				recreational fishery		move in response to environmental hazards such as sanding-in of reefs
Cancer productus	Red Rock Crab	U	U	fishing areas intensely exploited over an extended period show a lower catch-per-trap and a reduced size-frequency distribution	Kodiak Island to Central Baja California	waters from the low intertidal zone down to depths of 300 feet or more; prefer rocky or reef type substrate
Strongylocentrotus franciscanus	Red Sea Urchin	D	U	northern California fishery experienced rapid increase in 1988 and then declining ever since	California coast	subtidal; play an important ecological role in the structure of kelp forest communities
Crassadoma gigantea	Rock Scallop	U	U	locally uncommon, especially on offshore reefs, but in no case it is numerous	Sitka, Alaska to Magdalena Bay, Baja California	lower intertidal; offshore reefs are populated
Emerita analoga	Sand Crab	S	U	resources appear to be in good condition	British Columbia to Magdalena Bay, Baja California	open-coast sandy beaches
Laxorhynchus grandis	Sheep Crab	U	U	no evidence of declining populations; some have reported a decrease in overall crab size	Cordell Bank (Marin County) south to Cape Thurloe, Baja California	depths of 20 to 410 feet
Pandalus platyceros	Spot Prawn	U	U	this species is more numerous and widespread than previously believed as attested by the geographic expansion and rise in total landings	Alaska to San Diego, California	depths from 150 to 1600 feet
Cancer anthonyi	Yellow Rock Crab	U	U	fishing areas intensely exploited over an extended period show a lower catch-per-trap and a reduced size-frequency distribution	Humboldt Bay to southern Baja California	waters from the low intertidal zone down to depths of 300 feet or more; prefer open sand or soft bottom

Appendix 4. Nearshore Finfish of North Central California. I= increasing, D= decreasing, S=Stable, U= Undetermined, L=low (Leet et al. 2001. California's Living Marine Resources: A Status Report).

Scientific Name	Common Name	Commercial Fishery Status	Population Status	Population notes	Range	Habitat	Notes
Amphisticus argenteus	Barred Surfperch	U	U	No estimates have been made about population	Bodega Bay to Baja California	found in small schools along sandy beaches and near jetties and piers	
Raja binoculata	Big Skate	U	U		Bering Sea to southern Baja California, but rare south of Point Conception	depths from 10 to about 2,600 feet, being most common at moderate depths	
Sebastes melanops	Black Rockfish (aka Black Snapper, Black Bass)	I	U	marked declines in average fish size	Amchitka Island, Alaska to Santa Monica Bay in southern California, but are uncommon south of Santa Cruz	occur 10-15 ft. above shallow rocky reefs, resting on rocky bottom, or in midwater over deeper (to 240 ft.) reefs	
Sebastes chrysomelas	Black-and-yellow Rockfish	U	U	declines in certain localities. Limited fishing pressure but higher susceptibility to overfishing due to species ecology	abundant in Sonoma County and range south to the region of Point Eugenia, Baja California	high-relief rocky bottom at depths shallower than about 60 ft.	
Sebastes mystinus	Blue Rockfish (aka Blue Bass, Bluefish, Blue Perch, Priestfish, Reef Bass)	S	U	increased fisheries monitoring programs. Fishing concentrating in different areas. Declines in average fish sizes.	Bering Sea to Punta Baja, Baja California. Less common south of the northern Channel Islands and north of Eureka, CA.	surface waters to a maximum depth of 300 feet	

Scientific Name	Common Name	Commercial Fishery Status	Population Status	Population notes	Range	Habitat	Notes
Sebastes auriculatus	Brown Rockfish (aka Bolina)	I	U	declines in average fish size	northern Gulf of Alaska to central Baja California.	shallow subtidal waters and bay, commonly above 175 ft. but can be found at depths just over 400 ft. associated with sand-rock interfaces and rocky bottoms of reefs and kelp beds.	a species vulnerable to severe localized depletions in other geographic areas; in Washington state, the Puget Sound stock of brown rockfish was recommended for listing as a threatened species in 1999.
Scorpaenichthys marmoratus	Cabezon	I	U		eastern pacific coast from Point Abreojos, Baja California to Sitka, Alaska	hard bottoms in shallow water from intertidal pools to depths of 250 ft. frequent subtidal habitats in or around rocky reef areas and in kelp beds.	
Sebastes dalli	Calico Rockfish	U	U		Sebastian Viscaino Bay, Baja California to San Francisco	depth range of 60 to 840 ft. nearshore areas.	often caught accidentally and in bycatch
Amphistichus koelzi	Calico Surfperch	U	U		north central Washington to northern Baja California	sandy beaches; depths from surface down to 30 feet	
Semicossyphus pulcher	California Sheephead	U	U		Monterey Bay to the Gulf of California. Uncommon north of Point Conception.	rocky reefs, kelp beds, also found at depths of 280 ft.	affected by El Niño
Raja inornata	California Skate	U	U	For all of the following skates and rays: Landings are increasing dramatically, but this may or may not reflect an actual threat to the resource	Straits of Juan de Fuca, British Columbia, to southern Baja California	inshore in shallow bays at depths of 60 feet or less, but also occurs in deeper water to a depth of 2,200 feet	

Scientific Name	Common Name	Commercial Fishery Status	Population Status	Population notes	Range	Habitat	Notes
Sebastes pinniger	Canary Rockfish (aka Orange Rockfish)	D	D		Baja California to southeast Alaska. Their center of distribution is the Washington British Columbia area, and in California they have commercial importance only as far south as Bodega Bay.	have been caught at depths below 1,000 ft. but are taken in abundance only to 500 ft.	may have two subpopulations, one south and one north of central Oregon
Sebastes caurinus	Copper Rockfish (aka Whitebelly Rockfish, Gopher, White Gopher, Bolina)	U	U	compelling evidence populations are severely declined. declines in average fish size	Gulf of Alaska to off central Baja California, Mexico.	the shallow subtidal to 600 feet.	highly variable coloration, different pops once thought to be separate species which complicates historical harvest data.
Stereolepis gigas	Giant Sea Bass	L		Anecdotal information suggests that numbers may be beginning to rebound under current measures	From Humboldt Bay to the tip of Baja California, and occur in the northern half of the Gulf of California	Adults prefer the edges of nearshore rocky reefs; these reefs are relatively shallow (35 to 130 feet) and support thriving kelp beds	
Sebastes carnatus	Gopher Rockfish	U	U		south to the region of Point Eugenia, Baja California. not abundant north of Sonoma County.	rocky reefs from 40 feet to perhaps 150 feet.	low fecundity, restricted habitats, and limited movements of these species make them vulnerable to local fishing pressure.
Sebastes rastrelliger	Grass Rockfish	U	U	Limited fishing pressure but higher susceptibility to overfishing due to species ecology	California and southern Oregon	rocky areas shallower than about 20 ft.	

Scientific Name	Common Name	Commercial Fishery Status	Population Status	Population notes	Range	Habitat	Notes
Atherinopsis californiensis	Jacksmelt (a species of silverside)	U	U	Currently there are no indications that topsmelt are being overfished.	Yaquina Bay, Oregon to Santa Maria, Baja California	found in bays and within a few miles of shore in a salinity range from seawater to mesohaline	These species are at risk of being affected by pollutants and loss of habitat through development because they occur in inshore waters
Hexagrammos decagrammus	Kelp Greenling	D	U	spear fisherman could be more prevalent and catch individuals guarding nests	San Diego to the Aleutian Islands, but are common only north of Morro Bay.	common at depths between 10 and 60 feet, and range down to 150 feet.	
Sebastes atrovirens	Kelp Rockfish	U	U	declines in certain localities. Limited fishing pressure but higher susceptibility to overfishing due to species ecology	abundant in Sonoma County only and range south to the region of Point Eugenia, Baja California	occur mostly in kelp forests	
Triakis semifasciata	Leopard Shark (aka Tiger Shark, Cat Shark)	U	S	Regulated under the Pacific Fishery Management Council's Groundfish Management Plan; this species does not appear to be at risk	Mazatlan, Mexico to Oregon	shallow water from the intertidal down to 15 feet, less so down to 300 feet or deeper in ocean waters	
Ophiodon elongatus	Lingcod	D	D	newly enacted federal laws and more stringent regulations	northern Baja California to the Shumagin Islands along the Alaskan Peninsula. center of abundance is off British Columbia	mostly rocky areas from 30 to 330 ft. also can be found from 10 to 1,300 ft.	
Citharichthys xanthostigma	Longfin Sanddab	S	U		Monterey Bay to Costa Rica	depths from 7 to 660 feet; muddy to sandy bottoms	
Raja rhina	Longnose Skate	U	U		Bering Sea to southern Baja California	bottom at depths from 80 to 2,250 feet	

Scientific Name	Common Name	Commercial Fishery Status	Population Status	Population notes	Range	Habitat	Notes
Cebidichthys violaceus	Monkeyface Prickleback	U	U	recreational and commercial landings are considered to be low	San Quentin Bay, Baja California, Mexico to central Oregon. Most common off central California from San Luis Obispo County to Sonoma County	normally in the intertidal zone with a depth range of high intertidal to 80 ft. rocky intertidal areas, shallow subtidal areas particularly rocky reefs and kelp beds	
Sebastes serranoides	Olive Rockfish	U	U	clear evidence of declines south of Pt. Conception	southern Oregon to Islas San Benitos (central Baja California). Common from about Cape Mendocino to Santa Barbara and around the Northern Channel Islands.	subtidal waters to 396 ft. (from Cape Mendocino to Santa Barbara	
Squatina californica	Pacific Angel Shark	U	U	concern in the 80s that stocks were being over-exploited; a minimum size restriction was effective in decreasing the number of immature sharks harvested; no population studies have been conducted since the nearshore fishery in 1994	eastern Pacific Ocean from southeastern Alaska to the Gulf of California	range in depth from 3 to 600 feet; usually found lying partially buried on flat, sandy bottoms and in sand channels between rocky reefs during the day and are active at night	population information seems to pertain to southern California, but this species does range through northern California
Torpedo californica	Pacific Electric Ray	U	U		northern British Columbia to central Baja California	found over sandy bottoms, rocky areas and kelp beds	

Scientific Name	Common Name	Commercial Fishery Status	Population Status	Population notes	Range	Habitat	Notes
Citharichthys sordidus	Pacific Sanddab	S	U	Commercial landings indicate that sanddab populations are in good condition and are currently no being over harvested.	Bering Sea to Cape San Lucas, Baja California Sur, Mexico; makes landings in northern California waters	30 to 1,800 feet; muddy to sandy bottoms	Most of the commercial sanddab landings have been in northern and central California, with the largest landings at Eureka and San Francisco Bay
Sebastes maliger	Quillback Rockfish	U	U	1980s to mid-90's increased take and has since relaxed a little	Gulf of Alaska to Anacapa Passage in southern California, and are considered common between southeast Alaska and northern California.	near the surface to a depth of 900 feet and can be common at depths of several hundred feet.	
Amphisticus rhodoterus	Redtail Surfperch	D	U	Decrease in average weight	Vancouver Island, Canada to Monterey Bay, but the fishery is centered north of the SF Bay area		
Urolophus halleri	Round Stingray	U	U		northern California to Panama; most abundant south of Point Conception	benthic species restricted to relatively shallow coastal zone at depths from 3 to 100 feet; found of beaches and in protected bays, sloughs, channels and inlets	
Rhacochilus toxotes	Rubberlip Surfperch	U	U		Russian Gulch State Beach (Mendocino County), California, to central Baja California	lives near jetties and piers, nearshore or in kelp beds	

Scientific Name	Common Name	Commercial Fishery Status	Population Status	Population notes	Range	Habitat	Notes
Rhinobatos productus	Shovelnose Guitarfish	U	U		San Francisco to the Gulf of California, but rare north of Monterey Bay	shallow coastal waters, bays, sloughs, and estuaries over sandy or muddy bottoms to a depth of about 50 feet	
Galeorhinus galeus	Soupfin Shark	U	U	population has not been studied in over 50 years	British Columbia to central Baja California	continental shelf waters from close inshore, including shallow bays, often near the bottom, but also offshore waters up to 1,500 feet deep	
Citharichthys stigmaeus	Speckled Sanddab	S	U		Point Montague Island, Alaska to Magdalena Bay	surface depth of 1,200 feet; commonly found on sandy bottoms	
Platichthys stellatus	Starry Flounder	L	U	extremely low level population could arise from either a relocation of adult fish with the 1976-1977 oceanic regime shift or a rapid decline in the abundance of spawning due to fishing pressure	Arctic coasts of Alaska and Canada, and southward down the coast of North America to southern California; uncommon south of Point Conception	primarily coastal, living on sand and mud bottoms, and avoiding rocky areas. Sometimes found at depths of 900 ft., but mostly in shallower waters	fishery trends is substantiated by a fishery-independent trawl survey conducted by California Dept. of Fish and Game w/in the SF estuary from 1980 through 1985
Embiotoca lateralis	Striped Seaperch	U	U	No population estimates have been made, but recent figures indicate that this species should be able to sustain a healthy stability	southeastern Alaska to northern Baja California	lives near jetties, piers, beaches and skiffs	

Scientific Name	Common Name	Commercial Fishery Status	Population Status	Population notes	Range	Habitat	Notes
Atherinops affinis	Topsmelt (a species of silverside)	U	U	Currently there are no indications that topsmelt are being overfished.	Straits of Juan de Fuca, British Columbia, to the Gulf of California	different environments: kelp beds, harbor areas and sandy beach areas	These species are at risk of being affected by pollutants and loss of habitat through development because they occur in inshore waters
Sebastes miniatus	Vermilion Rockfish	U	U	often misidentified so harvest data is unclear. CPFV trips in N. and central California observed individuals consistently above size of sexual maturation.	San Benito Islands, Baja California, to Prince William Sound, Alaska	rocky bottoms from the shallow subtidal to 1,400 ft.	
Hyperprosopon argenteum	Walleye Surfperch	U	U		Vancouver Island, British Columbia to central Baja California	found in large schools along sandy beaches, jetties, kelp beds, and other habitats with rich invertebrate life	
Genyonemus lineatus	White Croaker	D	U	size of population is not known; recent declines in commercial catches imply that future monitoring may be needed	Vancouver Island, British Columbia to Magdalena Bay, Baja California; Not abundant north of Point Reyes	found in surf zones to depths as great as 780 feet and in shallow bays, sloughs and lagoons	
Atractoscion nobilis	White Seabass	U	U	Population decline in California waters but difficult to determine in general; few are found north of Point Conception; evidence from commercial fisheries show dramatic increase in juveniles	Magdalena Bay, Baja California to San Francisco area	each summer fish move northward with warming ocean temperatures, this movement is probably spawn related	

Scientific Name	Common Name	Commercial Fishery Status	Population Status	Population notes	Range	Habitat	Notes
Seriola lalandi	Yellowtail	U	U	no population estimate is available for the northern stock of yellowtail	From British Columbia, Canada to Mazatlan, Mexico	Move off shore in summer to spawn; mostly found in southern California but some in northern	

Appendix 5. Coastal protection, research and monitoring programs (from NOAA desktop study). The contact names, phone numbers and websites were recorded in 2001 and may not be current.

Monitors	Project Title	Project Description/Findings	Contact/Project Website
Audubon Canyon Ranch			
Research program	Audubon Canyon Ranch Research Program	ACR's research programs provide a scientific perspective on habitat management problems that benefit natural resource agencies also responsible for protecting ever-dwindling native habitats. Areas of study: heron & egret nesting ecology, winter shorebird ecology, wetland restoration, breeding ecology of ravens, status of winter waterbird populations, status of rare salt marsh plants, ecosystem effects of aquaculture	For more information contact Bolinas Lagoon Preserve at (415) 868-9244 or acr@egret.org Project Website: http://www.egret.org/programs_research.html
Bodega Bay Projects/Data			
Sea Surface & current waves	Bodega Ocean Observing Node (BOON)	A high frequency (HF) radar system, CODAR, is used to measure the surface currents of the coastal ocean. A transmitter sends out a radio frequency that scatters off the ocean surface and back to a receive antenna. Using this information and the principles of the Doppler shift, coastal radar provides speed and direction of the surface current.	For more information contact John Largier at (707) 875-1930; Project Website: http://www.bml.ucdavis.edu/boon/scur.html
Carbon Monoxide (CO)	BOON Environmental Data Downloads	Carbon monoxide (CO) measurements have been made nearly continuously at Horseshoe Cove at the Bodega Marine Laboratory beginning in September 2004. These high frequency (currently 1Hz) CO observations are being acquired using an Aero-laser, AL5002 resonance fluorescence instrument.	For more information contact Dr. Ian Faloona at icfaloona@ucdavis.edu or Dr. Douglas Day at daday@ucdavis.edu; Project website: http://www.bml.ucdavis.edu/boon/codata.html
Daily and Monthly Rain	BOON Environmental Data Downloads	Daily and Monthly Rain Data	For more information contact Vic Chow at vichow@ucdavis.edu; Project website: http://www.bml2.ucdavis.edu/boon/raindatasets.html
Salinity	BOON Environmental Data Downloads	Salinity Hourly Means	For more information contact Vic Chow at vichow@ucdavis.edu; Project website: http://www.bml2.ucdavis.edu/boon/salinitydatasets.html
Sea Temperature	BOON Environmental Data Downloads	Sea Temperature Hourly Means	For more information contact Vic Chow at vichow@ucdavis.edu; Project website:http://www.bml2.ucdavis.edu/boon/seatempdatasets.html
Currents at all depths, water temperature, salinity, chlorophyll fluorescence, light	Offshore Mooring and ADCP Data	Bodega Marine Laboratory (BML) maintains an oceanographic mooring on the 30m isobath, immediately offshore of the Lab. Deployed in August 2004, the mooring currently provides near-real-time data on currents at all depths, in addition to data on water temperature, salinity, chlorophyll fluorescence and light transmissivity.	For more information contact Bodega Marine Laboratory at (707)875-2211; Project website:http://www.bml.ucdavis.edu/boon/mooring.html

Monitors	**Project Title**	**Project Description/Findings**	**Contact/Project Website**
transmissivity			
Environmental Data	BOON Metadata	Summary Descriptions of Environmental Datasets	For more information contact Vic Chow at vichow@ucdavis.edu; Project website: http://www.bml.ucdavis.edu/boon/metadata.html
Coastal Conditions	1996-2005 Tides for Bodega Bay, Sonoma County, California	Tidal data/information	For more information contact Bodega Marine Laboratory at (707)875-2211; Project website: http://www.bml.ucdavis.edu/boon/cc.html
Salmon	Coastal Salmon Restoration GIS Interactive Mapping	Interactive mapping tool	For more information contact Bodega Marine Laboratory at (707)875-2211; Project website: http://www.bmlgis.ucdavis.edu/website/bml/bml/viewer.htm
California Coastal Commission			
Planning; Coastal Development	Local Coastal Programs	Local Coastal Programs (LCPs) are basic planning tools used by local governments to guide development in the coastal zone, in partnership with the Coastal Commission. LCPs contain the ground rules for future development and protection of coastal resources in the 74 coastal cities and counties. The LCPs specify appropriate location, type, and scale of new or changed uses of land and water.	For more information contact the appropriate district office of the Coastal Commission at http://www.coastal.ca.gov/address.html; Project website: http://www.coastal.ca.gov/lcps.html
Planning; Coastal Development	Regional Cumulative Assessment Project (ReCAP);	ReCAP evaluates the implementation of California's California Coastal Management Program (CCMP) through certified LCPs and the effectiveness of the LCPs in addressing cumulative impacts.	For more information contact Liz Fuchs, AICP Manager, Statewide Planning/Federal Consistency, California Coastal Commission (415) 904-5287; Project website: http://www.coastal.ca.gov/recap/rctop.html
Recreation Planning/Impacts	Coastal Access Program	Maximizes public access to and along the coast and maximizes public recreational opportunities in the coastal zone consistent with sound resources conservation principles and constitutionally protected rights of private property owners.	For more information contact Linda Locklin, the program manager at (831) 427-4875; Project website: http://www.coastal.ca.gov/access/accndx.html
Water Quality	Statewide Nonpoint Source (NPS) Program	The Plan for California's Nonpoint Source Pollution Control Program (NPS Program Plan) provides a single unified, coordinated statewide approach to dealing with NPS pollution. A total of 28 state agencies are working collaboratively through the Interagency Coordinating Committee to implement the NPS Program Plan.	For more information contact Jack Gregg of the California Coastal Commission at (415) 904-5246 or Steve Fagundes of State Water Resources Control Board at (916) 341-5487; Project website: http://www.coastal.ca.gov/nps/npsndx.html

Monitors	Project Title	Project Description/Findings	Contact/Project Website
Minerals Management	Minerals Management Service (MMS); Pacific OCS Region	The Minerals Management Service (MMS) of the U.S. Department of the Interior was established in 1982 to manage the Nation's rich offshore mineral resources and collect and disburse the revenues from the recovery of both onshore and offshore Federal mineral resources. The MMS manages more than a billion offshore acres and collects billions of dollars in minerals revenues annually.	For more information contact John Romero Minerals Management Service (805) 389-7533; Project website: http://www.mms.gov/omm/pacific/public/mmsamerica.htm
California Coastal Conservancy			
Coastal Management	Costal Conservancy Strategic Plan	The plan starts with background on the Conservancy, including the Conservancy's statutory authorities, business principles, and project criteria. The Conservancy's eleven statutory areas are grouped into three program areas: Public Access, Coastal Resource Conservation, The San Francisco Bay Area Conservancy Program.	For more information contact Neal Fishman (510) 286-1015; Project website: http://www.coastalconservancy.ca.gov/Programs/Strategic_Plan.pdf
Coastal Mapping	Coastal Atlas	The Coastal Atlas maps the Coastal Conservancy's strategic plan, highlighting conservation areas of interest and coastal wetland, river, watershed, habitat, and open space projects.	For more information contact California Coastal Conservancy (510) 286-1015; Project website: http://www.coastalconservancy.ca.gov/Maps/coastalatlas/caindex.pdf
California Dept. of Fish and Game			
Oil Spill Response	Office of Spill Prevention and Response (OSPR)	The project addresses habitat issues in areas identified as high priority through discussions with DOI (BRD, MMS, FWS, NPS) and collaboratively with by NOAA (NMFS, NMS) and the nation's regional Fishery Management Councils. By linking geologic studies with fisheries and benthic biology research to allow for better fisheries and environmental management with an emphasis on MPAs. Large scale benthic habitat maps for the EEZ from California to Washington State are being developed at this time. These maps are being compiled using a subset of available geophysical and geologic information some of which has been shown to lack the quality required to resolve habitat features essential to fish (Cochrane and Lafferty, 2002) This project is collaborating with other agencies to procure funding and is collecting high resolution geophysical data, imagery, geological samples, and mining existing databases to improve the habitat classification in high priority areas such as proposed MPA's	For more information contact Office of Spill Prevention and Response (OSPR) at (916) 445-9338; Project website: http://www.dfg.ca.gov/ospr/index.html
Biogeographic data	Wildlife Habitats-California Wildlife Habitat Relationships System	A predictive model for terrestrial vertebrate wildlife species in 59 wildlife habitats: 27 tree, 12 shrub, 6 herbaceous, 4 aquatic, 8 agricultural, 1 developed, and 1 non-vegetated.	Project website: http://www.dfg.ca.gov/whdab/html/wildlife_habitats.html#Aquatic
Coastal Conditions	Coastal Watershed Mapping Tool	The Coastal Watershed Mapping Tool locates watersheds of interest by zooming into a statewide map and using watershed boundaries and scanned U.S. Geological Survey quad maps. These maps illustrate key hydrographic components such as streams and watershed boundaries as well as major roads, urbanized areas, and coarse vegetation condition.	For more information contact Jeremy Lockwood FRAPwebmaster@fire.ca.gov or by phone at (916) 445-5817; Project website: http://frap.cdf.ca.gov/projects/coastal_wa

Monitors	Project Title	Project Description/Findings	Contact/Project Website
			tershed/index.asp
Vegetation	The Vegetation Classification and Mapping Program (VegCAMP)	The Vegetation Classification and Mapping Program (VegCAMP) facilitates and oversees efforts to develop accurate and scientifically defensible maps and classifications of vegetation and/or habitat throughout the state.	Project website: http://www.dfg.ca.gov/whdab/html/vegcamp.html
California Ocean Protection Council (OPC)			
Ocean/Coastal Management	California Ocean Protection Strategic Plan	The California Ocean Protection Council employs integrated and innovative approaches to protect, manage, and restore California's ocean and coastal ecosystems—from the top of the coastal watersheds to the deep ocean—for their intrinsic value and for the benefit of current and future generations.	For more information see staff directory at http://resources.ca.gov/copc/contact.html ; Project website: http://resources.ca.gov/copc/strategic_plan.html
Collaborative projects and databases:			
Coastal Database	The California Ocean and Coastal Environmental Access Network (Cal OCEAN)	The California Ocean and Coastal Environmental Access Network (Cal OCEAN) is a web-based virtual library for the discovery of and access to ocean and coastal data and information from a wide variety of sources and in a range of types and formats. The goal of Cal OCEAN is to provide the information and tools to support ocean and coastal resource management, planning, research and education via the Internet.	Project website: http://ceres.ca.gov/ocean/
Oceanography	University-National Oceanographic Laboratory System (UNOLS)	University-National Oceanographic Laboratory System (UNOLS) is an organization of 61 academic institutions and National Laboratories involved in oceanographic research and joined for the purpose of coordinating oceanographic ships' schedules and research facilities.	For more information contact UNOLS Office at (831)771-4410; Project website: http://www.unols.org/
Costal Management	Alliance for Coastal Technologies (ACT)	The Alliance for Coastal Technologies (ACT) is a NOAA-funded partnership of research institutions, state and regional resource managers, and private sector companies interested in developing and applying sensor/ sensor platform technologies for monitoring and studying coastal environments.	For more information contact ACT Headquarters at (410) 326 7385; Project website: http://www.act-us.info/
Ocean Currents	The Coastal Oceans Currents Monitoring Program (COCMP)	The Coastal Oceans Currents Monitoring Program (COCMP) is a multi-institution, interagency collaboration with the goal of integrated monitoring of currents in the coastal ocean. Initially, COCMP will emphasize technology to measure and map surface currents.	For more information contact Sheila Semans at California State Coastal Conservancy 1330 Broadway, 11th Floor Oakland, CA 94612-2530; Project website: http://www.cocmp.org/
Wetlands and Wildlife Restoration	The San Francisco Bay Joint Venture (SFBJV)	The San Francisco Bay Joint Venture (SFBJV) is one of fourteen Joint Ventures established under The Migratory Bird Treaty Act and funded under the annual Interior Appropriations act. It brings together public and private agencies, conservation groups, development interests, and others to restore wetlands and wildlife habitat in San Francisco Bay watersheds and along the Pacific coasts of San Mateo, Marin and Sonoma counties.	For more information contact Beth Huning at (415) 883-3854 or bhuning@sfbayjv.org; Project website: http://sfbayjv.org/
Spatial Data	Central Coast Joint Data Committee	The Central Coast Joint Data Committee (CCJDC) is a partnership of public and private agencies who agree to share spatial data about the 5-county	For more information contact gis@mbay.net or

Monitors	Project Title	Project Description/Findings	Contact/Project Website
	(CCJDC)	region of the Central Coast of California, from San Mateo through Santa Cruz, San Benito and Monterey to San Luis Obispo County.	mtsui@landsystemsgroup.com; Project website: http://www.ccjdc.org/
Shoreline Resources	Multi-Agency Rocky Intertidal Network (MARINe)	Scientists from Federal, State, and local government agencies, universities, and private and volunteer organizations have formed a Multi-Agency Rocky Intertidal Network (MARINe) to monitor important shoreline resources. The network is currently being supported by 23 organizations. Sites are monitored from San Luis Obispo County to San Diego County on the mainland and offshore Channel Islands. Key rocky intertidal habitats and species are sampled every fall and spring using a variety of methods. Mussels, seastars, abalone, surfgrass, acorn and goose barnacles, and several algal species, such as rockweed and turfweed, are among the key species and habitat types studied.	For more information contact Jack Engle at (805) 893-8547 or Mary Elaine Dunaway at (805) 389-7848; Project website: http://www.marine.gov/
Physical & Chemical Factors	The Central California Ocean Observing System (CeNCOOS)	The IOOS will be based on a national backbone of platforms and sensors, collecting data on a standard suite of variables, over broad spatial and temporal scales. The IOOS will also include regional ocean observing systems, such as CeNCOOS, to augment the national backbone with additional platforms and sensors and data on regionally-important variables over smaller spatial and temporal scales.	For more information contact CeNCOOS Coordinator Heather Kerkering at (831) 775-1987 or heather@mbari.org; Project website: http://www.cencoos.org/activities.htm
Kelp Forests, Estuaries, Oceanography	Center for Integrative Coastal Observation, Research and Education (CI-CORE)	The CSU Center for Integrative Coastal Observation, Research and Education (CI-CORE) is a distributed coastal observatory for applied coastal research and monitoring in the nearshore (<100 m water depth) along the entire California coastline.	For more information contact Dr. Kenneth Coale at (831)771-4406 or coale@mlml.calstate.edu; Project website: http://cicore.mlml.calstate.edu
Open Ocean, Oceanography, Seabirds & Shorebirds, Marine Mammals	West Coast CSCAPE: Collaborative Survey of Cetacean Abundance and the Pelagic Ecosystem.	CSCAPE is a collaboration between the National Marine Fisheries Service and the National Marine Sanctuary Program to assess the abundance and distribution of marine mammals and to characterize the pelagic ecosystem out to ~300 nautical miles off the U.S. West Coast.	For more information contact Annette Henry at (858) 546-5672; Project website: http://swfsc.nmfs.noaa.gov/PRD/PROJECTS/CSCAPE/default.htm
Water Quality	Central Coast Ambient Monitoring Program	The Central Coast Ambient Monitoring Program (CCAMP) is the Central Coast Regional Water Quality Control Board's regionally scaled water quality monitoring and assessment program.	For more information on the CCAMP program email kworcester@waterboards.ca.gov; Project website: http://www.ccamp.org
Kelp Forests, Fisheries	Cooperative Research and Assessment of Nearshore Ecosystems (CRANE)	The Cooperative Research and Assessment of Nearshore Ecosystems (CRANE) program was established in spring 2003. CRANE uses quantitative diver visual surveys to sample kelp forests for fishes, invertebrates, and algae.	Project website: http://www.mbnms-simon.org/sections/kelpForest/project_info.php?pid=100154&sec=kf
Water Quality	Central Coast Long-term Environmental Assessment Network (CCLEAN)	CCLEAN provides the initial nearshore component of the Central Coast Regional Water Quality Control Board's Central Coast Ambient Monitoring Program (CCAMP). This multidisciplinary program includes sampling in watersheds that flow into coastal regions, in estuarine coastal confluences, and at coastal sites.	For more information contact the CCLEAN office at (831) 426-6326; Project website: http://www.cclean.org
Marine Mammals	Structure of	SPLASH is an international cooperative effort to understand the population	For more information call 1-800-831-

Monitors	Project Title	Project Description/Findings	Contact/Project Website
	Populations, Levels of Abundance and Status of Humpbacks (SPLASH)	structure of humpback whales across the North Pacific, and to assess the status, trends and potential human impacts to this population. The project has broad international and national participation.	4888; Project website: http://www.hihwnms.nos.noaa.gov/special_offerings/sp_off/splash/splash_general.html
Cordell Bank National Marine Sanctuary			
Habitat characterization; biological monitoring	Habitat Characterization and Biological Monitoring on and around Cordell Bank	The Cordell Bank National Marine Sanctuary (CBNMS) in partnership with the National Marine Fisheries Service Laboratory in Santa The Delta Submersible. Photo credit: Michael Carver Cruz, the U.S. Geologic Survey, and the California Department of Fish and Game has initiated a long term study to classify habitats and monitor fishes and macro-invertebrates on and around Cordell Bank. Underwater surveys of fishes, invertebrates, and their habitats are conducted on and around Cordell Bank using direct observation and video-transect methods from an occupied research submersible	For more information contact Dan Howard at dan.howard@noaa.gov or (415)663-1443; Project website: http://cordellbank.noaa.gov/research/habitat.html
Ocean Monitoring	Cordell Bank Ocean Monitoring Project (CBOMP)	One of the current goals of CBNMS is to gain a better understanding of the variability of the pelagic ecosystem. To accomplish this goal CBNMS initiated, in the January of 2004 the Cordell Bank Ocean Monitoring program. This program is an interagency collaboration with Point Reyes National Seashore.	For more information contact Dan Howard at dan.howard@noaa.gov or (415)663-1443; Project website: http://cordellbank.noaa.gov/research/currentprojects.html
Black footed Albatross	Tracking Black footed Albatross	Study to provide needed information on the conservation status of the Black-footed Albatross (*Phoebastria nigripes*) off the West Coast of North America, and to enhance the understanding of the foraging grounds and movements of this threatened species across the northeast Pacific Ocean.	Project Website: http://cordellbank.noaa.gov/research/currentprojects.html
Deep Sea	Habitat Characterization and Biological Monitoring on and around Cordell Bank	The Cordell Bank Sanctuary, in partnership with other State and Federal Agencies, has initiated a long term study to classify habitats and monitor fishes and macro-invertebrates on and around Cordell Bank. While Sanctuary status does not offer protection from fishing, it appears that the deep boulder habitats provide a natural refuge for some overfished rockfishes.	For more information contact Dan Howard at dan.howard@noaa.gov or (415)663-1443; Project website:http://www.mbnms-simon.org/sections/deepSea/project_info.php?pid=100163&sec=ds
Farallones Marine Sanctuary Association			
Beach monitoring	Beach Watch	Beach Watch volunteers monitor 41 beach segments every two to four weeks from Bodega Head in Sonoma County to Año Nuevo County on the San Mateo/Santa Cruz county line. Survey methods along each beach segment include: Live bird and marine mammal count, Visitor/dog activity notation, Beached (dead) vertebrate documentation, General wrack and invertebrate assessment, Oil/tarball documentation, and Streams and lagoons status.	For further information contact Shannon Lyday at beachwatch@farallones.org or (415) 561-6625 x 302; Project website: http://www.farallones.org/volunteer/beach_watch_2.php
Harbor Seals	SEALS Program	The SEALS program was established to document and reduce the impact of human activity on harbor seals in Bolinas Lagoon and Tomales Bay.	For more information contact Joanne Mohr, Volunteer Program Coordinator at jmohr@farallones.org or call (415) 561-6625 x 307; Project website: http://www.farallones.org/volunteer/seals.php

Monitors	Project Title	Project Description/Findings	Contact/Project Website
Monterey Bay Aquarium Research Institute			
Mooring Data	Ocean Acquisition System for Interdisciplinary Science (OASIS)	MBARI's biological oceanography group produces a large volume of data from its mooring and cruise operations.	For more information contact the MBARI Office at (831) 775-1700; Project website: http://www.mbari.org/oasis/
Estuaries, Water Quality	Land/Ocean Biogeochemical Observatory (LOBO)	The LOBO observing system is designed to monitor the flux of nutrients (nitrate, phosphate and inorganic carbon) through the Elkhorn Slough ecosystem. The complete system will include up to eight nodes equipped with nutrient sensors developed at MBARI that are linked to the Internet through a wireless LAN (Local Area Network).	For more information contact Ken Johnson at (831) 775-1985 or johnson@mbari.org; Project website: http://www.mbari.org/lobo/
Bathymetric data	Mapping Program	The mapping project was established to support the mapping and surveying needs of all MBARI scientists. This includes analyzing previously collected seafloor data from sites of potential interest and collecting new survey data.	For more information contact the MBARI Office at (831) 775-1700; Project website: http://www.mbari.org/data/mapping/mapping.htm
Oceanography	Monterey Bay Ocean Time Series Observations	Studies on the biogeochemical response of the central California ecosystem to climate and ocean variability	For more information contact Francisco Chaves at chfr@mbari.org; Project website: http://www.mbari.org/bog/Projects/CentralCal/summary/ts_summary.htm
Oceanography	SCOPE: Simulations of Coastal Ocean Physics and Ecosystems	A proposal to model the coastal upwelling ecosystem within the Monterey Bay National Marine Sanctuary (MBNMS) with high spatial (kms) and temporal (days) resolution.	Project website: http://www.mbari.org/bog/NOPP/default.htm
Moss Landing Marine Laboratory			
Invasive species	Ballast Water Project	To assess new technology in ballast water sterilization for the prevention of invasive species	For more information contact Moss Landing Marine Laboratories- Biological Oceanography at (831) 771-4450; Project website: http://biooce.mlml.calstate.edu/
Water Quality	MEQ- Marine Environmental Quality	The Marine Environmental Quality project is concerned with metal levels in the water and sediments of Los Angeles, Long Beach, and South San Francisco Bay.	For more information contact Dr. Kenneth Colae at (831) 771-4400; Project Website: http://chemoce.mlml.calstate.edu/
Chemical Oceanography	Radiochemistry Research	Research that involves the application of radiochemical methods towards the determination of rate and growth processes in living marine systems.	For more information contact Dr. Kenneth Cole at (831) 771-4400; Project Website: http://chemoce.mlml.calstate.edu/
Geological Oceanography	Geological Oceanography and	Graduate students at Moss Landing Marine Laboratories (MLML) study marine geology and applied marine geophysics. Students, faculty, and	Project website: http://geooce.mlml.calstate.edu/

Monitors	Project Title	Project Description/Findings	Contact/Project Website
	Moss Landing Marine Laboratory (academic program)	researchers participate in scientific research projects that range from the study of submarine canyons to mapping and characterizing fish habitats. Two laboratories, Geological Oceanography and the Center for Habitat Studies, are established here to facilitate the educational needs and research desires of MLML graduate students and affiliated researchers.	
Habitat Studies	The Center for Habitat Studies at Moss Landing Marine Labs Habitat Mapping and Fisheries Research	The Center for Habitat Studies (Habitat Center) was established as a geophysical institute of MLML in 1994 to focus on the research of characterizing marine benthic habitats and marine and coastal geohazards. Since that time, it has grown into a geological and biological research facility that now leads in the field of deep-water marine benthic habitat mapping.	For further information contact H. Gary Greene greene@mlml.calstate.edu or Joseph J. Bizzarro jbizzarro@mlml.calstate.edu; Project website: http://geooce.mlml.calstate.edu/
Physical Oceanography	Physical Oceanography Group	The physical oceanography group at MLML focuses primarily on observational studies of dynamics of the coastal ocean and continental margin.	For more information contact Dr. Erika McPhee-Shaw at (831) 771-4470; Project website: http://physoce.mlml.calstate.edu/
Vertebrate Ecology	Moss Landing Marine Laboratories Vertebrate Ecology Lab	Graduate students in the MLML Vertebrate Ecology Lab study marine and estuarine birds, marine mammals, and sea turtles.	For more information contact James T. Harvey, Ph.D. (831) 771-4434; Project website: http://birdmam.mlml.calstate.edu/
Invertebrate Zoology	Invertebrate Zoology at Moss Landing Marine Laboratory	Research interests are broadly concerned with the evolution and ecology of marine invertebrates.	For more information contact Dr. Jonathan Geller at geller@mlml.calstate.edu or (831) 771-4436; Project website: http://invert.mlml.calstate.edu/
Phycology	Phycology Lab at at Moss Landing Marine Laboratory	Researchers in the Phycology Lab at MLML study the physiology, ecology and evolutionary biology of seaweeds and their associated communities. Work focuses primarily on rocky shore intertidal and subtidal seaweeds of the Pacific Coast of North America, and the unique seaweed assemblages of the Gulf of California.	Project website: http://phycology.mlml.calstate.edu/
Sandy Floors, Deep Sea, Fisheries	Archival of Midwater and Benthic Survey Data at Moss Landing Marine Laboratories	Since the early 1970s, faculty and students in Marine Ecology, Invertebrate Zoology, and Ichthyology courses at Moss Landing Marine Laboratories (MLML) have participated in class cruises aboard several research vessels to survey the fishes and invertebrates in shallow-benthic, deep-benthic and midwater habitats in Monterey Bay.	Project website: http://www.mbnms-simon.org/sections/sandyFloor/project_info.php?pid=100170&sec=sf
Benthic Ecology	Big Lagoon Restoration, Muir Beach, CA	In 1992-94, as mitigation for the fill disposal from the Lone Tree Slide, CalTrans provided funds for restoration of the historic wetland and riparian system of Big Lagoon at Muir Beach. As part of the preparation for the development of restoration alternatives, the Benthic Lab group researched historic and current biological conditions of the site. Historic information was collected from archival sources. Current biological conditions were obtained from surveys to describe and document bird, amphibian, reptile, mammal, invertebrate, fish and vegetation communities. From these data, the Benthic	For more information call the MLML Benthic lab at (831) 771-4198; Project website: http://benthic.mlml.calstate.edu/

Monitors	Project Title	Project Description/Findings	Contact/Project Website
		Lab group predicted future conditions under current environmental and sociological regimes as well as identified biological restoration opportunities for the site. Restoration alternatives were presented to Golden Gate National Recreation Area for their implementation.	
Benthic Ecology	Bolinas Lagoon Restoration, Bolinas, CA	In 1992-94, as mitigation for the fill disposal at the Lone Tree Slide, CalTrans provided funds to remove a causeway and fill disposal site in Bolinas Lagoon, Marin County. It was anticipated that these actions would increase the tidal prism, and restore natural hydrodynamic functioning and fishery habitat of the lagoon. The Benthic Lab group performed a year's baseline surveys describing benthic invertebrates, birds, marine mammals, fishes, and plants prior to the removal of the causeway and fill. Post construction monitoring continued for an additional two years to track the effects of the mitigation.	For more information call the MLML Benthic lab at (831) 771-4198; Project website: http://benthic.mlml.calstate.edu/
Shark and Ray Fisheries	The Pacific Shark Research Center (PSRC)	The Pacific Shark Research Center (PSRC) at Moss Landing Marine Laboratories (MLML), Moss Landing, California is the west coast branch of the National Shark Research Consortium (NSRC). The NSRC is a coalition of four major shark research organizations working in cooperation with the National Marine Fisheries Service (NMFS).	Project website: http://psrc.mlml.calstate.edu/
NOAA (National Oceanic Atmospheric Administration): PMEL (Pacific Marine Environmental Laboratory), NMFS (National Marine Fisheries Service)			
Oceanographic, Meteorological data	TAO (Tropical Atmosphere Ocean Project)	Real-time data from moored ocean buoys for improved detection, understanding and prediction of El Niño and La Niña.	For more information contact TAO Project Office at atlasrt@noaa.gov; Project website: http://www.pmel.noaa.gov/tao/jsdisplay/
Carbon Dioxide	PMEL CO2 Program	Conducts ocean carbon cycle research from ships and moorings in all of the major ocean basins.	For more information contact Project Laeader Dr. Richard Feely at (206) 526-6214; Project website:http://www.pmel.noaa.gov/co2/co2-home.html
Chloroflourocarbon Tracers	Chloroflourocarbon Tracers Program	Documents the transient invasion of Chlorofluorocarbons (CFCs) into the thermocline and deep waters of the the world ocean. These tracer data are used to estimate the rates and pathways of ocean circulation and mixing processes, and as a means of testing and evaluating numerical models of ocean circulation.	For more information contact John L. Bullister at John.L.Bullister@noaa.gov; Project website: http://www.pmel.noaa.gov/cfc/review/
Oceanic dimethylsulfide	Global Surface Seawater Dimethylsulfide (DMS) Database	This database is an attempt to put most of the global set of seawater DMS measurements on one server, where data can be selected from geographical regions and/or specific time periods. The statistics of each sub-set of DMS data can be viewed on the output page and the selected data can be downloaded as an ascii file .	For more information contact james.e.johnson@noaa.gov; Project website: http://saga.pmel.noaa.gov/dms/
Acoustic monitoring	PMEL Vents Program	The Acoustic Monitoring Project of the VENTS Program has performed continuous monitoring of ocean noise since August, 1991 using the U.S. Navy SOund SUrveillance System (SOSUS) network and autonomous underwater hydrophones.	For more information contact Acoustics Project Leader Robert Dziak at (541)867-0175; Project website: http://www.pmel.noaa.gov/vents/acoustic

Monitors	Project Title	Project Description/Findings	Contact/Project Website
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Chemical Oceanography	PMEL Vents Program	Hydrothermal Vent Geochemistry	For more information contact Dr. Stephen Hammond at (541) 867-0183; Project website: http://www.pmel.noaa.gov/vents/chemocean.html
Geology	Vents Geology Program	The NOAA/VENTS Geology Program aims to understand how submarine volcanic activity affects hydrothermal venting along the mid-ocean ridge system.	For more information contact Robert W. Embley at (541)867-0275; Project website: http://www.pmel.noaa.gov/vents/geology/geology.html
Mapping	Environmental Sensitivity Index (ESI) Maps	NOAA OR&R researchers, working with colleagues in State and Federal governments, have produced Environmental Sensitivity Index (ESI) maps.	For more information contact NOAA's Office of Response and Restoration at (301) 713-2989, ext. 122; Project website: http://response.restoration.noaa.gov/type_subtopic_entry.php?RECORD_KEY%28entry_subtopic_type%29=entry_id,subtopic_id,type_id&entry_id(entry_subtopic_type)=74&subtopic_id(entry_subtopic_type)=8&type_id(entry_subtopic_type)=2
Rocky Shores, Beaches	Long term Monitoring Program & Experiential Training for Students (LiMPETS)	LiMPETS is a program for middle school, high schools, and other volunteer groups to monitor rocky intertidal, sandy beach, and offshore areas of the five west coast National Marine Sanctuaries – Olympic Coast, Cordell Bank, Gulf of the Farallones, Monterey Bay, and Channel Islands.	For more information contact Claire Johnson, LiMPETS Program Manager at (805) 963-3238 ext. 18 or email claire.johnson@noaa.gov; Project website: http://limpets.noaa.gov
Rocky Shores	Monitoring and Management of the Invasive Alga *Undaria pinnatifida*	Monitoring the spread of the invasive seaweed *Undaria pinnatifida* within the Monterey Harbor, and studying the effectiveness of manual removal of *Undaria* from harbor docks and pier pilings	Project website: http://www.nmfs.noaa.gov/habitat/restoration/index.html
National Park Service			
Pinnipeds	Point Reyes National Seashore Pinniped Monitoring	Six species of pinnipeds have been documented for Point Reyes National Seashore. Two species, Northern elephant seals (*Mirounga angustirostris*) and harbor seals (*Phoca vitulina richardsi*), are monitored on a regular basis during their breeding and pupping seasons. The other four species have been censused weekly at the Point Reyes Headlands since 1995. This includes California sea lions (*Zalophus californicus*), Steller sea lions (*Eumetopias jubata*), Guadalupe fur seals (*Arctocephalus townsendi*), and Northern fur seals (*Callorhinus ursinus*).	http://www.nps.gov/pore/naturescience/index.htm
Intertidal Monitoring	Point Reyes National Seashore Intertidal	Surveys are conducted on the rocky intertidal in three locations. In the rocky intertidal there are two communities that are surveyed: areas characterized by	http://www.nps.gov/pore/naturescience/index.htm

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	Monitoring	algae (*Endocladia* and *Mastocarpus* spp.) and areas characterized by California mussels (*Mytilus californianus*). In each community, the percent cover of sessile species (such as algae and barnacles) and substrate (such as rock or sand) are documented using 12 permanent quadrats. Motile species such as predatory whelks (*Nucella* spp.), periwinkles (*Littorina* spp.), And black turban snails (*Tegula* spp.) are counted within quadrats. Finally, a population count of seastars is documented for the research area.	
Fish Populations	Point Reyes National Seashore Coho Salmon and Steelhead Trout Restoration	?	http://www.nps.gov/pore/naturescience/index.htm
Water Quality, Benthic Macroinvertebrates	Point Reyes National Seashore Water Quality and Benthic Macroinvertebrate Monitoring	?	http://www.nps.gov/pore/naturescience/index.htm
Rare Plants	Point Reyes National Seashore Rare Plant Monitoring	The rare plant monitoring program at Point Reyes National Seashore is a collaboration by Park staff and volunteers with the California Native Plants Society. The monitoring design is modeled from the California Department of Fish and Game's Natural Diversity Database, and will include locations of rare plant populations, extent of populations, numbers of individual plants, site/habitat descriptions, and potential threats to the populations.	http://www.nps.gov/pore/naturescience/index.htm
Nonnative Plants	Point Reyes National Seashore Nonnative Plant Management	Monitoring of nonnative species; 292 of the park's vascular plant species are nonnative, and all plant community types contain significant numbers of nonnative species, posing significant threats to native species. At least 30 of these nonnative species are invasive enough to threaten the diversity of native plant communities in the Seashore.	http://www.nps.gov/pore/naturescience/index.htm
Snowy Plover	Snowy Plover Recovery	After observing an alarming population decline in 1995, relative to the breeding population size recorded in the 70's and 80s, NPS worked with PRBO who recommended the use of nest exclosures to protect Snowy Plover eggs from ravens and other predators. Since the use of nest exclosures, PRBO has documented increased hatching success of Snowy Plovers.	http://www.nps.gov/pore/naturescience/index.htm
Coastal Monitoring	Coastal Inventory Project, National Park Service and University of California at Davis	Testing and revising protocols that were created for Glacier Bay National Park and modified for Point Reyes National Seashore and Golden Gate National Recreational Area. This inventory will give broad scale (about 100 miles of NPs managed coastline) information on the types of high-energy intertidal habitats and their juxtaposition.	http://www.nps.gov/pore/naturescience/index.htm
PISCO (Partnership for Interdisciplinary Studies of Coastal Oceans)			
Intertidal Communities	Partnership for Interdisciplinary Studies of Coastal	The goal of the intertidal PISCO (Partnership for Interdisciplinary Studies of Coastal Oceans) program is to investigate the nearshore rocky reef marine ecosystems of the west coast of the U.S. in an innovative, coordinated, and	For more information contact Dr. Pete Raimondi at raimondi@biology.ucsc.edu; Project website:

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	Oceans (PISCO): intertidal component	interdisciplinary fashion.	http://www.piscoweb.org/data/catalog/intertidal_community
Intertidal Recruitment Monitoring	Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO): intertidal component	The goal of the intertidal PISCO (Partnership for Interdisciplinary Studies of Coastal Oceans) program is to investigate the nearshore rocky reef marine ecosystems of the west coast of the U.S. in an innovative, coordinated, and interdisciplinary fashion.	For more information contact Dr. Pete Raimondi at raimondi@biology.ucsc.edu; Project website: http://www.piscoweb.org/data/catalog/intertidal_recruitment
Subtidal Community	Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO): subtidal component	The goal of the subtidal PISCO (Partnership for Interdisciplinary Studies of Coastal Oceans) program is to investigate the nearshore rocky reef marine ecosystems of the west coast of the U.S. in an innovative, coordinated, and interdisciplinary fashion.	For more information contact Dr. Mark Carr at carr@biology.ucsc.edu; Project website http://www.piscoweb.org/data/catalog/subtidal
Physical Oceanographic Monitoring	ADCP Current Meter and Moored Temperature Data	ADCP Current Meter and Moored Temperature Data	Project website: http://www.piscoweb.org/data/catalog/phys_ocean
Point Reyes Bird Observatory Conservation Science			
Seabirds	Año Nuevo Island Seabird Population Biology and Feeding Ecology	To promote growth of the Año Nuevo Rhinoceros Auklet population through (i) construction of boardwalks to reduce trampling of burrows, (ii) installation of nest boxes to supplement breeding habitat, provide protected nest sites, and aid in research and management efforts, and (iii) study the breeding biology, feeding ecology, and population trends to understand factors affecting auklet population dynamics.	For more information contact Julie Thayer at jthayer@prbo.org or Kirsten Lindquist at klindquist@prbo.org; Project website: http://www.prbo.org/ani
Seabirds	Seabird Conservation Biology and Feeding Ecology at Alcatraz Island	To study the population size, distribution, and breeding and feeding ecology of seabirds using Alcatraz Island. Research determines the extent and effects of human disturbance such as tourism, boating near the shoreline (kayaks, fisherman, and tour boats), and aircraft overflights (air tour operations), on breeding seabirds. Dredging the San Francisco Bay may also affect nesting birds by mobilizing contaminants and destroying essential foraging habitat.	For more information contact Julie Thayer at jthayer@prbo.org or Sara Acosta at sacosta@prbo.org; Project Website: http://www.prbo.org/cms/index.php?mid=311&module=browse
Seabirds	Seabird Breeding Biology on the Farallon Islands	To study the breeding biology, feeding ecology, and population dynamics of a seabird community in relation to naturally occurring and human-induced climate change.	For more information contact Russ Bradley atrbradley@prbo.org or Peter Warzybok at pwarzybok@prbo.org; Project website: http://www.prbo.org/cms/index.php?mid=159&module=browse
Seabirds	Seabird Aware Conservation Education Project	Seeks to heighten public understanding of seabird ecology and reduce threats to seabird populations in the California Current System.	For more information contact Point Reyes Bird Observatory at (707) 781-2555; Project website: http://www.prbo.org/cms/index.php?mid=326&module=browse
Least terns	Alameda Point Least Terns	The California Least Tern is listed as endangered by both the federal and state governments. Terns began breeding at the Naval Air Station in	For more information contact Meredith Elliott at melliot@prbo.org, Jennifer Roth

Monitors	Project Title	Project Description/Findings	Contact/Project Website
		Alameda, California in 1976. The colony was monitored by the Golden Gate Audubon Society from 1979–1999, the Point Reyes Bird Observatory from 2000–2001, and the United States Fish and Wildlife Service from 2002–present. This study looks at tern diet and foraging ecology in 2002.	at jroth@prbo.org or Christine Abraham at cabraham@prbo.org; Project website: http://www.prbo.org/cms/index.php?mid=313&module=browse
Double Crested Cormorants	Double-crested Cormorants on Bay Area Bridges	To investigate the timing of occupation, timing of breeding, population change, movement patterns, and overall productivity of the colonies on the Richmond-San Rafael and S.F.-Oakland Bay bridges. 2) To aid the California Department of Transportation (CalTrans) in conducting maintenance and earthquake retrofitting activities with minimal effects to birds.	For more information contact Meredith Elliott at melliot@prbo.org, Project website: http://www.prbo.org/cms/index.php?mid=316&module=browse
Northern Spotted Owl	Northern Spotted Owl Demography	Current research project that addresses human threats by locating and monitoring nests and promptly communicating these results to local land managers. USFWS rules require that land management activities do not harm or harass owls or their habitat. Data has resulted in better placement of new trails, timing of road and trail maintenance activities (mowing and grading) around nesting season, seasonal closure of shooting ranges near nesting owls, preservation of individual nest trees, and determination of owl activity centers to help with responsible placement of housing sites. The habitat analysis has broadened concept of "potential habitat" locally and expanded where protections are applied.	For more information contact kfehring@prbo.org; Project website: http://www.prbo.org/cms/index.php?mid=102
Marine Ecology	California Current Marine Conservation Initiative	PRBO Conservation Science is implementing the California Current Marine Conservation Initiative. Our goal is to conserve the complex food webs of the California Current System (CCS) that support rich marine wildlife and fisheries communities of the Pacific Ocean along the U.S. west coast, with an emphasis on central California. This effort will assist state and federal agencies with implementation of timely, legally mandated fishery and ocean management and conservation programs.	For more information contact William J. Sydeman, Director of Marine Ecology at wsydeman@prbo.org; Project website: http://www.prbo.org/cms/index.php?mid=322&module=browse
Marine Ecology	California Current System Marine Protected Areas	To establish pelagic marine protected areas (MPAs) and "no take" marine reserves (MRVs) designed to protect highly migratory marine species, and the habitats upon which they depend. This will be accomplished using observations of marine birds, cetaceans, and sea turtles as bio-indicators of spatial and temporal variability in pelagic ecosystem / food web productivity and aggregation of important prey species at "hotspots".	For more information contact William J. Sydeman, Director of Marine Ecology at wsydeman@prbo.org; Project website: http://www.prbo.org/cms/index.php?mid=309&module=browse
Terrestrial Ecology	Life History and Demography of Riparian-associated Birds in the Golden Gate National Recreation Area: A Monitoring Project	Monitoring the riparian songbird communities within watersheds owned and managed by the Golden Gate National Recreation Area and Point Reyes National Seashore, coastal Marin County California.	For more information contact Thomas Gardali at tgardali@prbo.org or (415) 868.0655 ext. 381; Project website: http://www.prbo.org/cms/index.php?mid=99
State Water Resources Control Board			

Monitors	Project Title	Project Description/Findings	Contact/Project Website
Mussels	State Mussel Watch (SMW) Program / Toxic Substance Monitoring (TSM) Program	Data on Mussels	For more information contact State Water Resources Control Board at (916) 341-5250; Project website: http://www.swrcb.ca.gov/programs/smw/
Water Quality	The Surface Water Ambient Monitoring Program (SWAMP)	Ambient monitoring refers of the physical, chemical and biological characteristics of the environment as they relate to the characteristics of water quality.	For more information contact State Water Resources Control Board at (916) 341-5250; Project website: http://www.waterboards.ca.gov/swamp/
US Fish and Wildlife Service			
Fish Health	The California - Nevada Fish Health Center (CA-NV FHC)	The center provides fish health services within California and Nevada. The center works in cooperation with other federal, state, and Tribal agencies in surveying, sampling, and analyzing hatchery and wild fish populations.	For more information contact Kimberly True at kimberly_true@r1.fws.gov; Project website: http://www.fws.gov/canvfhc/#
Endangered Species	AFWO Endangered Species Branch	Field research and monitoring, regulatory and advisory roles with various federal agencies, permit review, habitat conservation planning on nonfederal lands, and many other biological related activities	For more information contact Arcata Fish and Wildlife Office at (707) 822-7201; Project website: http://www.fws.gov/cno/arcata/es/fish/
Coastal Conditions	USFWS Coastal Program	The Coastal Program focuses the U.S. Fish and Wildlife Service's efforts in bays, estuaries and watersheds around the U.S. coastline.	For more information contact Martha Naley at (703)358-2201; Project website: http://www.fws.gov/coastal/CoastalProgram/
US Geological Survey			
Physical & Chemical Factors	LIDAR (Light Detection and Ranging)	USGS uses LIDAR technology	For more information contact Abby Sallenger at asallenger@usgs.gov; Project website: http://coastal.er.usgs.gov/lidar/
Physical: Coastal landslides	Coastal and Marine Slope Stability and Landslides	This project focuses on characterizing the geologic environment, properties, form, and historic incidence of coastal landsliding on the Pacific Ocean coast of California, which was chosen because of its diversity of geology and landslides that is representative of many western U.S. coastal landslide-prone regions. This information will then be used to extract more specific information about the triggering mechanisms for the different types of landslides and/or geologic setting; specific parameters that lead to increased landslide susceptibility of the different formations. Coastal and fjord landslides into water have been associated with catastrophic tsunami inundation in historic time. This project will develop the linkage between landslide volume and mechanics; bathymetry; and tsunami runup height.	For more information contact Robert Kayen at (650) 329-4195; Project website: http://walrus.wr.usgs.gov/research/projects/landslides.html
Physical: Earthquakes,	Coastal and Marine Catastrophic Hazards	As the population continues to migrate toward the coastlines, the societal impacts of these hazards are expected to grow. This project develops a strategy for optimizing our efforts by assisting broader hazard programs within	For more information contact Tom Parsons at (650) 329-5074; Project website:

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Tsunamis		the USGS and externally while maintaining a focus on marine and coastal regions. Products are intended to support the development of regional multi-hazard assessments, and might range from complete assessments to analysis tools, interpreted data, or models. The near-term aim of this project is to see our science directly impact the public through hazard forecasts and other decision-making efforts. Longer term, we will provide peer-reviewed published research efforts that incrementally improve our ability to mitigate geologic hazards via new tools and observations.	http://walrus.wr.usgs.gov/research/projects/catastrophichaz.html
Physical: Benthic habitats	National Seafloor Mapping and Benthic Habitat Studies: Pacific *(Project is linked to three projects below).*	The project addresses habitat issues in areas identified as high priority through discussions with DOI (BRD, MMS, FWS, NPS) and collaboratively with by NOAA (NMFS, NMS) and the nation's regional Fishery Management Councils. By linking geologic studies with fisheries and benthic biology research to allow for better fisheries and environmental management with an emphasis on MPAs. Large scale benthic habitat maps for the EEZ from California to Washington State are being developed at this time. These maps are being compiled using a subset of available geophysical and geologic information some of which has been shown to lack the quality required to resolve habitat features essential to fish (Cochrane and Lafferty, 2002) This project is collaborating with other agencies to procure funding and is collecting high resolution geophysical data, imagery, geological samples, and mining existing databases to improve the habitat classification in high priority areas such as proposed MPA's.	For more information contact Guy R. Cochrane at (831) 427-4754; Project website: http://walrus.wr.usgs.gov/research/projects/nearshorehab.html
Nearshore Benthic Habitats	USGS Nearshore Benthic Habitat Project	The Nearshore Benthic Habitats Project of the USGS Western Coastal and Marine Geology Team will map the benthic habitat in areas that have been selected because they have been set aside as National Marine Sanctuaries, National Parks, State Fish Preserves, or are areas of ongoing or planned fish population studies.	For more information contact Guy R. Cochrane at (831) 427-4754; Project website: http://walrus.wr.usgs.gov/nearshorehab/
Beaches, Sandy Floors, Geology	usSEABED: A USGS Pacific Coast Offshore Surficial Sediment Data and Mapping Project	Extrapolating results from regional to national settings, Mapping and characterizing benthic habitats at appropriate scales and resolutions, Understanding geologic processes and environmental change, Sea floor classification, Developing prediction and Modeling capabilities,	For more information contact Jane Reid at (831) 427-4727; Project Website: http://walrus.wr.usgs.gov/usseabed
Mapping	Pacific Seafloor Mapping Project	This project uses state-of-the-art digital multibeam systems to systematically map the sea floor. The two types of data collected include bathymetry and backscatter.	For more information contact Peter Dartnell at (650) 329-5460; Project website: http://walrus.wr.usgs.gov/pacmaps/intro.html
Physical: Coastal processes, erosion and sedimentation	Ocean Beach Coastal Processes Study	The USGS is conducting a study that documents and analyzes the processes that control the sand transport and sedimentation patterns of Ocean Beach, a National Park site within the Golden Gate National Recreation Area. This area encompasses a complicated coastal setting that is impacted by the tidal influence of San Francisco Bay, as well as the southwest and northwest	For more information contact Patrick Barnard at (831) 427-4756 or Daniel M. Hanes at (831) 427-4718; Project website: http://walrus.wr.usgs.gov/coastal_proces

Monitors	Project Title	Project Description/Findings	Contact/Project Website
		Pacific swell. High-energy conditions at this site have restricted comprehensive field surveys in the past; but recent innovations in field techniques now make it possible to perform detailed analysis of the physical processes operating on high energy coastlines, such as Ocean Beach.	ses/index.html
Rocky Shores	Characterization of geologic and oceanographic conditions at Pleasure Point, Santa Cruz County	The Santa Cruz County Department of Public Works, the Santa Cruz County Redevelopment Agency and the California Department of Boating and Waterways requested a proposal from the USGS Western Coastal and Marine Geology Team (WCMGT) to provide baseline geologic and oceanographic information on the coast and inner shelf off Pleasure Point, Santa Cruz County, California. This is a study to collect baseline scientific information on the morphology and waves at Pleasure Point. This study will provide high-resolution topography of the coastal bluffs and bathymetry of the inner shelf off East Cliff Drive between 32nd Avenue and 41st Avenue (see map below). Further, it will document the spatial and temporal variation in waves at the study site.	For more information contact Curt Storlazzi at (831)427-4721 or cstorlazzi@usgs.gov; Project website: http://walrus.wr.usgs.gov/research/projects/pleasurept.html
Waste Disposal	Gulf of Farallones Disposal Issue	A study by the U.S. Geological Survey, which sought to answer two questions: What is the fate of more than 47,800 containers of low-level radioactive waste--many of which now lie within the Sanctuary boundary--that were dumped in the ocean between 1946 and 1970? What geological processes characterize deep-ocean areas that may be used as disposal sites for material dredged from San Francisco Bay?	For more information contact Herman Karl, Project Coordinator at (650) 329-5280; Project website: http://walrus.wr.usgs.gov/farallon/
Geology and Geologic Hazards	San Francisco Bay Region Geology and Geologic Hazards	The U.S. Geological Survey, in cooperation with the California Geological Survey, is releasing three new maps of the San Francisco Bay Area designed to provide a new look at the geologic history and hazards of the region	Project website: http://sfgeo.wr.usgs.gov/index.html
El Nino effects	1982-83 El Niño Coastal Erosion: San Mateo County, California	In the Spring of 1983, the USGS photographed the San Mateo County coast from the air and on the ground to document the cliff erosion and structural damage caused by the severe winter storms.	For further information, contact Ken Lajoie at klajoie@usgs.gov; Project website: http://walrus.wr.usgs.gov/elnino/SMCO-coast-erosion/introtext.html
Mapping	GLORIA Imagery off of California	Imagery, bathymetric maps, and other geophysical data	Project website: http://walrus.wr.usgs.gov/nwgloria/swindex.html
Seafloor morphology	Seafloor Morphology between Año Nuevo and Santa Cruz, California	This preliminary seafloor map displays submarine rock exposures found along the northern part of Monterey Bay National Marine Sanctuary. The extent of rock exposures on the sea floor is based on interpretations of side-scan sonar records, seismic-reflection records, and underwater video.	For more information contact Roberto J. Anima at (650) 329-5212; Project website: http://walrus.wr.usgs.gov/morphology/
Hydrocarbons	Hydrocarbons Associated with Fluid Venting Process in Monterey Bay, California	Study to describe and interpret the hydrocarbons in surface and near-surface sediment of the sanctuary in order to define the hydrocarbon background and to describe the processes responsible for the hydrocarbon occurrences. Of special interest is the presence of chemosynthetic communities nestled in areas of fluid venting.	For more information contact Thomas D. Lorenson at (650) 329-4186; Project website: http://walrus.wr.usgs.gov/hydrocarbons/

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Landslides	Potential San Francisco Bay Landslides During El Niño	The U.S. Geological Survey produced special landslide hazard maps of the San Francisco Bay Area for the California State Office of Emergency Services (OES) and the National Weather Service (NWS), in light of the 1997-98 El Niño Season.	For further information, contact David Howell at dhowell@usgs.gov; Project website: http://walrus.wr.usgs.gov/elnino/landslides-sfbay/intro.html
Wetlands	San Francisco Bay Wetlands: Fragile Environment	USGS scientists, working in cooperation with university, state, and other federal scientists are documenting the geologic nature of the wetland loss and studying sedimentary processes that are important in understanding how to restore fringing areas to tidal wetlands. Research has been designed with the guidance of local management agencies, including the SF Bay Conservation and Development Commission and the CA Coastal Conservancy.	Project website: http://walrus.wr.usgs.gov/research/sfbay.html
Flood Effects	1995 West Coast Flood Deposits	Heavy January rains on the west coast in 1995 led to record river and sediment discharges along the northern California coast. From February 8 to February 18, 1995, USGS scientists joined the STRATAFORM project's "Rapid Response Sampling Team" aboard the R/V WECOMA of Oregon State University for sediment sampling of the new flood layer on the continental shelf off the Russian and Eel Rivers. This field effort was the first step in a multi-year study funded by the Office of Naval Research and coordinated by the State University of New York at Stony Brook. Other participants in the study included Old Dominion University, University of Virginia, University of Washington, Monterey Bay Aquarium Research Institute, Humboldt State University, Woodward & Clyde Inc., Lamont-Doherty Geological Observatory, and Woods Hole Oceanographic Institution.	Project website: http://walrus.wr.usgs.gov/strataform/cal_flood.html
Earthquake effects	Ground Failure	The Coastal and Marine Geology geotechnical group investigates the causes of ground deformation and ground failure as a result of earthquakes, storms, and wave action.	For more information cotact Robert Kayen (650) 329-4195; Project Website: http://walrus.wr.usgs.gov/geotech/intro.html
Beaches, Geology	Oblique Aerial Photography - Coastal Erosion from El Nino Winter Storms	The USGS as part of its Coastal Marine Program is taking aerial photographs to assess coastal erosion from severe storms. The mission is to acquire precision-located oblique still and video photography before and after storm events to document storm related changes to the coastline.	For more information contact Dennis Krohn at dkrohn@usgs.gov; Project website: http://coastal.er.usgs.gov/response/
Geology	Coastal Cliff Retreat Rates Along the Big Sur Coast, Monterey and San Luis Obispo Counties, California	Report on the Coastal Cliff Retreat Rates Along the Big Sur Coast, Monterey and San Luis Obispo Counties, California	For questions about the content of this report, contact Cheryl Hapke at chapke@usgs.gov; Project website: http://pubs.usgs.gov/sim/2004/2853/
Geology	Estimated Sediment Yield from Coastal Landslides and Active Slope Distribution Along the Big Sur Coast, Monterey and	Report on the Estimated Sediment Yield from Coastal Landslides and Active Slope Distribution Along the Big Sur Coast, Monterey and San Luis Obispo Counties, California	For questions about the content of this report, contact Cheryl Hapke at chapke@usgs.gov; Project website: http://pubs.usgs.gov/sim/2004/2852/

Monitors	Project Title	Project Description/Findings	Contact/Project Website
	San Luis Obispo Counties, California		
Beaches, Geology	Coastal Erosion Along the U.S. West Coast During the 1997-98 El Nino: Expectations and Observations	During late summer 1997, NASA's Wallops Flight Facility, NOAA's Coastal Services Center, and the USGS Coastal & Marine Program formulated a plan to determine the magnitude, spatial patterns, and causative processes of El Niño-induced change along the west coast of the United States.	For more information contact Abby Sallenger, USGS Center for Coastal Geology at asallenger@usgs.gov; Project website: http://coastal.er.usgs.gov/lidar/AGU_fall98/
Other Projects			
Invasive Species	San Francisco Estuary Invasive Spartina Project	The Invasive Spartina Project is a coordinated regional effort among local, state and federal organizations dedicated to preserving California's extraordinary coastal biological resources through the elimination of introduced species of *Spartina* (cordgrass).	For more information contact Peggy Olofson, Project Director at prolofson@spartina.org or (510) 548-2361; Project website: http://www.spartina.org/
Rocky Shores	Biodiversity of rocky intertidal of northern Monterey Bay: A 24-year comparison	Species richness of 10 sites between Pigeon Point and Soquel Point surveyed by students of UC, Santa Cruz in 1971-1973 and again in 1996-1997. The sites were Pigeon Point (north and south), Ano Nuevo Point, Ano Nuevo Cove, Scott Creek, Davenport Landing, Natural Bridges, Almar Street, Point Santa Cruz, and Soquel Point. The main conclusion from these surveys is that there was remarkably little difference between the 24 years separating the two study periods, and no evidence was found of degradation or deterioration despite the increasingly heavy use at most sites by people.	For more information contact John Pearse, University of California, Santa Cruz at pearse@biology.ucsc.edu; Project website: http://www.mbnms-simon.org/
Rocky Shores, Fisheries	Shoreline Inventory of the black abalone, Haliotis cracherodii	Researchers at UC Santa Cruz, working with the MARINe (Multi-Agency Rocky Intertidal Network) and PISCO (Partnership for Interdisciplinary Study of Coastal Oceans) monitoring groups have documented the northward progression of WS along the California coast. This project is on-going. Data is collected data bi-annually.	For more information contact Dr. Pete Raimondi at raimondi@biology.ucsc.edu; Project website: http://www.mbnms-simon.org/sections/rockyShores/project_info.php?pid=100293&sec=rs
Rocky Shores	A Comparative Intertidal Study and User Survey, Point Pinos, California	The purpose of this study was to investigate the effects of visitor use on the Point Pinos rocky shoreline by comparing intertidal sites with different levels of human use and conducting census surveys to account for visitor use. Planning for additional resource conservation measures and monitoring programs at Point Pinos may be warranted in light of the findings of this study, because visitor use will likely increase in the future.	Project website: http://www.mbnms-simon.org/sections/rockyShores/project_info.php?pid=100183&sec=rs
Rocky Shores, Kelp Forests, Geology	Marine Resources Survey in Big Sur	Highway 1 in Big Sur is often subject to delays and closures due to storms, washouts, and landslides. The Big Sur Coast Highway Management Plan (CHMP) develops sustainable strategies that ensure the safe and efficient operation of the highway while protecting the unique terrestrial and marine resources. The Marine Resources Survey will characterize targeted intertidal and nearshore subtidal areas along the Big Sur coast.	Project website: http://www.mbnms-simon.org/sections/rockyShores/project_info.php?pid=100280&sec=rs
Rocky Shores	Rocky-shore Community Variation	An assessment of how human and natural disturbances interact to affect coastal communities through intensive biodiversity surveys of rocky intertidal	Project website: http://www.mbnms-simon.org/sections/rockyShores/project_i

Monitors	Project Title	Project Description/Findings	Contact/Project Website
	Along Natural and Anthropogenic Gradients of Disturbance: implications for the design and evaluation of marine reserves	habitats of Monterey Bay, CA.	nfo.php?pid=100181&sec=rs
Rocky Shores, Kelp Forests	Persistence and Recovery of Abalone Populations in Central California	Patterns and processes of persistence and recovery of depleted invertebrate populations, red (*Haliotis rufescens*) and black (*H. cracherodii*) abalone, in central California.	Project website: http://www.mbnms-simon.org/sections/rockyShores/project_info.php?pid=100182&sec=rs
Rocky Shores	Shipwrecks on Sanctuary Shores: Disturbance and Recovery Along a Rocky Intertidal Exposure Gradient	Recovery rates and processes assessed along a rocky intertidal exposure gradient impacted by a shipwreck in Monterey Bay, California.	Project website: http://www.mbnms-simon.org/sections/rockyShores/project_info.php?pid=100156&sec=rs
Kelp Forests, Estuaries, Marine Mammals	Nutritional Constraints on Sea Otters in the Monterey Bay National Marine Sanctuary	Investigation of the nutritional constraints on southern sea otters (*Enhydra lutris nereis*) by examining the nutrient composition of sea otter prey while coupling these data with studies on otter foraging behavior.	Project website: http://www.mbnms-simon.org/sections/kelpForest/project_info.php?pid=100263&sec=kf
Kelp Forests, Fisheries	Juvenile Rockfish Abundance Surveys	Scuba surveys are conducted by the National Marine Fisheries Service (NMFS) throughout late spring and summer to count the number of juvenile rockfish of all species that settle to the kelp bed and nearshore environments. An annual index is produced from this data for each species.	For more information contact Tom Laidig at tom.laidig@noaa.gov; Project website: http://www.mbnms-simon.org/sections/kelpForest/project_info.php?pid=100227&sec=kf
Beaches	Coastal Ocean Marine Mammal & Bird Education and Research Surveys (Beach COMBERS)	Survey program called Coastal Ocean Mammal and Bird Education and Research Surveys (Beach COMBERS) using trained volunteers to survey beached marine birds and mammals monthly at selected sections of beaches from Wadell Creek to Morro Bay.	For more information contact Hannah Nevins, Project Leader at hnevins@mlml.calstate.edu or (831) 771-4422; Project website: http://www.mbnms-simon.org/sections/beachCombers/index.php?l=n
Beaches, Sandy Floors, Water Quality	Ecological Effects of the Moss Landing Thermal Discharge	This study was designed to provide a quantitative evaluation of the impacts of the thermal discharge into the Sanctuary from the Moss Landing Power Plant.	Project website: http://www.mbnms-simon.org/sections/beaches/project_info.php?pid=100179&sec=b
Beaches, Geology	The Interaction of Seawalls and Beaches: Eight Years of Field Monitoring, Monterey Bay,	A long-term investigation of how coastal armoring structures affect beach morphology, both seasonally and over many years.	Project website: http://www.mbnms-simon.org/sections/beaches/project_info.php?pid=100253&sec=b

Monitors	Project Title	Project Description/Findings	Contact/Project Website
	California		
Sandy Floors, Deep Sea	Pattern and Dynamics of Benthic Soft Sediment Faunal Communities	The objectives of this project are to determine the patterns of abundance of marine megafaunal populations on the continental shelf and slope to 1000 m depth in Monterey Bay, and measure changes in abundance over time.	Project website: http://www.mbnms-simon.org/sections/sandyFloor/project_info.php?pid=100169&sec=sf
Sandy Floors, Fisheries	Delineation of Critical Inshore Spawning Grounds for Commercially Valuable Squid Fisheries on the East and West Coast of the USA	This project proposes to use the best available acoustic sampling technology (hardware, software, and sampling routines) to find and measure the areas of greatest concentration of benthic egg beds of the squids *Loligo opalescens.*	Project website: http://www.mbnms-simon.org/sections/sandyFloor/project_info.php?pid=100186&sec=sf
Sandy Floors	Seafloor Mapping in Monterey Bay, Cordell Bank, and Gulf of the Farallones National Marine Sanctuaries	National Oceanic and Atmospheric Administration and U.S. Geological Survey scientists mapped and characterized seafloor area on the continental shelf in three West Coast National Marine Sanctuaries using side-scan sonar and underwater video technology.	Project website: http://www.mbnms-simon.org/sections/sandyFloor/project_info.php?pid=100237&sec=sf
Sandy Floors, Water Quality	Southwest Ocean Outfall Regional Monitoring Program	The City and County of San Francisco owns and operates the Oceanside Water Pollution Control Plant that collects, treats to secondary standards, and then discharges municipal wastewater and storm water into the Pacific Ocean approximately 3.75 miles offshore of Ocean Beach.	Project website: http://www.mbnms-simon.org/sections/sandyFloor/project_info.php?pid=100212&sec=sf
Sandy Floors, Estuaries, Water Quality, Marine Mammals	The effect of the Moss Landing Power Plant thermal discharge plume on the distribution and behavior of sea otters (*Enhydra lutris nereis*): a preliminary study	Southern sea otters (*Enhydra lutris nereis*) have occupied various parts of Elkhorn Slough over the past few decades. Recently, a large raft of otters has been noted just within the Moss Landing harbor entrance. Some otters have been observed within and adjacent to the thermal plume generated by the Moss Landing Power Plant. This project studies sea otter behavior in and adjacent to the plume.	Project website: http://www.mbnms-simon.org/sections/sandyFloor/project_info.php?pid=100292&sec=sf
Estuaries	Characterization of the Benthic and Planktonic Communities of Elkhorn Slough	An ecosystem description of Elkhorn Slough that will serve as a baseline for assessments of the rapid change in this coastal habitat.	Project website: http://www.mbnms-simon.org/sections/estuaries/project_info.php?pid=100116&sec=e
Estuaries	Hydrodynamics and sedimentation in Elkhorn Slough	The goal of this project is to develop a calibrated 3D circulation model for Elkhorn Slough capable of predicting currents, water levels and transport. It is also intended to be used to estimate rates of sediment erosion, deposition, and transport.	Project website: http://www.mbnms-simon.org/sections/estuaries/project_info.php?pid=100174&sec=e
Estuaries, Water Quality	Volunteer Water Quality in Elkhorn Slough	Elkhorn Slough National Estuarine Research Reserve , the Elkhorn Slough Foundation, and the Monterey County Resources Agency have been supporting a volunteer water monitoring program since 1988. Striking	For more information contact Kerstin Wasson, Research Coordinator at research@elkhornslough.org; Project

Monitors	Project Title	Project Description/Findings	Contact/Project Website
		differences between sites and seasons were observed but significant long term changes over time are few.	website: http://www.elkhornslough.org/research/waterquality_volunteer.htm
Estuaries	Invertebrate Monitoring in Elkhorn Slough	Monitoring native and non-native crab species and count burrows of large invertebrates at sites along an estuarine gradient in Elkhorn Slough.	For more information contact Susie Fork at skfork@pacbell.net; Project website: http://www.elkhornslough.org/research/biomonitor_invert.htm
Estuaries, Water Quality	NERR System Wide Monitoring Program	The National Estuarine Research Reserve System is a network of state-federal protected areas, representing diverse estuarine ecosystems. Elkhorn Slough NERR has 24 partner reserves that are located on both coasts of the US, as well as the Great Lakes and Puerto Rico. Since 1995 these 25 NERRs carry out consistent system-wide water quality and weather monitoring.	For more information contact John Haskins at jhaskins@mlml.calstate.edu; Project website: http://www.mbnms-simon.org/sections/estuaries/project_info.php?pid=100215&sec=e
Estuaries	The influence of varying tidal exchange on the fish and crab assemblages of Elkhorn Slough	This study investigated how assemblage structure, species distribution and the abundance patterns of fishes and crabs are influenced by variation in tidal flow and freshwater input throughout shallow-water habitats in the Elkhorn Slough estuary.	Project website: http://www.mbnms-simon.org/sections/estuaries/project_info.php?pid=100301&sec=e
Seamounts, Deep Sea	Davidson Seamount Expedition	The Davidson Seamount is an impressive geologic feature located 120 km southwest of Monterey, California. This inactive volcano is roughly 2,300 m tall and 40 km long, yet its summit is far below the ocean surface (1,250 m). In May 2002, a diverse group of scientists led by the Monterey Bay National Marine Sanctuary embarked on an exploration to more fully characterize the Davidson Seamount.	For more information contact oceanexplorer@noaa.gov; Project website: http://oceanexplorer.noaa.gov/explorations/02davidson/davidson.html
Seamounts, Oceanography	Pioneer Seamount Ocean Acoustic Observatory	A vertical array of four hydrophones installed on Pioneer Seamount passively monitor the Pacific Ocean in the region south of San Francisco, CA.	For more information contact Roger Bland at (415)338-2433; Project website: http://www.physics.sfsu.edu/~seamount/
Submarine Canyons, Geology, Oceanography	In-situ Measurements of Turbidity Currents in the Monterey Submarine Canyon	Monitoring of speed and character of turbidity currents in Monterey Canyon.	Project website: http://www.mbnms-simon.org/sections/submarineCanyons/project_info.php?pid=100277&sec=sc
Submarine Canyons, Deep Sea	Long-term Monitoring of Demersal Fishes and Macroinvertebrates in the Monterey Bay National Marine Sanctuary	Long-term monitoring plan to assess changes of fishes and macroinvertebrates in the Sanctuary. Planning to annually survey fishes and macroinvertebrates in selected deep rocky shelf and slope habitats in the Sanctuary using a submersible and hydroacoustic techniques.	For more information contact Rick Starr, Marine Advisor, University of California at (831) 771-4442; Project website: http://www.mbnms-simon.org/sections/submarineCanyons/project_info.php?pid=100145&sec=sc
Submarine Canyons	December 20, 2001 Gravity Flow Event in Monterey Canyon	A sediment gravity flow descended through Monterey Canyon on December 20, 2001. The timing of this event is documented by a current meter found 550 m down-canyon from its deployment site, buried completely within a thick deposit of sediment.	For more information contact Bill Ussler at (831) 775-1879; http://www.mbnms-simon.org/sections/submarineCanyons/project_info.php?pid=100134&sec=sc

Monitors	Project Title	Project Description/Findings	Contact/Project Website
Submarine Canyons	Deepwater Demersal Fishes and Habitats	An assessment of benthic groundfishes (primarily of rockfishes in the genus Sebastes) and associated habitats in deep water conducted in Soquel Submarine Canyon, Monterey Bay, California.	For more information contact Mary Yoklavich at (831)420-3940 or mary.yoklavich@noaa.gov; Project website: http://www.mbnms-simon.org/sections/submarineCanyons/project_info.php?pid=100162&sec=sc
Deep Sea	Population Dynamics of Sessile Deep-sea Invertebrates in Monterey Bay	The objectives of this study are to determine the rates of survival and reproduction of common benthic invertebrate megafauna that inhabit the continental slope in Monterey Bay.	Project website: http://www.mbnms-simon.org/sections/deepSea/project_info.php?pid=100168&sec=ds
Deep Sea	Abyssal Fauna Associated With a Whale Fall in Monterey Canyon	Reports on a discovery of an unusual deep-sea community associated with the remarkably well-preserved carcass of a gray whale (*Eschrichtius robustus*) at 2,891 m depth in the axis of Monterey Canyon in 2002.	For more information contact Robert C. Vrijenhoek at (831) 775-1799; Project website: http://www.mbnms-simon.org/sections/deepSea/project_info.php?pid=100167&sec=ds
Open Ocean	Tagging of Pacific Pelagics (TOPP)	The Tagging of Pacific Pelagics (TOPP) research program aims to understand the migration patterns of large predators in the North Pacific basin and how these animals act and interact in their open ocean habitats. By using satellite tagging techniques, TOPP researchers follow the movements of different species across multiple trophic levels and in relation to physical oceanographic features in order to piece together a whole ecosystem picture.	For more information contact Randy Kochevar at rkochevar@mbayaq.org; Project website: http://www.toppcensus.org
Open Ocean, Water Quality	Center for Integrated Marine Technologies: Harmful Algal Blooms	The Center for Integrated Marine Technologies (CIMT) is using a variety of techniques to study harmful algal blooms (HABs)	For more information contact Mary Silver at msilver@ucsc.edu; Project website: http://www.mbnms-simon.org/sections/openOcean/project_info.php?pid=100173&sec=oo
Open Ocean, Oceanography, Marine Mammals	Center for Integrated Marine Technologies: Wind to Whales	The Center for Integrated Marine Technologies' (CIMT) mission is to create a coastal ocean observing and forecasting system that provides a scientific basis for the management and conservation of Monterey Bay, and serve as a model for all of California's coastal marine resources and the U.S. Integrated Ocean Observing System (IOOS).	For more information contact CIMT office at (831) 459-5007 or cimt@pmc.ucsc.edu; Project website: http://cimt.ucsc.edu/
Geology	December 20, 2001 Gravity Flow Event in Monterey Canyon	A sediment gravity flow descended through Monterey Canyon on December 20, 2001. The timing of this event is documented by a current meter found 550 m down-canyon from its deployment site, buried completely within a thick deposit of sediment.	For more information contact Bill Ussler at (831) 775-1879; Project website: http://www.mbnms-simon.org/sections/geology/project_info.php?pid=100134&sec=g
Oceanography	Spatial and Temporal Variability in Oceanographic and Meteorologic Forcing	High-resolution hourly data from 8 NOAA buoys deployed since the early 1980's off Central California were analyzed to improve understanding of spatial and temporal variability of oceanographic and meteorologic forcing along the coastline.	For more information contact Curt Storlazzi at (831)427-4721 or cstorlazzi@usgs.gov; Project website: http://www.mbnms-

Monitors	Project Title	Project Description/Findings	Contact/Project Website
	along Central California: 1980-2002		simon.org/sections/oceanography/project_info.php?pid=100252&sec=o
Oceanography, Water Quality	Monterey Bay Aquarium Incoming Seawater Monitoring	Part of the Monterey Bay Aquarium's ongoing water quality program; incoming seawater is monitored with both spot measurements and continuously on a 5minute interval using in situ sensor technology. Both seasonal events, such as upwelling, and periodic events, such as El Niño are visible in the data record.	Project website: http://www.mbnms-simon.org/sections/oceanography/project_info.php?pid=100240&sec=o
Oceanography	California El Niño	The project compares large-scale forcing associated with tropical El Niño and La Niña events, to describe and understand differences in the west coast response to these events.	Project website: http://www.mbnms-simon.org/sections/oceanography/project_info.php?pid=100144&sec=o
Oceanography	Monterey Bay Microbial Observatory	This study aims to describe the microbes of the Monterey Bay and create a model for understanding marine microbial communities in general.	For more information contact The Institute for Genomic Research at (301)795-7000h; Project website: http://www.tigr.org/tdb/MBMO/
Water Quality	Monterey Bay Aquarium Nearshore Surface Seawater Bacteria Monitoring	Monitoring various aspects of near shore seawater quality including levels of bacteria by The Monterey Bay Aquarium.	Project website: http://www.mbnms-simon.org/sections/waterQuality/project_info.php?pid=100241&sec=wq
Water Quality	Santa Cruz County Beach Water Quality	Santa Cruz County Environmental Health Service (EHS) has conducted regular testing of freshwater and saltwater swimming areas since 1968.	Program website: http://sccounty01.co.santa-cruz.ca.us/eh/environmental_water_quality/env_water_quality_home.htm
Water Quality	Santa Cruz County Beach Non-Point Pollution	Santa Cruz County Environmental Health Services (EHS) monitors county beaches and provides water quality information to concerned swimmers to alert them of possible areas that may be contaminated by fecal coliform bacteria.	Program website: http://sccounty01.co.santa-cruz.ca.us/eh/environmental_water_quality/env_water_quality_home.htm
Water Quality, Marine Mammals	A Literature Review To Characterize Environmental Contaminants That May Affect The Southern Sea Otter	The objectives of this study are to characterize environmental contaminants present in sea otter habitats that may affect population recovery, synthesize existing data on contaminant concentrations, and map their distribution.	For more information visit http://www.amarine.com/
Water Quality	Sanctuary Citizen Watershed Monitoring Network: First Flush Event Monitoring	Monitoring of the "First Flush," an event that occurs when the first sheeting rain of the season flushes roadways and impermeable surfaces, carrying months of accumulated contaminants and debris into the ocean.	For more information contact Bridget Hoover at (831) 883-9303 or bhoover@monitoringnetwork.org; Project website: http://www.mbnms-simon.org/sections/waterQuality/project_info.php?pid=100141&sec=wq
Water Quality	Monterey Bay Sanctuary Snapshot Day	Volunteers collect water quality data in watersheds from Pacifica, south to Cambria. In 2003, within the Monterey Bay National Marine Sanctuary, 157 sites were monitored by 155 people. Water bodies as diverse as urban	For more information contact Bridget Hoover at (831) 883-9303 or bhoover@monitoringnetwork.org; Project

Monitors	Project Title	Project Description/Findings	Contact/Project Website
		drainages, brackish sloughs, and major river systems were monitored.	website: http://www.mbnms-simon.org/sections/waterQuality/project_info.php?pid=100142&sec=wq
Fisheries	Reef Environmental Education Foundation (REEF) Fish Survey Project	The Reef Environmental Education Foundation (REEF)'s Fish Survey Project enlists the help of recreational SCUBA divers to identify and count nearshore fishes.	For more information contact REEF at (305) 852-0030 or reefhq@reef.org; Project website: http://www.reef.org
Fisheries	Characterization of Salinas Watershed Stream Habitat & Fish Species Composition	This project examines fish species distribution and quantitatively evaluates physical habitat quality throughout the Salinas Watershed.	For more information contact Dr Fred Watson at (831) 582-4452 or fred_watson@csumb.edu; Project website: http://science.csumb.edu/~ccows/
Fisheries	Coastal Ecology of Juvenile Salmonids in California	The goal of this study is to determine the abundance, distribution, growth, and health of juvenile salmonid stocks (chinook salmon, *Oncorhynchus tshawytscha*, coho salmon, *Oncorhynchus kisutch*, and steelhead, *Oncorhynchus mykiss*) and the influences of environmental factors on the central California coast.	For more information contact Bruce MacFarlane at (831) 420-3939 or Bruce.MacFarlane@noaa.gov; Project website: http://santacruz.nmfs.noaa.gov/ecology_branch/salmon_ecology/index.php
Fisheries	Carmel River Steelhead Count	The Monterey Peninsula Water Management District's monitoring program of the Carmel River steelhead population	For more information contact Monterey Peninsula Water Management District at (831) 658-5600; Project website: http://www.mpwmd.dst.ca.us/whatsnew/fishery/fishery.htm
Fisheries	NMFS Juvenile Rockfish Recruitment Survey	The National Marine Fisheries Service Groundfish Analysis Branch has done an annual survey of distribution and abundance of pelagic juvenile rockfishes. The goal of the survey is to provide an information base for forecasting future recruitment to rockfish fisheries.	Project website: http://www.mbnms-simon.org/sections/fisheries/project_info.php?pid=100118&sec=f
Green Crab	Green Crab Monitoring Program	MSI began monitoring the abundance of the European green crab (*Carcinus maenas*) in May 1995. MSI is contributing to the body of knowledge on Green Crab proliferation and growth by noting the carapace size, sex, and location of collected crabs. Study sites are open water and shoreline habitats of South San Francisco Bay.	Project website: http://www.cmiregistration.com/user/org/category.jxp?id=6544&org=261
Seabirds & Shorebirds	Distribution and Abundance of Marine Birds in Nearshore Waters of Monterey Bay, CA	This study measured the seasonal abundance of nearshore (<1 km from shore) marine birds and some of the factors affecting their distribution in Monterey Bay from 1999 to 2000.	Project website :http://www.mbnms-simon.org/sections/birds/project_info.php?pid=100131&sec=ss
Seabirds	The Distributions and Important Areas for Seabirds and Marine Mammals off	Collect and assemble necessary seabird and marine mammal datasets, Develop species distribution maps and maps of biologically important areas and time periods for seabirds and marine mammals in the study area, Provide related GIs analytical products and summary report of important areas,	For more information contact Carol Keiper,Oikonos carol@oikonos.org; Project Website: http://www.oikonos.org/projects/noaa.ht

Monitors	Project Title	Project Description/Findings	Contact/Project Website
	North/Central California	Assess spatial and temporal distribution of marine birds and mammals off central California, Use final reports and products to support concurrent sanctuary management plan reviews off north/central California.	m
Seabirds	Castle Rock Seabird Project	This project is designed to study the abundance and health of the populations of seabirds nesting on Castle Rock.	For more information contact Richard Golightly at rtg1@humboldt.edu; Project website: http://www.humboldt.edu/~rtg1/research/castle_rock.html
Marine Mammals	Abundance and Movements of Humpback Whales	Photo-identification research to examine humpback whale movements, migratory destinations, stock structure, and behavior.	Project website: http://www.cascadiaresearch.org/SPLASH/splash.htm
Marine Mammals	California Sea Otter Survey	Bi-annual aerial and land-based standardized surveys of Southern sea otters conducted in California during late spring and early fall, since 1983. The surveys record the total otter numbers, the number of dependent pups, and the number of adults and sub-adults, or independents observed. Spring survey results are used as an indicator of the population trend of California sea otters.	For more information contact Brian Hatfield at brian_hatfield@usgs.gov; Project website: http://www.mbnms-simon.org/sections/marineMammals/project_info.php?pid=100172&sec=mm
Marine Mammals	Pt. Lobos State Reserve Otter Survey	Monthly land-based standardized surveys of southern sea otters are conducted by Point Lobos volunteers to determine population trends in the reserve area.	Project website: http://www.mbnms-simon.org/sections/marineMammals/project_info.php?pid=100219&sec=mm
Marine Mammals	Underwater Behavior of Large Whales Using Suction-cup Attached Tags	This project examines underwater movements, behavior, and vocalizations of individual blue, fin, and humpback whales using suction-cup tags. Tags included a variety of instrument packages.	Project website: http://www.cascadiaresearch.org/SPLASH/splash.htm
Marine Mammals	Photo-identification of Blue Whales	The focus of this project is to collect identification photographs of blue whales to examine movements, migratory destinations, stock structure, and behavior, and to estimate abundance and trends in abundance.	Project website: http://www.cascadiaresearch.org/SPLASH/splash.htm
Marine Mammals	Long-term Monitoring of Northern Elephant Seals: Colony Development and Growth Rates in the Monterey Bay National Marine Sanctuary	A population study in 1968 involving systematic censuses and mark/recapture studies on the major rookeries which continues to the present; this long-term study permits a detailed documentation of population growth and colonization of the Sanctuary via dispersion and emigration.	Project website: http://www.mbnms-simon.org/sections/marineMammals/project_info.php?pid=100132&sec=mm

Appendix 6. Water Quality Monitoring Programs.

Organization	**Program Title**	**Program Description**	**Contact/Website**
California Department of Health Services, Division of Drinking Water and Environmental Management	Preharvest Shellfish Protection and Marine Biotoxin Monitoring Program	The Preharvest Shellfish Protection and Marine Biotoxin Monitoring Program conducts, surveys, classifies and monitors commercial shellfish growing areas in conformance with the National Shellfish Sanitation Program. The program also monitors numerous points along the California coastline for marine biotoxins in shellfish and toxigenic phytoplankton in the waters. Warnings are issued or quarantines are established as needed for recreational and commercial shellfish harvesting. The purpose of the preharvest shellfish activities is to establish sanitary requirements for shellfish growing waters and to regulate the commercial growing and harvesting of shellfish to assure that shellfish are safe for human consumption.	For more information on Shellfish activities, contact Gregg Langlois by phone at 510 412-4635 or by e-mail to glangloi@dhs.ca.gov; Program website: http://www.dhs.ca.gov/ps/ddwem/environmental/Shellfish/default.htm
California Environmental Protection Agency, Central Coast Regional Water Quality Control Board	Central Coast Ambient Monitoring Program	The Central Coast Ambient Monitoring Program (CCAMP) is the Central Coast Regional Water Quality Control Board's regionally scaled water quality monitoring and assessment program. The CCAMP monitoring strategy for watershed characterization calls for dividing the Region into five watershed rotation areas and conducting sampling each year in one of the areas. Sites are placed at the lower ends of tributaries and along the mainstem, with additional sites placed to characterize changes in land use, or to focus on waterbodies of special concern. Over a five-year period all of the Hydrologic Units in the Region are monitored and evaluated. Hydrologic Unit reports are available on the CCAMP website. PORE and especially GOGA should investigate possible linkages with this program (most northern sampling location is well south of GOGA, Scott Creek)	For more information on the CCAMP program email kworcester@waterboards.ca.gov; Program website: http://www.ccamp.org
The Center for Integrated Marine Technologies (CIMT)	Center for Integrated Marine Technologies: Harmful Algal Blooms	The Center for Integrated Marine Technologies (CIMT) is using a variety of techniques to study harmful algal blooms (HABs)	For more information contact Mary Silver at msilver@ucsc.edu; Project website: http://cimt.ucsc.edu/

Organization	Program Title	Program Description	Contact/Website
Central Coast Long-term Environmental Assessment Network	Central Coast Long-term Environmental Assessment Network (CCLEAN)	CCLEAN provides the initial nearshore component of the Central Coast Regional Water Quality Control Board's Central Coast Ambient Monitoring Program (CCAMP). This multidisciplinary program includes sampling in watersheds that flow into coastal regions, in estuarine coastal confluences, and at coastal sites. Sampling includes river sampling, nearshore sediment, and mussels. PORE and especially *GOGA should investigate possible linkages with this program (most northern sampling location is well south of GOGA, Waddell Creek; however, the group has an excellent monitoring and data management program)*	For more information contact the CCLEAN office at (831) 426-6326; Project website: http://www.cclean.org
The City and County of San Francisco	Southwest Ocean Outfall Regional Monitoring Program	The City and County of San Francisco owns and operates the Oceanside Water Pollution Control Plant that collects, treats to secondary standards, and then discharges municipal wastewater and storm water into the Pacific Ocean approximately 3.75 miles offshore of Ocean Beach.	Program website: http://www.mbnms-simon.org/sections/sandyFloor/project_info.php?pid=100212&sec=sf
City of Pacifica, San Mateo County	City of Pacifica, San Mateo County - NPDES Self-Monitoring Program	The City of Pacifica submitted a Report of Waste Discharge dated July 28, 1994 for reissuance of waste discharge requirements and a permit to discharge wastewater to waters of the State and the United States under the National Pollutant Discharge Elimination System (NPDES).	For more information contact Scott Holmes at (415) 738-7348; Program website: http://www.sfei.org/camp/servlet/DisplayProgram?which=General&pid=SFCA0037494; Dataset available at http://gis.ca.gov/catalog/BrowseRecord.epl?id=964
County of San Mateo health Department	Beach, Pool, and Other Recreational Water Closures	Water samples from the natural recreational waters (beaches, lagoons, creeks, and lakes) of San Mateo County are examined each week for the presence indicator bacteria. The concentration of these bacteria is used to determine if the water is safe for water contact activities (swimming, wading, and surfing). When they exceed State and/or County standards the area is posted to warn potential users that they may become ill if they engage in water contact activities in the posted area. Symptoms associated with swimming in areas with high levels of indicator bacteria include nausea, vomiting, fever, skin rashes, and diarrhea. These waters are also posted anytime they are contaminated by known sewer spills. Signs are removed when waters no longer have high levels of indicator bacteria. *Results included in Beach Water Quality in this report.*	Project website: http://www.co.sanmateo.ca.us/smc/department/home/0,,1954_191102_187763,00.html

Organization	Program Title	Program Description	Contact/Website
Earth 911	Marin County/San Mateo County Beach Water Quality Reporting Section	Earth 911 provides information generated and uploaded directly by local government agencies. Earth911 provides no independent analysis or historical reporting of water quality.	Project website: Marin County- http://www.earth911.org/waterquality/default.asp?cluster=6041; San Mateo County- http://www.earth911.org/waterquality/default.asp?cluster=6081
Environmental Protection Agency	The Environmental Monitoring and Assessment Program (EMAP) National Coastal Assessment	To answer broad-scale questions on environmental conditions, EMAP and its partners have collected estuarine and coastal data from thousands of stations along the coasts of the continental United States. EMAP's National Coastal Assessment comprises all the estuarine and coastal sampling done by EMAP beginning in 1990. This includes the sampling done in the biogeographic provinces as well as data from the Regional EMAP (REMAP) studies done by EPA Regional Offices. These data can be retrieved and stations mapped from applications under NCA Data.	Project website: http://www.epa.gov/emap/nca/index.html
Monterey Bay Aquarium Research Institute	Land/Ocean Biogeochemical Observatory (LOBO)	The LOBO observing system is designed to monitor the flux of nutrients (nitrate, phosphate and inorganic carbon) through the Elkhorn Slough ecosystem. The complete system will include up to eight nodes equipped with nutrient sensors developed at MBARI that are linked to the Internet through a wireless LAN (Local Area Network). *GOGA and PORE should investigate this program for possible synergies with their attempt to evaluate nutrient pollution in park estuaries and lagoons.*	For more information contact Ken Johnson at (831) 775-1985 or johnson@mbari.org; Project website: http://www.mbari.org/lobo/
Monterey Bay Sanctuary Citizen Monitoring Network	Monterey Bay Sanctuary Snapshot Day	Volunteers collect water quality data in watersheds from Pacifica, south to Cambria. In 2003, within the Monterey Bay National Marine Sanctuary, 157 sites were monitored by 155 people. Water bodies as diverse as urban drainages, brackish sloughs, and major river systems were monitored. *GOGA should investigate possible linkages with this program.*	For more information contact Bridget Hoover at (831) 883-9303 or bhoover@monitoringnetwork.org; Project website: http://www.mbnms-simon.org/sections/waterQuality/project_info.php?pid=100142&sec=wq
Monterey Bay Sanctuary Citizen Monitoring Network	Sanctuary Citizen Watershed Monitoring Network: First Flush Event Monitoring	Monitoring of the "First Flush," an event that occurs when the first sheeting rain of the season flushes roadways and impermeable surfaces, carrying months of accumulated contaminants and debris into the ocean.	For more information contact Bridget Hoover at (831) 883-9303 or bhoover@monitoringnetwork.org; Project website: http://www.mbnms-simon.org/sections/waterQuality/project_info.php?pid=100141&sec=wq
Moss Landing Marine Laboratory	MEQ- Marine Environmental Quality	The Marine Environmental Quality project is concerned with metal levels in the water and sediments of Los Angeles, Long Beach, and South San Francisco Bay.	For more information contact Dr. Kenneth Colae at (831) 771-4400; Project Website: http://chemoce.mlml.calstate.edu/

Organization	Program Title	Program Description	Contact/Website
San Francisco Bay Regional Water Quality Control Board	California Cleanup and Abatement Account - Mine Tailing Monitoring Program	The Gambonini Mercury Mine Site is located in Northwest Marin County approximately 50 miles north of San Francisco. Mercury mining wastes were placed in a steep canyon bounding Gambonini Ranch Creek, a tributary to Walker Creek and Tomales Bay. The remaining 200,000 cubic yards of mining waste is undergoing severe erosion. Using funds from the California Cleanup and Abatement account, Board Staff have been monitoring runoff from the site, Walker Creek, and Tomales Bay to assess the impact to beneficial uses. Site remediation will commence in August 1998. Board Staff will continue to monitor the watershed for five years in order to assess the net environmental benefits of the cleanup effort.	For more information contact Dyan C. White at dyan@rb2.swrcb.ca.gov; Program website: http://www.sfei.org/camp/servlet/DisplayProgram?which=General&pid=NCCA000006
The San Francisco Estuary Institute (SFEI), the Southern California Coastal Water Research Project (SCCWRP) and the Marine Pollution Studies Laboratory (DFG-MPSL) of the California Department of Fish and Game in Moss Landing developed this coastal water quality monitoring inventory under contract to the State Water Board.	California Coastal Water Quality Monitoring Inventory	This web site provides information about California's Coastal Water Quality Monitoring Programs	Project website: http://www.sfei.org/camp/
San Francisco Public Utilities Commission	Beach Water Quality- Shoreline bacteria monitoring	Shoreline bacteria monitoring is routinely conducted at 14 locations around the perimeter of San Francisco. All of San Francisco's beaches are monitored, including three stations at Candlestick Point Recreation Area, two stations at Aquatic Park Beach, two stations along Crissy Field Beach, three stations at Baker Beach, one location at China Beach and three locations along Ocean Beach at the foot of Balboa, Lincoln and Sloat. Samples are collected weekly year round. Additional monitoring is conducted whenever a combined sewer overflow (CSO) occurs from the City's sewer system. CSOs only occur during heavy rain events. In the event of a CSO samples may also be collected along Ocean Beach at the foot of Pacheco, Vicente and at Fort Funston in addition to the routine sample sites.	Program website: http://sfwater.org/custom/lims/beachmain1.cfm/MC_ID/4/MSC_ID/70

Organization	Program Title	Program Description	Contact/Website
State Water Resource Control Board	Bay Protection and Toxic Cleanup Program	California Water Code, Division 7, Chapter 5.6 established a comprehensive program within the SWRCB to protect the existing and future beneficial uses of California's bays and estuaries. The Bay Protection Toxic and Cleanup Program (BPTCP) has provided a new focus on the SWRCB and the RWQCBs (Regional Water Quality Control Boards) efforts to control pollution of the State's bays and estuaries and to establish a program to identify toxic hot spots and plan for their cleanup. The BPTCP has four major goals: (1) protect existing and future beneficial uses of bay and estuarine waters; (2) identify and characterize toxic hot spots; (3) plan for the prevention and control of further pollution at toxic hot spots; and (4) develop plans for remedial actions of existing toxic hot spots and prevent the creation of new hot spots.	For more information contact Craig Wilson at (916) 657-1108 or via email at wilscj@dwq.swrcb.ca.gov; Project website: http://www.sfei.org/camp/servlet/DisplayProgram?which=General&pid=NC2215091002
State Water Resource Control Board	Nonpoint Source Pollution Control Program	The Plan for California's Nonpoint Source Pollution Control Program (NPS Program Plan) provides a single unified, coordinated statewide approach to dealing with NPS pollution. A total of 28 state agencies are working collaboratively through the Interagency Coordinating Committee to implement the NPS Program Plan.	For more information contact Steve Fagundes of at (916) 341-5487; Program website: http://www.swrcb.ca.gov/nps/index.html
State Water Resource Control Board	State Mussel Watch (SMW) Program / Toxic Substance Monitoring (TSM) Program	The State Mussel Watch Program began in 1977 and is a joint program of the California State Water Resources Control Board and the California Department of Fish and Game. The main objective of the program is to quantify contaminant concentrations in the tissue of bivalve mollusks along California's coast, and in some inland waters of California (SWRCB, 1988). The State Mussel Watch Program conducts some monitoring on sediment quality, and on bioaccumulation in freshwater bivalve mollusks as well.	For more information contact Del Rassmussen at (916) 657.0916; Program website: http://www.swrcb.ca.gov/programs/smw/
State Water Resource Control Board	The Surface Water Ambient Monitoring Program (SWAMP)	Ambient monitoring refers of the physical, chemical and biological characteristics of the environment as they relate to the characteristics of water quality.	For more information contact State Water Resources Control Board at (916) 341-5250; Program website: http://www.waterboards.ca.gov/swamp/

Organization	Program Title	Program Description	Contact/Website
State Water Resource Control Board	Total Maximum Daily Load Program	The Federal Clean Water Act (CWA), contains two strategies for managing water quality. One, a technology-based approach that envisions requirements to maintain a minimum level of pollutant management using the best available technology, was an of the 1972 Act. The other, a water quality-based approach, relies on evaluating the condition of surface waters and setting limitations on the amount of pollution that the water can be exposed to without adversely affecting the beneficial uses of those waters. Section 303(d) of the CWA bridges these two strategies. Section 303(d) requires that the states make a list of waters that are not attaining standards after the technology-based limits are put into place. For waters on this list (and where the US EPA administrator deems they are appropriate) the states are to develop total maximum daily loads or TMDLs. A TMDL must account for all sources of the pollutants that caused the water to be listed. Federal regulations require that the TMDL, at a minimum, account for contributions from point sources (federally permitted discharges) and contributions from nonpoint sources. US EPA is required to review and approve the list of impaired waters and each TMDL. If US EPA cannot approve the list or a TMDL they are required to establish them for the state.	For more information contact State Water Resources Control Board at (916) 341-5250; Program website: http://www.swrcb.ca.gov/tmdl/tmdl.html
University of California, Davis Cooperative Extension	Marin Coastal Watershed Enhancement Project	The Marin Coastal Watershed Enhancement Project was designed to address the issue of NPS pollution on a local level. A primary focus of the project is to provide landowners with the resources that they need to demonstrate cooperative, voluntary compliance with water quality regulations. This approach will minimize regulatory involvement in local land management.	Project website: http://sarep.ucdavis.edu/NEWSLTR/v8n3/sa-4B.htm

Appendix 7. Golden Gate National Recreation Area water quality historic data summary.

Contaminant / Parameter	Total Number Observa-tions	Number Observa-tions Exceeded	Percent Observa-tions Exceeded	Number Stations	Number Stations Exceeded	Percent Stations Exceeded	Water Quality Criterion Exceeded	Standard	Measure-ment Dates	Maximum Exceedance
Dissolved oxygen concentrations	4,631	233	5.03%	131	20	15.27%	(less than or equal to standard) EPA criterion for the protection of aquatic life from 1972 through 1998	4 milligrams per liter (mg/L)	1963-1998	
pH range	5,012	62	1.24%	155	19	12.26%	EPA chronic criteria for marine aquatic life OR EPA chronic criteria for freshwater aquatic life	6.5 to 8.5 standard units (SU) for marine; 6.5 to 9.0 SU for freshwater	1951-1998	Lowest pH of 6.2 SU (GOGA 0032) in February 1975. Highest pH of 10.8 SU (GOGA 0379) in December1997.
Turbidity concentrations	1,448	66	4.56%	80	30	37.50%	WRD screening criterion	50 JTU/FTU/NTU*	1972-1998	950 FTU (GOGA 0011) in January 1975
Total coliform concentrations	27,542	1,660	6.03%	97	76	78.35%	(equaled or exceeded) WRD bathing water screening criterion	1,000 CFU/MPN/100 mL**	1972-1999	500,000 CFU/100 mL (GOGA 0193) in February 1994
Fecal coliform concentrations	14,451	1,364	9.44%	104	83	79.81%	WRD bathing water screening criterion	200 CFU/MPN/100 mL	1972-1999	300,000 CFU/100 mL (GOGA 0186) in February 1994
E. coli concentrations	55	27	49.09%	8	7	87.50%	WRD bathing water screening criterion	126 CFU/100 mL	1994-1996	300,000 CFU/100 mL (GOGA 0186) in February 1994
Enterococci	14,044	2,344	16.69%	45	32	71.11%	(equaled or exceeded) WRD marine water bathing screening criterion	35 CFU/100 mL	1989-1997	20,000 CFU/100 mL; reported 18 times at GOGA 0098, 0172, 0177 in 1989 and 1993. 2 concentrations of 20,000 CFU/100 mL were reported at GOGA 0131 in January 1990

Contaminant / Parameter	Total Number Observa-tions	Number Observa-tions Exceeded	Percent Observa-tions Exceeded	Number Stations	Number Stations Exceeded	Percent Stations Exceeded	Water Quality Criterion Exceeded	Standard	Measure-ment Dates	Maximum Exceedance
Chloride concentrations (dissolved and total)	1,090	1	0.09%	120	1	0.83%	secondary drinking water criterion AND the acute freshwater criterion	250 mg/L and 860 mg/L, respectively	1906-1998	4,600 mg/L (GOGA 0246) (only 1 exceeded)
Total residual chlorine concentrations	20	20	100.00%	3	3	100.00%	acute marine criterion	0.013 mg/L	1972	11.5 mg/L in October 1972
Fluoride concentrations (dissolved and total)	599	1	0.17%	75	1	1.33%	drinking water criterion	4 mg/L	1951-1998	6.03 mg/L (GOGA 0154) (only 1 exceeded)
Sulfate concentrations (dissolved and total)	910	1	0.11%	105	1	0.95%	secondary drinking water criterion	250 mg/L	1951-1998	760 mg/L (GOGA 0246) (only 1 exceeded)
Nitrate concentrations (dissolved and total as N and dissolved and total as NO_3)	1,044	1	0.10%	115	1	0.87%	drinking water criterion	10 mg/L NO3-N	1906-1998	10.08 mg/L (GOGA 0173) (only 1 exceeded)
Arsenic concentrations (dissolved and total)	253	2	0.79%	42	1	2.38%	drinking water criterion	50 µg/L	1953-1996	160 µg/L in February 1994
Cadmium concentrations (dissolved and total)	202	6	2.97%	40	4	10.00%	the acute freshwater criterion; AND 4 of these 6 concentrations exceeded the drinking water criterion	3.9 µg/L and 5 µg/L, respectively	1972-1997	
Chromium concentrations (dissolved and total)	242	2	0.83%	40	1	2.50%	drinking water criterion	100 µg/L	1972-1997	170 µg/L

Contaminant / Parameter	Total Number Observa-tions	Number Observa-tions Exceeded	Percent Observa-tions Exceeded	Number Stations	Number Stations Exceeded	Percent Stations Exceeded	Water Quality Criterion Exceeded	Standard	Measure-ment Dates	Maximum Exceedance
Copper concentrations (dissolved and total)	253	16	6.32%	45	13	28.89%	acute freshwater criterion	18 µg/L	1953-1997	810 µg/L was reported in San Carlos between Smith and Steinberger sloughs (GOGA 0033) in August 1972
Lead concentrations (dissolved and total)	258	2	0.78%	45	2	4.44%	drinking water criterion	15 µg/L	1953-1997	100 µg/L (GOGA 0373) in February 1987
Mercury concentrations (dissolved and total)	241	2	0.83%	37	2	5.41%	drinking water criterion AND the acute freshwater criterion	2.0 µg/L and 2.4 µg/L, respectively	1972-1997	3.5 µg/L (GOGA 0154) in 1994
Nickel concentrations (dissolved and total)	80	2	2.50%	27	1	3.70%	drinking water criterion	100 µg/L	1993-1997	210 µg/L (GOGA 0182)
Zinc concentrations (dissolved and total)	257	14	5.45%	45	9	20.00%	(equaled or exceeded) acute freshwater criterion	120 µg/L	1953-1997	3,374 µg/L (GOGA 0139) in February 1996
Total DBCP concentrations	95	2	2.11%	2	1	50.00%	drinking water criterion	0.2 µg/L	1994-1997	8.293 µg/L (GOGA 0154)
Totals	58,683	5,828	9.93%	1361	308	22.63%				

*Jackson Candle/Formazin/Nephelometric Turbidity Units

**Colony Forming Units/Most Probable Number/100 milliliters

Appendix 8. Point Reyes National Seashore water quality historic data summary.

Contaminant / Parameter	Total Number Observa-tions	Number Observa-tions Exceeded	Percent Observa-tions Exceeded	Number Stations	Number Stations Exceeded	Percent Stations Exceeded	Water Quality Criterion Exceeded	Standard	Measure-ment Dates	Maximum Exceedance
Dissolved Oxygen concentrations	397	2	0.50%	62	2	3.23%	EPA criterion for the protection of freshwater aquatic life	4 mg/l	1959 through 1991.	
Chloride (dissolved & total)	35	6	17.14%	22	2	9.09%	Secondary drinking water criterion	250 mg/L	1954-1988; 6 observations exceeded Secondary drinking water criterion in 1958-1964	19,000 mg/l in September 1959
Sulfate (dissolved & total)	33	2	6.06%	22	1	4.55%	Secondary drinking water criterion	250 mg/L	1954-1988; 2 observations exceeded in 09/58 and 05/60	
Nitrite (total as N and dissolved and total as NO_2)	169	13	7.69%	40	6	15.00%	Drinking water criterion	1 mg/L NO_2-N	1978-1998; 13 observations exceeded in 1994-1995	2.25 mg/L in December 1994
Nitrite plus Nitrate (dissolved and total)	1,104	8	0.72%	38	4	10.53%	Drinking water criterion	10 mg/L	1974-1998; exceeded observations from 1987-1995	62 mg/L in August 1995
Total Coliform	2,524	712	28.21%	65	52	80.00%	WRD bathing water screening criterion	1,000 CFU/MPN/100ml*	1971-1998	at least 24,190 MPN/100ml in April 1997

Contaminant / Parameter	Total Number Observa-tions	Number Observa-tions Exceeded	Percent Observa-tions Exceeded	Number Stations	Number Stations Exceeded	Percent Stations Exceeded	Water Quality Criterion Exceeded	Standard	Measure-ment Dates	Maximum Exceedance
Fecal Coliform	2,539	601	23.67%	60	51	85.00%	WRD bathing water screening criterion	200 CFU/MPN/100ml	1971-1998	at least 24,000 MPN/100ml (reported 6 times @ 5 stations from 1977-1994)
Total Cadmium	2	2	100.00%	4	2	50.00%	(1)Acute freshwater criterion AND (2)Drinking water criterion	(1)3.9 micrograms/L (2)5.0 micrograms/L	1986-1988; exceeded observations in February 1987	2 observations reported as 10 micrograms/L (assume from text this is the max.)
Total Copper	12	5	41.67%	4	3	75.00%	Acute freshwater criterion	18 micrograms/L	1986-1988	5 exceeded observations were 20 micrograms/L (assume from text this is the max.)
Total Lead	12	2	16.67%	4	2	50.00%	(1)Acute freshwater criterion AND (2)Drinking water criterion	(1)82 micrograms/L (2)15 micrograms/L	1986-1988	The 2 exceeded observations were 100 micrograms/L in February 1987 (assume from text this is the max.)
TOTALS	6,430	1351	21.01%	259	123	47.49%				

*CFU/MPN/100 mL = Colony Forming Units/Most Probable Number/100 milliliters

NPS 641/120272, 612/120272, March 2013

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov