



Plant Community Monitoring Protocol for the San Francisco Bay Area Network of National Parks

Narrative Version 1.0

Natural Resource Report NPS/SFAN/NRR—2016/1284



ON THE COVER

Scenes from Pinnacles National Park, John Muir Historic Site, Golden Gate National Recreation Area, Muir Woods National Monument, and Point Reyes National Seashore (top to bottom).
Photographs by Robert Steers.

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Standard Operating Procedures

Standard operating procedures (SOPs) are bound as a separate volume, Plant community monitoring protocol for the San Francisco Bay Area Network of National Parks: Standard operating procedures version 1.0 (Steers et al. 2016).

SOP 1: Workspace Setup and Data Storage

SOP : Field Work Preparation

SOP 3: Observer Training

SOP 4: Setting up the Electronic Field Equipment

SOP 5: Stand Selection and Plot Placement

SOP 6: Plot Set-up, Monumentation, and Description

SOP 7: Photographing Plots and Photo Management

SOP 8: North American Weed Management Association Subplot Sampling

SOP 9: Woody Plant Density Sampling in 3 m x 3 m Quadrats

SOP 10: Point Line Intercept Transects for Vegetation Cover

SOP 11: Live and Dead Tree Sampling

SOP 12: Litter, Duff, and Down Wood Sampling

SOP 13: Vegetation Database

SOP 14: Data Entry, Quality Assurance, and Quality Control

SOP 15: Power Analyses, Data Analyses, and Reporting

SOP 16: Metadata Guidelines

SOP 17: Collecting and Identifying Unknown Plants

SOP 18: Post Field Season

SOP 19: Revising the Protocol

SOP 20: Sensitive Data

SOP 21: Life Forms Master List

SOP 22: Safety and Job Hazard Analysis

SOP 23: Plot Location Manuals

Abstract

The San Francisco Bay Area Network (SFAN) has identified a suite of vital signs, indicators of ecosystem health, which represent various ecological phenomena operating across multiple temporal and spatial scales. Plant community monitoring is a high priority vital sign for this network, specifically at Golden Gate National Recreation Area (GOGA), Muir Woods National Monument (MUWO), Pinnacles National Park (PINN), and Point Reyes National Seashore (PORE). In these park units, plant communities are numerous and exhibit a complex spatial arrangement on the landscape. Because it is not possible to monitor every type that occurs in SFAN, and because these areas lack any relatively permanent feature of the landscape that can be utilized to reduce variability in the data set through stratification, SFAN park managers selected a set of mapped vegetation types for monitoring.

The sampling design consists of randomly selecting a subset of stands of each selected vegetation type from preexisting vegetation maps. One sampling plot per stand is used to collect data on a suite of vegetation parameters that represent structure and composition metrics, such as cover by species, density of woody plants, and species richness, among others. The sampling plot is based on modifications to the design used by the US Forest Service, Forest Inventory and Analysis program. Each vegetation type is on either an annual or three year sampling rotation: a subset of communities is sampled annually (some herbaceous vegetation types) to better understand interannual variability, other communities are monitored every three years to promote the ability of managers to respond if large undesirable changes are detected.

This protocol consists of two separate volumes, a narrative with appendixes and a set of standard operating procedures (SOPs) that detail steps required to collect, manage, and disseminate the data representing the status and trend of targeted vegetation types (Steers et al. 2016). SFAN staff collected pilot data during 2011 and 2012 to help resolve logistical and methodological questions for the monitoring program. In 2013, 2014, and 2015 the program began implementing the monitoring of selected vegetation types to establish baseline conditions. Relatively little information is known about temporal dynamics for many of the vegetation types being monitored. These data will also be helpful to park managers by providing reference conditions for many vegetation types and providing a means to detect changes in vegetation in a timeframe that allows managers to react appropriately to protect park resources.

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List of Acroynyms and Initialisms

CFP: California Floristic Province

DBH: Diameter at breast height

DEM: Digital elevation model

FGDC: Federal Geographic Data Committee

FIA: Forest Inventory Analysis

GOGA: Golden Gate National Recreation Area

I & M: Inventory and monitoring program

MUWO: Muir Woods National Monument

NAWMA: North American Weed Management Association

NPS: National Park Service

NRCS: Natural Resources Conservation Service

NRDT: Natural resources database template

NVC: National Vegetation Classification

PINN: Pinnacles National Park

PORE: Point Reyes National Seashore

QA/QC: Quality assurance and quality control

SFAN: San Francisco Bay Area Network of National Parks

SOD: Sudden Oak Death

SOP: Standard operating procedure

T & E: Threatened and endangered

USFS: United States Forest Service

WUI: Wildland Urban Interface

Revision History Log

Details on the procedure for protocol revisions are described in SOP 20 (Steers et al. 2016).

Revision History Log:

Previous Version	Revision Date	Author	Changes Made	Reason for Change	New Version

I. Background and Objectives

I.1. General Setting of the San Francisco Bay Area Network of National Parks

The San Francisco Bay Area Network (SFAN) encompasses National Park Service (NPS) lands found within or adjacent to the San Francisco Bay Area (Bay Area) in California. The San Francisco Bay is part of an expansive estuary that drains over 40 percent of California (The Bay Institute 2011), including the Central Valley, one of the most productive agricultural regions in the world (California Department of Food and Agriculture 2010). This large, natural bay is situated in the middle of California's Coast Ranges, separating the North Coast Range from the South Coast Range. Park units within SFAN range from Point Reyes National Seashore (PORE) north of the bay to Pinnacles National Park (PINN) approximately 200 km to southeast. Golden Gate National Recreation Area (GOGA), PORE, and Muir Woods National Monument (MUWO) are adjacent to one another, situated among the most western slopes of the Coast Ranges (Figure 1). The Bay Area is the sixth largest metropolitan area in the United States (US Census Bureau 2009) and all SFAN park units, except PINN, are directly adjacent to suburban or urban environments.



Figure 1. Geographic setting of San Francisco Bay Area Network park units.

I.2. Climate

The climate of the greater Bay Area is Mediterranean-like, with cool wet winters and dry warm summers. However, sub-regional climates can vary substantially with high precipitation and fog influence in coastal park units (GOGA, MUWO, and PORE) and almost desert-like precipitation and limited fog in the interior and southern portion of the network (PINN). The greatest variation in mean annual precipitation among park units is between PORE and PINN with a difference of approximately 81.3 cm in mean yearly precipitation per year. This difference could be much greater with supplemental water from fog (i.e., fog drip) as a factor. For example, Azevedo and Morgan (1974) recorded 42.5 cm of supplemental precipitation associated with fog drip during the summer months in a coastal forest dominated by *Pseudotsuga menziesii* in Humboldt County, California.

Due to spatial climate variability within the greater Bay Area, several ecological regions and sub-regions exist (Hickman 1993, Beidleman and Kozloff 2003). Within each ecological region, topographic complexity creates local scale climates that can vary widely (Stephenson 2000). For example, north vs. south facing slopes can receive dramatically different amounts of solar radiation, which translates to different plant communities on opposing aspects (Holland and Keil 1995). Furthermore, at a much smaller scale, drainages, large outcrops, steep cliffs, and other features that drain cold-air, cast shade, and/or alter water availability can also be associated with different plant species compared to the vegetation away from these features (Figure 2).



Figure 2. Plant species associated with relatively mesic conditions at PINN, such as *Quercus agrifolia* and *Prunus ilicifolia*, form rings around large rhyolitic rock outcrops surrounded by chaparral composed of *Adenostoma fasciculatum*, *Ceanothus cuneatus*, and others species.

I.3. Geology, Topography, and Soils

The geology of the Bay Area has been described by Sloan (2006) as a “crazy-quilt pattern of rocks almost defying description and order.” Numerous faults dissect this landscape. Notably, the San Andreas is a unifying fault that runs directly through or in close proximity to all SFAN park units. However, the Hayward and Calaveras are other similarly oriented, major strike-slip faults that, when combined with the San Andreas, split the greater Bay Area into three geologic blocks, the Salinan, San Francisco, and East Bay blocks, from west to east, respectively (Sloan 2006). Within each of these blocks are numerous additional smaller faults, and together with the elevated historic and

current tectonic activity in this region, a diverse set of land formations exist that are composed of numerous surficial sediments, overlying rocks, and/or basement complex rocks of varied age, which all have a distinct mineral composition (Graymer et al. 2006). Consequently, this complex geology has produced a region with diverse topography and soils.

The landscape of the Bay Area consists of mountain ranges, hills, valleys, and other topographical features associated with California Coast Ranges, which extend from Humboldt County to Santa Barbara County, and are split into the North and South Coast Ranges by the San Francisco Bay. At a regional scale, the mountainous terrain of the greater Bay Area can be subdivided into smaller topographical features, like the Marin Hills, Santa Cruz Mountains, East Bay Hills, and the Gabilan Range, among others. Elevation relief found within all SFAN park units ranges from about 380 to 750 m (Table 1). Despite relatively low relief in each park unit here compared to those in other networks on the west coast (e.g., North Coast Cascades, Klamath, Sierra), orographic precipitation, rain shadows, and other climatic influences associated with regional and local scale topography still have a significant effect on vegetation (Beidleman and Kozloff 2003, Evens 2008).

Table 1. Minimum and maximum elevations and topographic relief in SFAN park units.

Elevation Category	GOGA	MUWO	PINN	PORE
Min. Elevation (m)	0	34	257	0
Max. Elevation (m)	636	415	1007	429
Relief (m)	636	381	750	429

Bay Area soils are correspondingly complex with hundreds of soil types that overlap the SFAN park units. These soil types range from ultramafic serpentines to derivatives of sandstone, granite, and a variety of other rock types, including alluvial deposits (NRCS 2011). The complexity of soils and topography found in the Bay Area has resulted in a region with high plant species and community diversity.

I.4. Flora of the Greater San Francisco Bay Area

I.4.A. Flora

The Bay Area is located within one of the most important regions of biodiversity in the world (Myers et al. 2000, Olson and Dinerstein 2002), the California Floristic Province (CFP). There are many factors associated with high species richness in the CFP. First, the province has been a meeting ground for northern (Arctotertiary) and southern (Madrean) floristic elements, some of which have remained relatively unchanged for millions of years (e.g., *Sequoia sempervirens*, *Sequoiadendron giganteum*, and *Lyonothamnus floribundus* ssp. *asplenifolius*) (Axelrod 1958). Second, many species have radiated in response to repeated climatic shifts associated with mountain-building and altered oceanic currents (Raven and Axelrod 1995, although see Lancaster and Kay 2013). Third, high topographic complexity has resulted in numerous meso- and local-scale climates, which foster habitat heterogeneity that has allowed some species to persist as relicts and others to speciate in response to

new selective forces. Fourth, geologic complexity and numerous soils types exist, producing edaphic heterogeneity and opportunities for persistence or speciation (Ricklefs 1977, Richerson and Lum 1980). For example, serpentine soils, which are generally low in calcium and high in magnesium, can be found throughout many portions of the CFP, including some SFAN park units, and contain numerous “serpentine endemics” (Safford et al. 2005). Fifth, as a drier, Mediterranean-like climate developed over California in geologic time, increased fire frequency may have influenced selective pressures and speciation (although see Pausas et al. 2006).

The greater Bay Area is a landscape where multiple environments and their associated floristic elements abut. At a continental scale, phytosociological examination of coastal vegetation from British Columbia to the tip of Baja California has discovered overlap of two distinct floristic associations (Mesomediterranean and Coline) occurring over the greater Bay Area (Peinado et al. 1994). Similarly, based on the division of North America into 15 broad ecoregions, both Marine West Coast Forests and Mediterranean California ecoregions are present in the Bay Area (Commission for Environmental Cooperation 1997). At a smaller regional scale, plant species that are geographically associated with the North Coast Range, South Coast Range, Pacific Ocean, and Central Valley all intermix in the greater Bay Area (Axelrod 1981, Hickman 1993). Lastly, the mixture of floristic elements that occur here is also apparent when comparing the floras from each SFAN park unit with other park units to the north and south of this network. For example, PORE shares more native species with Redwood National Park, which is 325 km to the north than it does with PINN. Likewise, PINN shares more native species with Santa Monica Mountains National Recreation Area, which is 320 km to the southeast than it does with PORE (Table 2).

Endemic species make up approximately 48% of the native vascular species found in the California Floristic Province. The reasons for the high number of endemics are similar to those that explain why total species richness in the CFP is high (Raven and Axelrod 1995). However, certain portions of the state contain higher numbers of endemics than others and some of these endemics are relicts while others are neo-endemics that have speciated during relatively recent periods of aridity (Raven and Axelrod 1995, Carlsbeek et al. 2003). Within the CFP, the Coast Ranges have relatively high endemism (Kraft et al. 2010), and within the Coast Ranges, the Bay Area, in particular, contains local-hotspots of endemism (Stebbins and Major 1965). Thorne et al. (2009) found a relatively high number of restricted endemics (species that occupy less than 1,000 km²) in several portions of the Bay Area that overlap with SFAN park units.

The high native floristic richness and endemism associated with the Bay Area, combined with its high population density and urbanization, has resulted in a large number of vascular plant taxa that are now listed by the US Fish and Wildlife Service and the California Department of Fish and Wildlife as species of special concern, threatened, or endangered (Seabloom et al. 2006).

Table 2. Native species similarity (Sørensen index) among SFAN park units and other large NPS units found in the Coast and Transverse Ranges of California in the top right quadrant of the table; number of common native species in the bottom left quadrant. Numbers in gray-shaded cells indicate total number of native plant species known per park. Parks are listed from north to south. Data used in analyses were obtained from the NPSpecies-IRMA database (NPS 2011).

Park	CHIS*	GOGA	JOMU*	MUWO	PINN	PORE	REDW*	SAMO*	WHIS*
CHIS	585	0.327	0.264	0.181	0.366	0.304	0.177	0.505	0.199
GOGA	246	918	0.278	0.361	0.325	0.683	0.398	0.314	0.329
JOMU	109	161	242	0.308	0.338	0.263	0.245	0.234	0.256
MUWO	75	207	74	245	0.196	0.338	0.332	0.146	0.226
PINN	205	235	132	76	540	0.29	0.177	0.456	0.294
PORE	198	559	128	162	182	731	0.388	0.271	0.272
REDW	105	299	102	140	100	255	599	0.16	0.356
SAMO	358	275	126	78	312	210	113	836	0.24
WHIS	135	277	129	115	193	203	244	193	772

* NPS park units not included in this protocol: CHIS (Channel Islands National Park), JOMU (John Muir National Historical Site), REDW (Redwood National Park), SAMO (Santa Monica Mountains National Recreation Area), and WHIS (Whiskeytown National Recreation Area).

I.5. Vegetation of the Greater Bay Area

Vegetation of the Bay Area reflects the diverse climates, geology, topography, soils, flora, disturbance regimes, and human influences that characterize this region. Thus, vegetation diversity in the Bay Area is extremely complex with multiple plant communities arranged across the landscape in a mosaic-like pattern, with sharp to broad transitions between neighboring stands, similar to other portions of the Coast Ranges (Wells 1962, Steers et al. 2008). Different processes likely control plant community diversity depending on the spatial scale (*sensu* Sarr et al. 2005), with climate and area regulating diversity at macro-scales, topography at meso-scales, and interspecific competition interacting with soil heterogeneity at local scales.

Even when considered at a coarse level of classification, SFAN parks contain a high number of plant communities, such as sparsely vegetated barrens, annual forblands and grasslands, perennial grasslands, coastal dune scrub, northern coastal scrub, chaparral, freshwater wetlands, brackish marshes, riparian shrublands and woodlands, arid woodlands, mesic woodlands, mixed evergreen hardwood forests, closed-cone coniferous forests, Douglas-fir forests, and redwood forests, among others. At the finest level of classification available, GOGA, MUWO, and PORE, the vegetation of which were analyzed simultaneously, collectively contains 86 associations (Schirokauer et al. 2003), and PINN contains 45 associations plus 29 higher-level vegetation types that could only be classified to the alliance or “park special” level (Kittel et al. 2012).

I.5.A. Vegetation Dynamics

There are many ways that SFAN plant communities can change over time. For example, species composition can change while physiognomy remains the same. Also, structural changes can take place with little change in composition. Typically, however, both species composition and structure change together. This can be seen during successional processes along the coast, such as when northern coastal scrub succeeds to *Pseudotsuga menziesii* forest in the absence of disturbances (Figure 3), or in cases of type-conversion associated with disturbances, such as when northern coastal scrub coverts to *Pinus muricata* forests following wildfire (Forrestel et al. 2011, Harvey et al. 2011).



Figure 3. Douglas-fir colonizing northern coastal scrub above Abalone Point, PORE.

I.5.A.a. Vegetation Succession

In the absence of natural or anthropogenic disturbance, successional trends in the SFAN park units push plant communities to more structurally complex physiognomies. Grasslands are prone to conversion to shrublands (McBride and Heady 1968, Elliot and Wehausen 1974, McBride 1974, Williams et al. 1987, Williams and Hobbs 1989, Russell and McBride 2003, Zavaleta 2006), and shrublands typically convert to woodlands or forests (McBride 1974, Safford 1995, Dunne and Parker 1999, Horton et al. 1999, Van Dyke et al. 2001, Russell and McBride 2003). Hardwood forests can also succeed to coniferous forests (although see Russell and McBride 2003). Succession can result in changes to ecosystem processes, like nitrogen and carbon sequestration (Zavaleta and Kettley 2006), land bird dynamics (Chase et al. 2005), increased prevalence of Sudden Oak Death (SOD; Meentemeyer et al. 2008), and altered fire regimes in certain communities (Russell and McBride 2003, although see Keeley et al. 1999).

While some broadly-classified vegetation types are undergoing succession in Bay Area locales, in others, these same vegetation types appear relatively stable (Davis and Mooney 1985, Russell and McBride 2003) and it is unclear what factors are responsible for differences in successional rates between sites. It is possible that some areas may be responding to recent decreases in disturbances,

like grazing and fire (Keeley 2005). However, it is also likely that other factors associated with soils, water availability, propagule pressure, among others, influence rates of change.

The influence of water availability on successional rates (Williams and Hobbs 1989, Prach et al. 1993) has high relevancy in regard to future impacts from climate change. It appears that places with greater water availability are likely to be associated with higher rates of succession (Prach et al. 1993, Hsu et al. 2012). Furthermore, if climate change creates a drier, warmer environment where water is more limiting (Hayhoe et al. 2004, Cayan et al. 2008), then with everything being equal, successional rates in relatively wet areas, like PORE and GOGA, could eventually resemble those currently in drier places, like PINN. Likewise, PINN could experience die-off of species in the future (*sensu* Kelly and Goulden 2008) instead of remaining relatively stable as it has in recent history.

I.5.A.b. Human Disturbances and Altered Ecosystem Processes

Signs of human influence within and adjacent to park units are a common feature of SFAN. Many of the park units are in areas classified as wildland urban interfaces (WUIs). Landscapes such as these are associated with altered ecosystem properties and processes (reviewed by Radeloff et al. 2005). SFAN park units in WUIs are especially prone to invasion fronts from exotic species originating from human settlements (Schwartz et al. 2006, Seabloom et al. 2006) and altered fire regimes (Moritz and Stephens 2006). While some WUIs are prone to increased fire intensities, such as in southern California (Syphard et al. 2007), fire suppression activities in and around the SFAN park units have likely increased the fire return interval relative to those in prehistoric time, which has consequently allowed for successional processes to take place. For example, in the absence of fire, shrublands can be colonized by *Pseudotsuga menziesii*, which shades-out special status species, like *Arctostaphylos virgata* (Parker 2007). SFAN park units are also likely impacted by habitat fragmentation and loss of corridors associated with human development (reviewed by Harrison and Bruna 1999, Ewers and Didham 2006, Markovchick-Nicholls et al. 2008). Lastly, pollution originating in nearby urban areas, such as nitrogen deposition, increased CO₂, elevated ozone, heat-island effects, and other types of anthropogenic influences have been associated with vegetation impacts in other ecosystems (Takemoto et al. 2001, Fenn et al. 2003, Ziska et al. 2004) and most likely influence vegetation in SFAN park units to some degree. However, the critical loads or biologically meaningful amounts of exposure to these anthropogenic pollutants have not been determined for any SFAN park unit (*sensu* Rao et al. 2010).

While current human impacts within and adjacent to park units have affected natural processes, historic human impacts are also significant. SFAN park units likely have, at most, a 15,000 year history of human land use beginning with the indigenous Californians who originated from Beringia (Tamm et al. 2007). Land-uses by indigenous cultures included frequent burning and foraging/agriculture (Greenlee and Langenheim 1990, Anderson and Rowney 1999, Keeley 2002, 2005). As people of European descent displaced indigenous people, ranching, logging, and intensive agricultural operations were implemented in addition to the introduction of exotic species, some of which would become highly invasive (Minnich 2008). Disturbances associated with ranching included shrub and tree clearing through various means (Jones and Love 1945, Biswell 1954) and arrested successional processes (Hayes and Holl 2003, Johnson and Cushman 2007). Tree harvesting

in *P. menziesii* and *Sequoia sempervirens* forests of GOGA and PORE was widespread. The practice of clear-cutting in these parks likely began in the 1850s and lasted until the early 1900s (Hute 2008), excluding MUWO (McBride and Jacobs 1978) and other small areas. Additional disturbances to vegetation included row-cropping and other modern agricultural practices that were implemented in portions of park units like PINN, PORE, and GOGA, and military installations and training practices throughout coastal slopes of PORE and GOGA. In general, woody vegetation was thought to be much more prevalent in Bay Area landscapes prior to human influences (beginning approximately 15,000 years before present), and not until recently have human land-uses decreased in severity or frequency to the extent that successional processes are once again occurring in localized areas (Keeley 2005).

I.5.A.c. Plant Pests and Diseases

Introduced plant pathogens like SOD and pine pitch canker are in the process of transforming plant communities in SFAN park units, particularly in GOGA, MUWO, and PORE. As its name implies, SOD kills oak species (*Quercus* and *Lithocarpus* spp.). This disease is caused by a water mold known as *Phytophthora ramorum*, which has, thus far, impacted coastal woodlands and forests throughout central California, from Monterey County north to southern Oregon (California Oak Mortality Task Force 2011). The presence of SOD in PINN has been investigated by the park botanist and UC Davis collaborators with negative findings to date (Brent Johnson, unpublished report). In coast live oak woodlands of the Bay Area, dominance can shift from *Q. agrifolia* to *Umbellularia californica* as SOD progresses (Brown and Allen-Diaz 2009). In forests, SOD can reduce *Lithocarpus densiflorus*, an important tree component, leading to altered structure and increased fuel loads (Ramage and O'Hara 2010, Ramage et al. 2010, 2011). A decrease in *L. densiflorus* can cause increases in herbaceous species richness and recruitment of *Arbutus menziesii* and *U. californica* (Ramage et al. 2010). It is believed that SOD has only been afflicting oak species in the Bay Area since the mid-1990s (California Oak Mortality Task Force 2011), and since the disease may still become more widespread in the Bay Area and mortality does not occur immediately, many impacts from this pathogen are yet to be seen.

Pine pitch canker has purportedly been present in the Bay Area longer than SOD. The first known case in the wild appeared in 1986, in Santa Cruz County (McCain et al. 1987). This species was first noticed to inflict *Pinus radiata*, but other exotic and native pines in the state are also susceptible, notably, *P. muricata* (McCain et al. 1987). Because the disease seems to progress more rapidly in coastal versus inland environments (Wikler et al. 2003), native *P. muricata* forests, such as those in PORE, could be severely altered in the future, if not already. Stem die-back and mortality of *P. muricata* have been documented in PORE and consequences to forests dominated by this pine are a focus of ongoing research.

I.5.A.d. Invasive Plant Species

The Bay Area has higher exotic plant species richness than any other area in California (Williams et al. 2005). The threat of losing native plant species at the expense of invasive exotic plants is a major concern in this region (Schwartz et al. 2006, Seabloom et al. 2006). Some of these exotic species were introduced at the time of the arrival of the first Spanish missionaries in the 18th century, while

others came with successive waves of newer immigrants (Minnich 2008). Many exotic species found in the Bay Area are considered invasive because they can spread into wildlands and displace native species, hybridize with native species, alter biological communities, or alter ecosystem processes (Cal-IPC 2006). Currently, many invasive species that are the focus of control efforts in SFAN parks are escaped ornamentals. Housing density and proximity to wildlands has been positively associated with exotic plant species invasions (Sullivan et al. 2005, Gavier-Pizarro et al. 2010) so it is no surprise that ornamental plants appear to have a large impact on SFAN park units and are a primary focus of network early detection efforts (Williams et al. 2009).

Invasive species are notorious at transforming vegetation into species-depauperate assemblages with completely altered ecosystem processes compared to the native habitat they displace. Many invasive species are dominant in SFAN plant communities. Research conducted within SFAN park units have investigated the following invasive plants: annual grasses (Haubensak and D'Antonio 2006), *Ammophila arenaria* (Peterson 2004, Dangremond et al. 2010), *Delairea odorata* (Alvarez and Cushman 2002), *Genista monspessulana* (Alexander and D'Antonio 2003), *Spartina alterniflora* x *foliosa* (Brusati and Grosholz 2006, 2009), among others. In general, invasive plant impacts are numerous (Richardson et al. 1994, Mack et al. 2000, Ehrenfeld 2003, Brooks et al. 2004, Henderson et al. 2006) and plant communities in SFAN park units are highly threatened by them.

I.5.A.e. Vegetation Response to Climate Change

Climate has the strongest control on plant species distributions (Stephenson 2000). Based on paleobotanical and climatological studies, vast changes in species composition have occurred throughout California in response to past climatic shifts (Raven and Axelrod 1995, Minnich 2007). Briefly, California was once covered by dense rainforest and savanna vegetation made up of tropical and subtropical taxa during the Eocene and early Oligocene (50 to 28 million years ago [MYA]). Then, a cooling and drying trend from the mid-Tertiary to the mid-Miocene (33 to 13 MYA) was associated with widespread coniferous forests. However, these vast forests gave way to sclerophyllous shrublands and woodlands, in addition to savannas, as the drying and cooling trend increased and summer precipitation became scarce into the Pliocene (5.3 to 2.6 MYA). By the end of the Pliocene, the general plant communities likely resembled present day plant communities at a coarse level yet their spatial extent would shift dramatically during the Pleistocene (2.6 to 0.01 MYA).

The Quaternary has been a period of persistent Mediterranean-like climatic conditions in California but with fluctuations in precipitation and temperature corresponding to glacial and interglacial cycles (Johnson 1977). During this time, coniferous forests displaced sclerophyllous woodlands and shrublands at lower elevations corresponding to cool, wet glacial periods, and would retreat upslope with warm, dry interglacials (Raven and Axelrod 1995). Similarly, coastal species shifted latitudinally within maritime influence (Johnson 1977). For example, *Sequoia sempervirens* was formerly present at least as far south as Los Angeles County 40,000 to 28,000 years ago, whereas its current distribution does not extend further south than Monterey County. At Tomales Bay, adjacent to PORE, *Picea sitchensis* occurred 29,000 years ago, whereas its present day distribution along the coast is 170 km to the north near Fort Bragg (Johnson 1977). Also at PORE, pollen evidence

suggests a dramatic shift from *Psuedotsuga menziesii*/*Abies grandis* forests to coastal scrub and grassland at the Pleistocene-Holocene boundary approximately 10,000 years ago (Rypins et al. 1989). As little as 8,000 to 4,000 years ago the Xerothermic period, a particularly arid and warm climatic phase, had a profound effect on species ranges and plant community composition throughout California, including the Bay Area (*reviewed in* Axelrod 1981). Specifically in the Bay Area, *P. menziesii* forests were reduced in size or completely disappeared from some areas while many new plant species from warmer, interior or southern regions colonized.

Future changes to the climate of California due to elevated anthropogenic CO₂ emissions include warming and possibly increased aridity (Hayhoe et al. 2004, Cayan et al. 2008) that could surpass conditions that typified the Xerothermic period. Modeled changes in bioclimatic envelopes of CFP plant species show dramatic shifts corresponding to increases in just several degrees Celsius (Loarie et al. 2008). However, these types of models are only a first step in understanding the impacts of climate change and may not be accurate at regional or smaller spatial scales (Pearson and Dawson 2003). Also, the use of past climates to predict future changes may be unreliable since present day human interferences have severely limited the ability of plant species or vegetation types to track their optimal climatic envelopes like they may have done in the past (Loarie et al. 2008). In addition, the rate of future climate change may be too great for plant species to respond adequately (Pearson 2006), which could make future responses different from the past. In general, climate change leaves much uncertainty in regard to future floristic and plant community patterns in SFAN, especially at spatial scales typical of park units.

The uncertainty in the response of vegetation to future climate change brings about many questions for land managers. For example: will some classified vegetation types be more prone to change than others? For vegetation types that are supplemented by coastal fog during the otherwise dry summer months (Ingraham and Matthews 1995, Corbin et al. 2005), how will the fog regime change and what will the impact be? For communities that are edaphically restricted to certain soil types, like serpentine, will they be able to persist in place, shift to new soil types, or require dispersal to other patches of serpentine elsewhere? Will plant communities continue to maintain the species composition that characterize them today or will novel vegetation types form with new combinations of species not seen in current assemblages?

I.6. Existing Vegetation Studies in SFAN National Parks

I.6.A. Monitoring Projects

Currently, there are several NPS projects that include vegetation sampling (Table 3). Fire effects monitoring, which is implemented in GOGA, PINN, and PORE, is the largest of such efforts in SFAN park units. However, the fire effects monitoring program differs greatly from plant community monitoring in that it is primarily focused on short- and long-term prescribed fire effects in relation to unburned controls in a limited number of vegetation types. Nevertheless, data generated by fire effects monitoring can potentially be very useful for interpreting plant community trends derived from the I&M program and vice versa. Recent funding cuts to the fire program have substantially reduced the fire effects program from 2.75 full-time personnel equivalents (FTE) to 0.5 FTE. Because of this, the breadth and depth of this program into the future is uncertain.

Other than fire effects monitoring, all other past or ongoing vegetation monitoring projects in SFAN parks are relatively small in scope and restricted to small portions of parks or restoration/study sites (e.g., Parsons and Allen 2004, Peterson 2004). In addition to the multi-species monitoring projects, several species-specific monitoring projects also occur in the SFAN park units. Current species-specific monitoring projects vary from investigating populations at relatively small study sites to large landscapes as big as the park units (Table 3).

Table 3. Some past and on-going vegetation or plant species monitoring projects in SFAN park units. This table is not exhaustive.

Project Name	Year	Park	Reference
Vegetation Monitoring			
Beach and Dune Vegetation	1974–1975	PORE	Barbour (1975)
Muir Woods Vegetation	1977–1978	MUWO	McBride and Jacobs (1978)
Elk Reintroduction Enclosure – Tomales Point	1978–present	PORE	Lathrop (1981), Lathrop and Gogan (1985), McEachern et al. (2001a, 2001b), Johnson and Cushman (2007)
Range RDM and Composition Plots	1987–present	GOGA, PORE	unpublished data
Fire Effects Monitoring	1989–2012	GOGA, PINN, PORE	Stephens (2004), Forrestel (2010)
Myrtle’s Silverspot Butterfly Habitat	1995	PORE	Woods (1995)
Vision Fire Monitoring Plots	1996–1998	PORE	Allen (1999)
Riparian Forests and Birds	1997–1998	GOGA, PORE	Holmes et al. (1999)
Vegetation response to pig removal	2003-present	PINN	Grinde and Sweitzer (2006)
Species-specific Monitoring			
Rare Plants	1980s–present	GOGA, PORE	Davis and Sherman (1992), Coppoletta and Moritsch (2002), Coppoletta and Skaer (2004), Parker (2007), Ryan and Parsons (2010a, 2010b), Speith and Taylor (n.d.)
Blue Oak	1992	PINN	Swiecki et al. (1993)
*Exotic Plant Species	2008–present	SFAN	Williams et al. (2009)

* Indicates a SFAN I&M Monitoring Program

1.6.B. Vegetation Maps

From 1997 to 2003, vegetation was classified and mapped for GOGA, MUWO, PORE, and neighboring lands belonging to California State Parks and local municipalities (Schirokauer et al. 2003). This effort utilized the National Vegetation Classification (NVC) system, which resulted in 87

vegetation types described based on 366 relevé vegetation plots throughout all NPS and non-NPS lands. The vegetation map contained 74 vegetation types using a 0.5 ha minimum mapping unit over an approximately 62,725 ha area. A similar vegetation mapping effort using the NVC was performed at PINN from 2003 to 2008 (Kittel et al. 2012). This mapping effort utilized 1,357 relevé plots, which resulted in 67 vegetation types described. The vegetation map contained 34 vegetation types using a 0.5 ha minimum mapping unit over an 18,210 ha area.

Other vegetation maps for PORE and GOGA have utilized remote sensed imagery from 2001 plus classification and regression tree algorithms (Gong et al. 2005, Yu et al. 2006). Also, PORE and Marin County portions of GOGA were classified and mapped based on WEKA algorithms using 2003 remote sensed imagery (Redmond et al. 2005b). PINN vegetation was also mapped with remote imagery from 2000 and classified based on WEKA algorithms (Redmond et al. 2005a). Other existing maps include a 1983 PINN vegetation map (see Kittel et al. 2012), digitized Weislander (Kelly et al. 2005) vegetation maps from the 1930s and 40s, and vegetation maps of recent GOGA acquisitions in San Mateo County (Dahlin 2007, URS 2009). Currently, a historic black and white aerial photography set dating back to the 1940s is being used to map vegetation changes up to the present day (Forrestel et al. unpublished data), and a similar historic vegetation analysis based on a very coarse vegetation classification recently compared 1985 to 2010 Landsat imagery for MUWO, GOGA, PORE, and surrounding counties (Hsu et al. 2012).

1.6.C. Research Studies

In addition to monitoring projects, research studies examining central coastal California ecosystems are also useful for understanding how certain plant communities change or do not change, or for identifying environmental factors or plant traits that correlate with species distributions across landscapes. Research projects relating to vegetation in the Bay Area have been conducted by both NPS and outside investigators, and are too numerous to summarize here, but range from paleobotanic studies to modeling plant community response to future climate change scenarios. Many vegetation-related studies have occurred within or adjacent to SFAN park units. Because of the close proximity of SFAN park units to a large number of universities and environmental agencies, we expect that research from outside the NPS will continue to supplement park studies with management-relevant information.

1.7 Justification for Long-term Vegetation Monitoring

In light of the complexity and dynamic nature of SFAN plant communities, their uniqueness and vulnerability, and the known and unknown functions they provide, land managers will benefit greatly from a long-term plant community monitoring program that establishes a baseline that future changes can be measured against. Land managers require information about vegetation change in order to fulfill law and policy mandates to protect park resources. Network parks provide habitat for over 160 non-marine special status species, including vascular plants, mammals, birds, amphibians, and invertebrates (Adams et al. 2006). In SFAN, multiple plant communities create essential habitat for a diverse flora and fauna, and are integral to various ecosystem processes relating to the atmosphere, hydrology, fire regime, community dynamics, and resiliency/resistance to external perturbations

(Chapin et al. 2002). The ability to relate measured changes in plant communities to multiple biotic and abiotic parameters is virtually unparalleled among other SFAN vital signs.

In the past, the SFAN I&M and park staff prioritized vital signs for monitoring after a series of interdisciplinary workshops (Adams et al. 2006); 18 out of 63 potential vital signs were selected for long-term monitoring by the I&M program (Table 4). The plant community monitoring protocol has direct relevance to the following top ranked vital signs: invasive plant species, rare plant species, landscape dynamics, wetlands, and riparian habitat. Furthermore, trends in other vital signs, such as weather, climate, and air quality, may provide insight into changes in plant communities. Likewise, changes in plant communities may correlate with changes in other vital signs, such as northern spotted owl (*Strix occidentalis caurina*), amphibians and reptiles, western snowy plover (*Charadrius nivosus nivosus*), T & E (threatened and endangered) butterflies, wetlands, and landbird population dynamics. In addition, monitoring plant communities will also have direct relevance to other vital signs that did not rank in the top 18 chosen for monitoring, and include (rank in parentheses): dune vascular plant assemblages (22), grasslands (37), oak woodlands (38), Sudden Oak Death (39), resilience monitoring – fire (40), lichens (45), ozone sensitive vegetation (54), and plant species at the edge of their range (58).

Table 4. Top ranked SFAN vital signs chosen for monitoring at SFAN park units: Eugene O'Neill National Historic Site (EUON), Fort Point National Historic Site (FOPO), GOGA, John Muir National Historic Site (JOMU), MUWO, PINN, PORE, and the Presidio of San Francisco (PRSF). Adapted from Adams et al. 2006.

Vital Sign	Rank	Parks Units Monitored							
		EUON	FOPO	GOGA	JOMU	MUWO	PINN	PORE	PRSF
Weather and Climate	1	X		X	X		X	X	
Invasive Plant Species	2		X	X	X	X	X	X	X
Fresh Water Quality	3			X	X		X	X	
Air Quality	4			X			X	X	
Stream Fish Assemblages	5			X	X		X	X	
Rare Plant Species	6			X			X	X	X
Northern Spotted Owl	7					X		X	
Amphibians and Reptiles	8			X	X	X	X	X	X
Western Snowy Plover	9			X				X	
Pinnipeds	10			X				X	
Plant Communities	11		X	X	X	X	X	X	X

Table 4 (continued). Top ranked SFAN vital signs chosen for monitoring at SFAN park units: Eugene O'Neill National Historic Site (EUON), Fort Point National Historic Site (FOPO), GOGA, John Muir National Historic Site (JOMU), MUWO, PINN, PORE, and the Presidio of San Francisco (PRSF). Adapted from Adams et al. 2006.

Vital Sign	Rank	Parks Units Monitored							
		EUON	FOPO	GOGA	JOMU	MUWO	PINN	PORE	PRSF
Landscape Dynamics	12	X	X	X	X	X	X	X	X
T & E Butterflies	13			X				X	
Freshwater Dynamics	14			X	X		X	X	
Wetlands	15			X	X	X	X	X	X
Riparian Habitat	16			X	X	X	X	X	X
Landbird Population Dynamics	17			X	X		X	X	X
Raptors and Condors	18						X		

I.8. Questions about Vegetation Community Change and Monitoring Objectives

I.8.A. Questions about Vegetation Community Change

While the vegetation and floristics of California, and the Bay Area in particular, have received attention through various investigations, much still remains unknown about how vegetation within any park unit has changed in the past and will continue to change into the future. For example, in regard to future climate change, a regional model of the Bay Area has been developed to understand how vegetation patterns may shift spatially (Cornwell et al. 2012), but like many contemporary bioclimatic envelope models, it may be inaccurate at smaller spatial scales representative of SFAN park units (Pearson and Dawson 2003). In addition, strategies for managing biodiversity in the face of climate change have been outlined (Heller and Zavaleta 2009), but critical knowledge gaps still exist relating to basic vegetation dynamics that are needed to make management decisions.

The number of plant communities in SFAN park units is large and it follows that the questions land managers have about changes in these communities are numerous. Much remains unknown about basic processes, like succession. Therefore, NPS managers from this network have identified several key monitoring questions. These focus on understanding changes in plant communities, based on observing changes within previously classified and mapped vegetation types.

- 1. How does structure and species composition of selected plant communities change with time?** For example, invasive species abundance, species richness, density of woody plants, and vegetative cover could change over time in any SFAN vegetation type.
- 2. What ecosystem processes are associated with plant community change or stasis?** For example, fire suppression, herbivory, disease spread/severity, and climate change, are all process-related factors that influence vegetation change.

3. **What environmental factors are associated with structural or compositional properties of a site?** For example how does water availability, soil depth, or soil chemistry influence the physiognomy or the species composition at a site?
4. **What environmental factors are associated with the spatial distribution of plant communities across a landscape?** For example, aspect, soil type, and fire history can correlate with the spatial distribution of certain plant communities.
5. **How does the spatial extent of stands change with time?** For example, are stand boundaries static or dynamic? Will future plant communities resemble present day ones?

1.8.B. Monitoring Objectives

It is not the intention of this protocol to address every question stated above. Furthermore, portions of these questions would best be addressed by use of experimental or modeling approaches that are beyond the means of this protocol (but could be opportunities for collaborating with outside researchers). On another note, it is without doubt that there are still unknown factors that currently impact plant communities or will so in the future. For example, SOD has and will continue to have profound impacts on certain vegetation types in the SFAN parks, yet did not exist in wildlands of the Bay Area just 20 years ago. In the future, a new, even more damaging disease than SOD could be introduced. It is impossible to identify every important factor that has or will influence vegetation change. Nevertheless, the questions outlined above are focused on basic patterns and processes that are relevant to resource management. Designing a monitoring protocol that can capture changes in species composition and structure will still be able to inform management decisions even if underlying causes of change are not clear or are unforeseen.

The primary monitoring objective of this protocol is to detect changes in vegetation structure and species composition of selected vegetation types over time. Very limited baseline information exists for the plant communities that occur in the SFAN parks. Therefore, the goal of this program is to establish the baseline conditions for as many plant communities as possible and then to track change over time. This will allow SFAN to answer question 1 above. It is not the intention of this protocol to answer the other questions (2–5); however, we feel that the data gathered by this program will be useful, in part, to helping answer questions 2 and 3. Questions 4 and 5 would best be answered by use of a vegetation mapping approach. In addressing how to monitor for changes in structure and composition to selected vegetation types, we will focus on collecting the following attributes:

1. Structure

- Herbaceous plants: monitor cover by species.
- Woody plants: monitor density by species, including seedlings, saplings, and dead individuals; monitor cover of shrubs by species and the cover of tree species collectively.

2. Composition

- Species Richness: determine species richness at the 1 m² scale and at the scale of a North American Weed Management Association plot (168.3 m²).

Changes over time in the parameters listed above will be used to inform resource management. While a 20% change in these parameters has been used to validate the methodology (see [Chapter II](#)), no specified levels of change for any of the parameters measured in this protocol have been identified as thresholds or trigger points for management action. The reasons why trigger points have not been specified are numerous. Primarily, depending on the vegetation type, the type of change, the reason for that change, and other contextual matters, there are many trigger points that would need to be specified. In addition, the determination of threshold amounts would be entirely speculative since we know so little about resiliency, resistance, and other transition state properties regarding the plant communities being monitored. Based on these reasons, levels of change for the different parameters measured by this protocol will be reported to managers but the response to those changes will be the responsibility of the individual managers and will be determined on a case-by-case basis.

We will also collect data on other attributes that may help us understand why changes to structure or composition are taking place. Some of these will be collected each time a sampling plot is monitored while others will only need to be collected once, when the sampling plot is first visited. These attributes either relate to processes that shape plant communities or they relate to the environmental context that the targeted plant communities occur in. Thus, they will help address, in part, monitoring questions 2 and 3 above. While our monitoring objective is solely focused on tracking changes in structure and composition, measuring these extra parameters requires relatively little extra effort:

- Pathogens: record SOD and Pine Pitch Canker symptoms to understand influence of these pathogens on tree dynamics.
- Wildfire:
 - Fuels: record changes in density and size of coarse woody debris.
 - Disturbance recovery: intensify sampling frequency following fire to determine recovery rate or factors impeding recovery (e.g., invasive species).
 - Fire history: summarize historic fire disturbances when possible plus record future disturbances as they occur.
- Exotic Species Invasion: track change in native versus exotic plant abundance by species.
- Landscape position of sampled stand: collect physical location data including slope, aspect, and terrain.
- Soil Properties/Ground Cover: monitor percent cover of bryophytes/lichens, rock, litter, and bare ground.

Lastly, fulfilling objectives related to monitoring question 5 (tracking changes in spatial properties of plant communities) are beyond the scope of this protocol and methods are not outlined herein. However, baseline vegetation maps exist for this purpose in the form of both traditional ground-based (Schirokauer et al. 2003, Kittel et al. 2012) and remote-sensed approaches (Gong et al. 2005, Redmond et al. 2005a, 2005b, Yu et al. 2006). Following the methods utilized in the ground-based approaches would result in detailed community classifications and delineations at the same scale that parameters measured in the SFAN plant community monitoring protocol are meant to represent, and thus, would complement certain aspects of this protocol over remote-sensed based approaches.

However, technological advances in remote sensed image quality and processing could potentially achieve similar results in the future. Thus, we are not endorsing either approach for fulfilling monitoring question 5.

II. Sample Design

II.1. Rationale for Selecting the Sample Design

II.1.A. Plant Community Patterning

As mentioned previously, the patterning of plant communities in the SFAN parks strongly resembles a mosaic-complex (Mueller-Dombois and Ellenberg 1974), which can take the appearance of strikingly different plant communities intermixed in often small spatial areas (Wells 1962; Figure 4). In coastal California, the diversity of habitats that confronts ecologists in the field and the very real differences between these communities is reflected in vegetation research and management literature, which includes bodies of work specific to chaparral, coastal scrub, coast live oak woodland, coast redwood forests, and many other specific plant communities. This community-centric perspective is an obvious result of the environment, and, as Mueller-Dombois and Ellenberg (1974) point out, “a plant community is unimaginable without the space it occupies.” It is therefore not surprising that research and management units often correspond to discrete stands of a particular plant community. Furthermore, classification and mapping efforts in SFAN park units have made available the delineation of these stands.

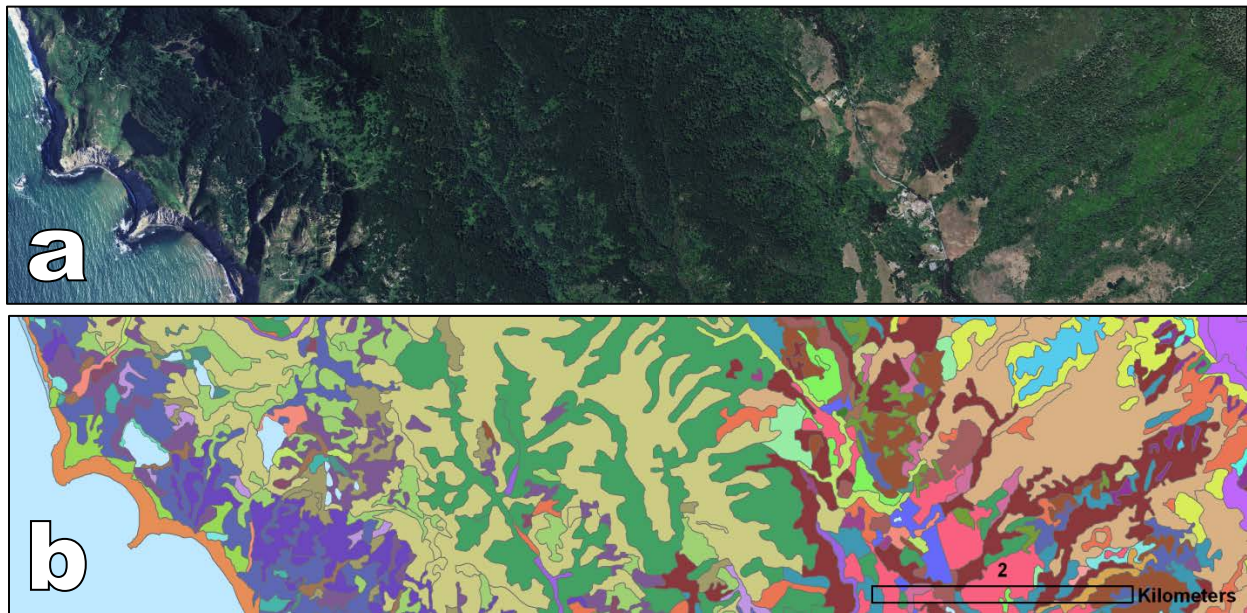


Figure 4. A vegetation cross section from Double Point (PORE) to the top of Bolinas Ridge (GOGA north district). Figure 4a is aerial imagery showing unmapped vegetation and figure 4b is the same geographic extent, but includes mapped vegetation, which portray the mosaic-complex patterning.

Contemporary views of the plant community are combinations of prior organismic (Clements 1916) and individualistic (Gleason 1926) concepts in addition to new knowledge of plant interactions, like facilitation and indirect interactions (Lortie et al. 2004). Holland and Keil (1995) define a plant community as, “an assemblage of plants that interact among themselves and with their environment within a space-time boundary.” Mueller-Dombois and Ellenberg (1974) define a plant community as, “a combination of plants that are dependent on their environment and influence one another and

modify their own environment.” The vegetation classification and mapping projects that have occurred in SFAN park units have utilized the NVC standards, which hierarchically categorize vegetation types much the same way as species are classified into kingdoms, divisions, *etc.* The finest classification level used by the NVC standard is the association, which is analogous to a species. Barbour et al. (1999) defines an association as, “a particular type of community that has been described sufficiently and repeatedly in several locations such that we can conclude that it has (a) a relatively consistent floristic composition, (b) a uniform physiognomy, and (c) a distribution that is characteristic of a particular habitat,” While some specialists may disregard the existence of plant communities, the majority of plant ecologists believe they are a construct that has utility in advancing science and managing landscapes (Lortie et al. 2004).

II.1.B. Diversity of Plant Communities

121 distinct vegetation types have been classified and mapped in all SFAN park units where monitoring is taking place (Schirokauer et al. 2003, URS 2009, Kittel et al. 2012). These mapped vegetation types form the initial “sampling universe” for this monitoring protocol. More vegetation types than these have been classified but not mapped due to their rarity or difficulty delineating them from other types based on aerial photographs (see Schirokauer et al. 2003 and Kittel et al. 2012). Due to monetary and logistical constraints, it is not possible to sample all of the multiple types of forests, shrublands, and grasslands that exist in the SFAN parks. It is also not realistic to think that these multiple types will respond in the same way to future environmental stressors or the lack thereof.

II.1.C. Abiotic Environmental Factors

While strong gradients in precipitation, temperature, and fog frequency exist across the whole Bay Area (Hsu et al. 2012), the SFAN park units are too small or are oriented in such a way that they lack any one over-riding gradient that could be utilized in the sample design (Figure 5). However, there are many smaller-scale gradients that influence the patterning of stands within parks. For example, moving from the coastal plain east to the top of Inverness Ridge on the Point Reyes peninsula, plant communities exhibit a combination of mosaic and vegetation belt patterning associated with the increase in orographic precipitation (Evens 2008). Also, one can find very different climatic conditions between north and south-facing slopes in any of the park units. Lastly, other environmental variables, like fog frequency, may create a gradient in a portion of a park but the influence of this factor is compounded by a number of other variables that vary throughout the terrain.

Further compounding the effect of any one topographically-mediated gradient is a spatially complex arrangement of soil types. Soil types have been mapped throughout the SFAN park units (NRCS 2011) but these maps are generally at too coarse of a scale for local resource management purposes. More recently, completed geologic maps appear to be relatively accurate (Niven et al. 2009), but are inclusive of too many vegetation types within each park unit. Furthermore, they are not available for all parks in SFAN.

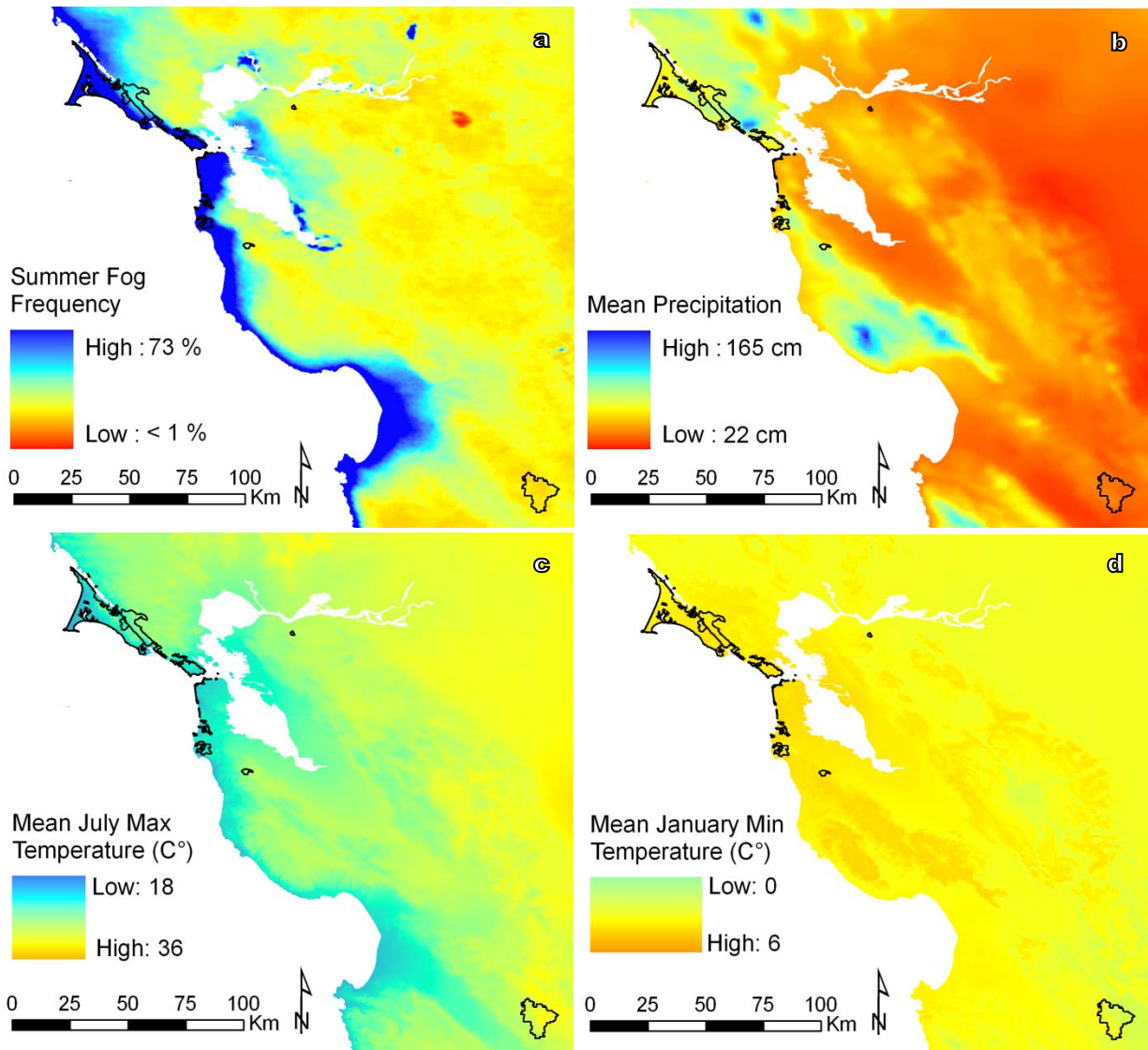


Figure 5. Climatic gradients in the San Francisco Bay Area *sensu* BAOSPC (2011).

II.1.D. Population Selection

Because the number of plant communities in our parks is very high, the number of sampling plots required to detect trends would far exceed what is possible given current funding. Since there is a lack of strong unidirectional environmental gradients and a lack of confidence in using existing substrate type maps for direct gradient analyses or stratification, there are no relatively static variables that can be used to minimize variability in the data.

Since land-managers in SFAN parks are interested in monitoring specific plant communities, we decided to use each park unit's vegetation map as a base layer for choosing the target populations to monitor. Based on the complexity in these park units, we believe that these mapped and classified vegetation types capture the suite of underlying environmental variables that govern species distributions better than anything else that is available. There are too many vegetation types that could be monitored; therefore, a priority list of the most important vegetation types to monitor was

created. Then, individual stands for each vegetation type to be monitored were randomly selected. Although vegetation types are a dynamic variable that may change over time, understanding how these targeted vegetation types change is our primary objective and we have decided to focus on those communities that are most abundant and are currently of the highest management importance ([Section II.2.A](#)).

Limitations on Sampling Design

Changes in Bay Area vegetation that occurred over the last 10,000 years (reviewed above) and projected changes in our future climate suggest that current SFAN vegetation types may have no future analogs. In other words, as plant species respond individually to changing conditions, future vegetation types will not resemble current ones. Another possible outcome includes little long-term changes to the composition or structure of communities, but spatial shifts in species occurrence (e.g., some species may shift from south-facing to north-facing slopes). Drawbacks of utilizing a sample design based on selected vegetation types include 1) the inability to make inferences about the other vegetation types not sampled and 2) potential confusion about whether to maintain the sampling effort once a selected vegetation type no longer exists where permanent plots are located.

Monitoring based on selection of stands within mapped vegetation types is predicated on a conceptual simplification of complex *plant communities* into discrete, classified *vegetation types*. This conceptual simplification is necessary in order to group similar plant communities together so that we can understand changes occurring within these assemblages. However, this simplification overlooks ecotonal variability in the margins between mapped vegetation types. Some of these margins are characterized by abrupt changes from one vegetation type to another; other margins are characterized by a gradual transition from one type to the next. With the high number of plant communities in the parks and their spatial integration with one another, the number of ecotone types is tremendous and ecotonal space has not been mapped as a distinct vegetation type within SFAN parks. The objectives of this protocol are to track changes within select plant communities represented as mapped vegetation types; capturing changes in ecotonal zones across park landscapes would not be feasible within the scope of this monitoring program.

The SFAN park managers acknowledge that this sample design, based on selected vegetation communities, will not track trends for unselected vegetation types. The SFAN park managers are interested in how the selected communities will change over time and what they will convert to. If a selected vegetation type ceases to exist or still exists but not in areas where current permanent sampling plots are located, they want to know exactly that. If managers wish to track changes in additional vegetation communities and have additional funding in the future, additional communities can be added using the framework described below, to identify sampling units using updated vegetation maps.

II.2. Sample Design Overview

This monitoring program will determine baseline structure and composition for multiple vegetation types found in the SFAN parks and then monitor changes over time. To accomplish this, we used vegetation classifications and maps of the existing park units, in addition to management priorities, to choose the specific vegetation types to be monitored. Once the different vegetation types were

chosen, we then used the vegetation maps as base layers to randomly select individual stands from each of the chosen vegetation types in a spatially balanced manner (the selection process is described in Appendix A). The stand is our sampling unit; so, for each vegetation type, n equals the number of stands sampled. Because type-conversion (*e.g.*, grassland to shrubland, shrubland to forest) is common and can occur in a relatively short timeframe, a sampling plot was designed for this monitoring program that can accurately capture structure and species composition for herbaceous-, shrub-, and tree-dominated communities. In other words, one plot design is being used for all vegetation types, regardless of physiognomy since physiognomy has the potential to change; switching sampling plot designs as vegetation converts introduces unwanted complexities in long-term data sets. Sampling plots are permanently placed within each stand.

Only vegetation mapped on NPS property using National Vegetation Classification (NVC) standards (or in very few cases retroactively cross-walked) was included. All of the included park units (GOGA, MUWO, PORE, and PINN) had vegetation mapped that was outside park boundaries; this was excluded from this monitoring design. For the coastal parks sampling frame, the largest and most complete vegetation mapping project was conducted by Schirokauer et al. (2003). After this vegetation mapping project was complete, GOGA acquired new lands in San Mateo County. These lands were mapped by May and Associates, Inc. and URS, Inc., using a classification system that May and Associates, Inc. created called the Vegetation Management Community classification system (Appendixes [D](#) and [E](#)). This system differs from the NVC in that it is based on classifying vegetation by treatment regimes for vegetation management purposes (URS 2009). It can only be cross-walked with NVC types mapped by Schirokauer et al. (2003) at a very coarse-scale. This newly mapped vegetation was excluded from the spatial statistics used to determine which vegetation types would be monitored. However, some stands of vegetation types in San Mateo County cross-walked from the May and Associates approach to NVC classification were incorporated into the sample design after field visits verified that they met the required criteria to match NVC types.

The number of stands sampled per vegetation type is based on the abundance of that vegetation type at the time the vegetation maps were created. Also, the frequency of sampling each vegetation type is a maximum return interval of every third year: this return interval is short enough to allow SFAN to detect changes in management-relevant timeframes and make needed adjustments to the program before long timeframes have elapsed, but long enough to allow for true community changes. Some vegetation communities will be monitored annually, at least initially, due to likely high variability between years. After an initial period of annual sampling, staff will evaluate the data to assess whether or not these communities can be monitored effectively on a three-year-return-interval.

In summary, since our resources limit the number of vegetation types that we can monitor, we sought a sample design that provides a framework for determining which vegetation types to monitor, a process to randomly select monitoring sites in a spatially balanced way, and a framework for adding monitoring efforts to new places or to new vegetation types if there is room to expand the program in the future.

II.2.A. Prioritization Process for Choosing Vegetation Types to Monitor

The vegetation in SFAN park units consists of many unique types with a complex spatial organization across the landscape. The prioritization process for choosing which vegetation types to monitor was a two-stage exercise that began with first selecting broadly classified vegetation types based on their abundance in the parks plus resource management priorities. Then, for each broadly classified vegetation type that was chosen, one more finely classified vegetation type (e.g., association or alliance) that was encompassed by the broadly classified type was selected for monitoring (e.g., redwood forests were chosen in stage 1 and the *Sequoia sempervirens* / *Pseudotsuga menziesii* / *Umbellularia californica* association was selected for monitoring in stage 2; Figure 6).

The fine-scale vegetation type with the greatest abundance was typically chosen for monitoring. If abundance did not differ greatly among suitable fine-scale vegetation types, their spatial spread was used as the next criteria for selection. Fine-scale vegetation types with greater spatial spread throughout each sampling frame (i.e., coastal and PINN sampling frames) were selected over types with low spatial spread.

Coarse-Scale Vegetation Types Selection Process

To prioritize which coarse-level vegetation types would be monitored, several metrics were utilized relating to the abundance and management concerns/questions for each vegetation type classified. Out of the 25 coarse-level vegetation types proposed for sampling in the SFAN parks, 21 were chosen.

The general criteria for prioritizing a community type for *inclusion* in this monitoring protocol during this stage included these factors:

Abundance and Distribution of the Community

- Near the edge of its range in SFAN parks
- Formerly more extensive in the Bay Area
- Rare elsewhere
- High spatial coverage in SFAN parks

Susceptibility of the Community to Degradation

- Climate change (including changes in temperature, rainfall, and fog regimes) predicted to cause change in structure and composition
- Susceptible to invasions of exotic species or a high proportion of exotic species of management concern (e.g., California annual grassland) or populations of invasive species may cause change in structure and composition
- Moderate amount of change in species structure and composition expected in a 10-20 year time frame or ability to collect baseline data for communities that may change quickly
- Susceptible to pathogens of concern.

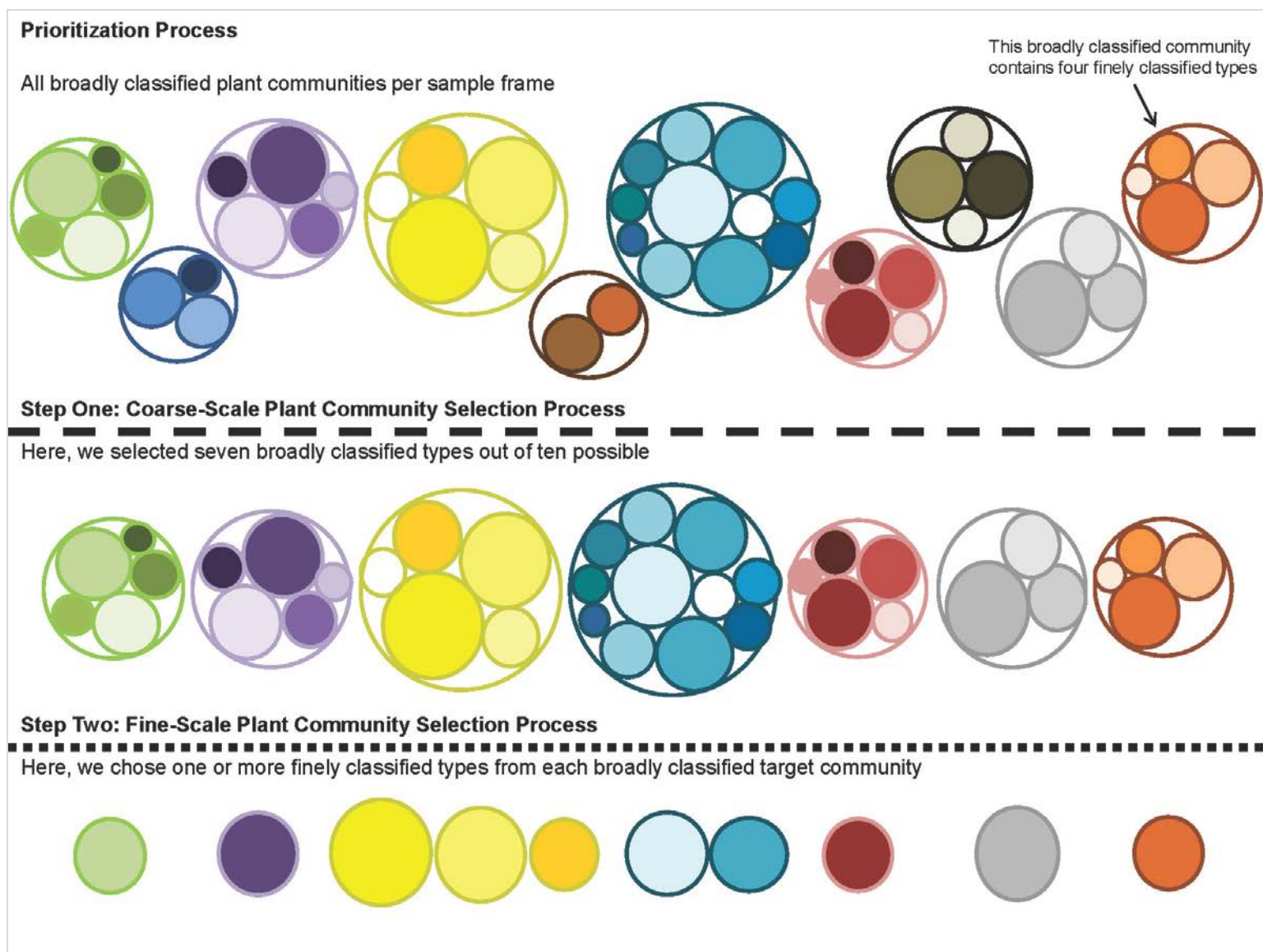


Figure 6. The prioritization process for choosing which vegetation types to monitor.

- Fire or fire-induced sediment loads may cause sudden change in structure and composition
- Susceptible to trampling
- Highly vulnerable to erosion or sea level rise

Ecology of the Community

- Includes many special-status species
- High species richness
- High proportion of native species
- Distinctive species composition in SFAN parks compared with this community elsewhere
- High habitat value for many species
- Dominant plants with special adaptations to dynamic fire regime
- Early colonizer of disturbed areas
- Relatively dynamic structure and composition
- Slow recruitment of species of interest

Transferability of Information Gathered to Other Agencies, Universities, NGOs, etc.

- Trend data would be of state-wide interest
- Compliments other SFAN monitoring protocols
- Specific monitoring question of concern that could be addressed by this protocol

Conversely, the authors of this protocol ranked some communities as lower priority for inclusion in this monitoring protocol due to factors including:

- Existing studies or other protocols already provide structure and composition data
- Remote sensing tools can better track questions of interest about the community
- Difficulty of obtaining highly reliable data with this protocol due to dense vegetation cover or steepness of slopes
- Extensive management of dominant vegetation in the community (e.g., non-native trees)
- Very stable community not likely to show signal of change in management-relevant timeframes

Communities were not included in the monitoring protocol if the monitoring plot design described here would not be suitable for tracking change over time in these communities (e.g., Bishop pine forest). Also, managers attempted to select a suite of communities to be monitored that includes a diversity of physiognomic types and balanced between the northern and southern network parks.

For herbaceous and shrub communities, a vegetation type was not excluded due to dominance of non-native species in the vegetation type (e.g., many grassland communities). A list of all coarse-level vegetation types, number of stands/polygons, justifications for inclusion, justifications for exclusion, and related management concerns/questions are included in Appendixes [B](#) and [C](#).

Fine-Scale Vegetation Type Selection Process

Most of coarse-scale vegetation types chosen for monitoring in SFAN park units contain multiple associations. Thus, on a floristic basis alone, each association contains variations that could affect trajectories and rate of change due to differences in species traits. For example, the dense coyote brush and related scrub mesocluster at PORE and GOGA, contains five superalliances, 10 alliances, and 15 associations (Keeler-Wolf et al. 2003). While *Baccharis pilularis* is either dominant or co-dominant in almost all of these associations, other co-dominant or associated species can differ greatly. For example, some associations are characterized by the prevalence of *Ceanothus thyrsiflorus*, an obligate seeding shrub while others are characterized by *Rhamnus californica*, an obligate sprouting shrub. Thus, response to fire or the long-term absence of fire will vary considerably between these two associations. If these differences are not accounted for, they could diminish the ability of the monitoring program to detect real trends. In another example, California Bay/Coast Live Oak Superalliance contains bay laurel dominated woodlands and oak-dominated woodlands. Because of SOD, oak-dominated communities would be expected to change much more rapidly and in different ways (see Brown and Allen-Diaz 2009). For each coarse-scale vegetation type, the most spatially abundant fine-scale vegetation type within that coarse-level was chosen as the vegetation type that would be monitored. Ideally, for every coarse-level type chosen, one association was selected for monitoring. However, not every coarse-level vegetation type selected included mapped stands at the association level, or if associations were mapped, the number of stands was inadequate or the only association mapped was not the best representation of the coarse-level type. Thus, for some coarse-level types selected, only alliances or mapping units could be chosen for monitoring.

Variability in vegetation monitoring data can be attributed to differences among sites, interannual variability, observers, or is unexplained (Deutschman *et al.* 2007). Minimizing variability among stands that represent a specific vegetation type was performed to the greatest extent possible to increase the usefulness of the monitoring effort and our confidence that measured changes were real. In other words, the goal of these steps was to reduce factors that could cause differences in the way vegetation types under the same classification would change with time. Due to the high number of vegetation types present in each park unit and a limited budget, these restrictions were necessary to acquire meaningful results. Details of the vegetation type selection process are included in [Appendix A](#).

The twenty-one vegetation types selected are:

Coastal Units (GOGA, MUWO, PORE)

Forests

- Redwood Forest
- Douglas-fir Forest
- Coast Live Oak Woodlands
- Bay Laurel Forest
- Red Alder Forest

- Arroyo Willow Forest

Shrub Dominated Communities

- Northern Coastal Scrub
- Coastal Dune Scrub

Herbaceous Dominated Communities

- California Annual Grassland
- Bald Hills Prairie
- Coastal Terrace Prairie
- Freshwater Wetlands

Salt Marsh Communities

- Coastal Salt Marsh

Pinnacles NP

Forests and Woodlands

- California Buckeye Woodlands
- Blue Oak Woodlands
- Juniper Woodlands

Shrublands

- Mixed Chaparral
- Chamisal or Dry Chaparral
- Southern Coastal Scrub

Herbaceous Dominated Communities

- California Annual Grassland
- Bushy Spikemoss Mats

II.3. Excluding Areas Unsuitable for Sampling

To limit risk to field personnel and reduce anthropogenic erosion, all potential sampling plots found on slopes $\geq 30^\circ$ were removed from consideration. This was done with a digital elevation model (DEM) using GIS. However, since the DEM is not 100% accurate, field crews are also required to reject sample sites if they measure slopes greater than 30° at plot center or if the entire site is surrounded by excessively steep slopes that pose a danger for site access. In addition, sites will be excluded if the area is found or suspected to be used for illegal marijuana cultivation (Steers et al. 2016, SOP 5) during plot establishment.

Since the park units in the coastal sampling frame have a high density of roads and trails, a road and trail buffer was not utilized to limit the sampling plot locations. While doing so could lessen potential influences from roads, trails, and other infrastructure, utilizing a buffer removed too great a proportion of the park. For example, at MUWO, a road and trail buffer 100 m or even 50 m would

leave an inadequate amount of vegetation left for sampling, so no buffer was used. However, this buffer was used for the PINN sampling frame due to its much lower road and trail density.

II.4. Stand Selection

For each of the two sampling frames (Coastal and PINN), the number of stands that would be sampled per vegetation type was determined based on the spatial extent of each vegetation type selected. Vegetation types that had a greater spatial extent were chosen to have a greater sampling effort or more stands sampled than less abundant types. Power analyses conducted on pilot data (section II.8 below) demonstrated that in order to detect a change of 20% with an alpha and beta of 0.05 and 0.2 respectively, 12 sampled stands per vegetation type would be adequate for most parameters (see Table 7). These analyses also suggest that for four parameters the design would not pick up such a small amount of change, and would only detect changes larger than 20% due to high between-plot variability of these parameters in the pilot data. Therefore, the protocol designers set the number of samples per vegetation type between 12 and 18 plots per type (see Table 5), proportional to the mapped areal extent of each vegetation type. The parameters requiring larger sample sizes than 12 to detect small changes are dead tree density, live and dead sapling density, and tree seedling density. These parameters often exhibit high variability between-plots and over time, and changes in these metrics are generally only ecologically significant when changes are large and sustained over time. Once the number of stands that were to be sampled for each vegetation type was determined, the actual stands that would be sampled was selected. For each vegetation type, this was accomplished by taking the total number of all eligible stands and dividing by the maximum number of stands that could be sampled for that type. This number was used to determine how many subsets of stands needed to be created. Stands were grouped together based on nearest neighbor analyses so that stands in closest proximity to one another would be in the same subset (Figure 7). For example, if the total number of eligible stands for vegetation type X was 36 and a maximum of nine stands could be sampled for vegetation type X, then 36 was divided by nine. In this calculation, the result is four, which represents the number of stands that had to be grouped together to make nine equal subsets. A nearest neighbor analysis was then used to create nine subsets of four stands each. Then, within each subset, the numbers one through four were assigned to each stand using a random number table and the stand given the number one was selected for long-term monitoring. If during field validation the chosen stand was determined to not be classified correctly or for any other reason was found unsuitable for sampling, then the next randomly chosen stand per group was selected and so on. Further details are available in Steers et al. 2016, SOP 5: Stand Selection, Plot Placement, and Sampling Frequency.

Although it is unlikely, future NPS managers and specialists may determine that it is necessary to add new plots to existing selected vegetation types, incorporate more vegetation types from the baseline vegetation maps (i.e., Schirokauer et al. 2003 for the coastal sampling frame and Kittel et al. 2012 for the PINN sampling frame), or initiate monitoring of novel vegetation types that have no present-day analog. A brief discussion of procedures for these actions is in Steers et al. 2016, SOP 5.

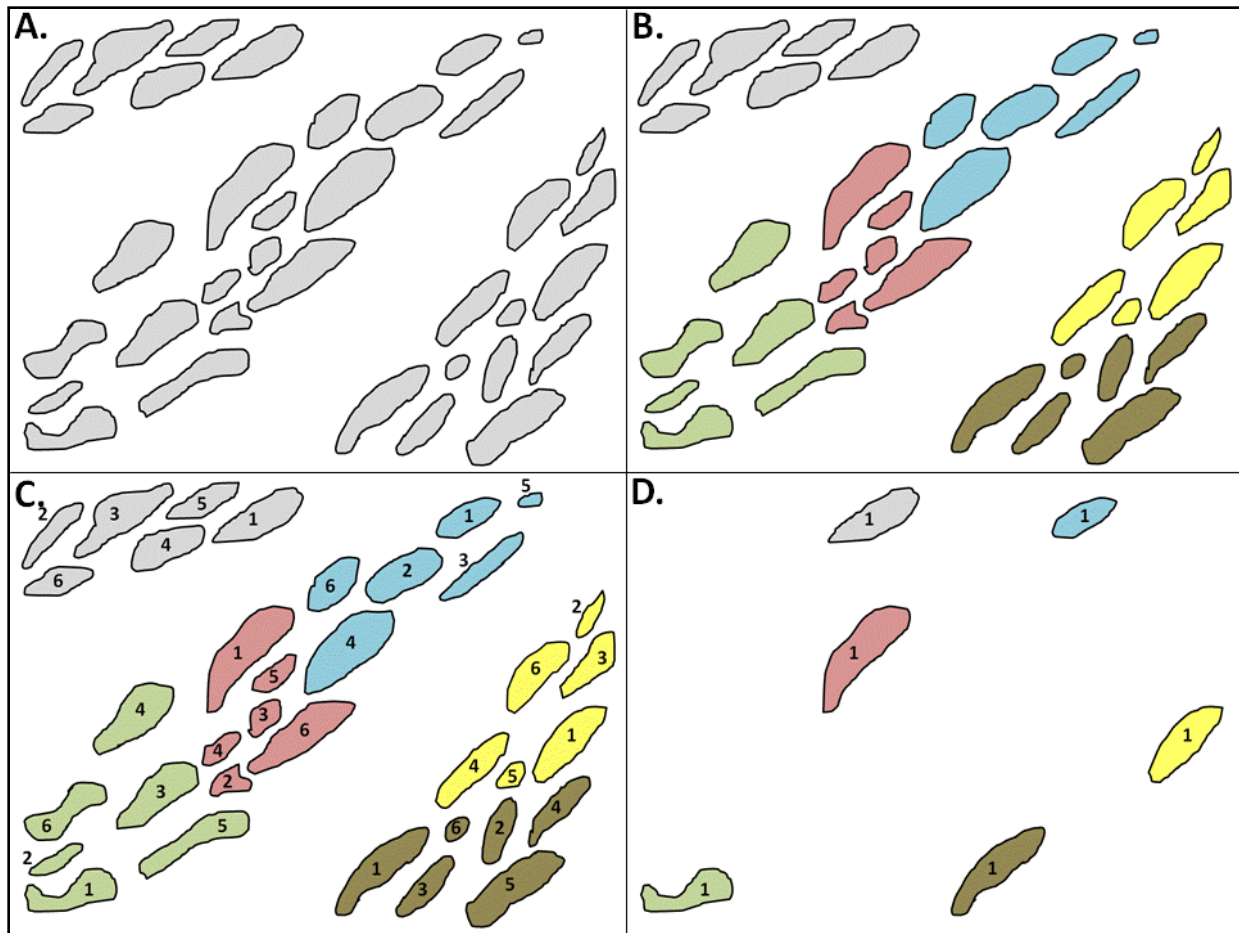


Figure 7. A hypothetical stand selection procedure where, starting with all 36 stands per one specific vegetation type (A), all stands are split into six groups based on nearest neighbor analyses (B), then each stand per group is assigned a number from one to six using a random number table (C), and finally, each stand assigned the number one in every group is chosen for long-term term monitoring (D). Upon field validation, if stand one is unsuitable, then stand number two from that subset will be sampled instead, and so on.

II.5. Vegetation Sampling

II.5.A. Sampling Plot Placement

One permanently-placed sampling plot is monitored for each selected polygon (Figure 8). The location of the plot within the stand is determined through selection of multiple random points within GIS that then undergo field visit verification for suitability. Ten candidate points are selected within a 20 m interior buffer of the polygon, to accommodate the 17.95 m radius of the circular sampling plot. On the first field visit, surveyors attempt to establish the plot at the first randomly identified coordinates. If that plot location must be rejected due to a pre-determined set of criteria (including excessive grade, plot would intersect with a trail, non-target vegetation patch, etc.), the surveyors locate the position of the second pair of randomly selected coordinates on the list and evaluate that point for suitability as they did with the first point. Surveyors repeat this process until a suitable point is identified. It is not expected that more than three randomly selected points will need to be

evaluated before establishing a plot. Further details are available in Steers et al. 2016, SOP 5: Stand Selection, Plot Placement, and Sampling Frequency.



Figure 8. The full extent of a stand selected for sampling is outlined in white. An example sample plot is outlined in black, showing the 7.32 m and 17.95 m radius circular subplots.

II.6. Sampling Frequency and Timing

II.6.A. General Sampling Schedule

Due to logistic constraints we will be utilizing a serial alternating (also known as rotating panel) sampling schedule to maximize status and trend (Deutschman et al. 2007). All stands from each vegetation type will be sampled on a no-greater-than three year return interval (Table 5). To facilitate scheduling, SFAN vegetation managers divided the twenty-one selected plant communities into four priority groups based on the original criteria for including communities in the monitoring protocol (criteria described in [Section II.2.A](#)). That is, the better each community met the original selection criteria, the higher priority it would have among the selected community types. These priority groups were used to create a 12-year sampling schedule: monitoring of higher priority community types begins earlier in the schedule. In addition, if the SFAN I&M program is unable in any one year to sample all the communities scheduled for the year for any reason, the lower-priority communities will not be monitored that year.

Table 5. Sampling schedule of vegetation types. Numbers in cells represent the number of plots to be sampled in each vegetation type per year. Parentheses surround numbers for lowest priority groups. Green text represents highest priority communities, orange text represents moderate priority, gray text represents lower priority, and black text (without corresponding color in the numbered cell) represents lowest priority. A * symbol represents possible monitoring during that year, based on analysis of previous monitoring years' data, and numbers in parentheses represent monitoring plots to be sampled if grassland monitoring plots can be read on a three year rather than annual basis (see Section II.6.A text).

Park and Vegetation Type	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12
GOGA, MUWO, and PORE												
Coastal Terrace Prairie	14	14	14	14	*	*	14	*	*	14	*	*
Bald Hills Prairie	12	12	12	*	*	12	*	*	12	*	*	12
Northern Coastal Scrub	18			18			18			18		
Coast Live Oak Woodlands			18			18			18			
Coastal Salt Marsh	12			12			12			12		
Redwood Forest	18			18			18			18		
Coastal Dune Scrub			12			12			12			12
Bay Laurel Forest						15			15			15
Douglas-fir Forest						15			15			15
Freshwater Wetlands							12			12		
Red Alder Forest							(12)			(12)		
Arroyo Willow Forest							(12)			(12)		
California Annual Grassland								(12)			(12)	
PINN												
California Annual Grassland		15	15	15	15	*	*	15	*	*	15	*
Blue Oak Woodlands		15			15			15			15	
Southern Coastal Scrub		12			12			12			12	

Table 5 (continued). Sampling schedule of vegetation types. Numbers in cells represent the number of plots to be sampled in each vegetation type per year. Parentheses surround numbers for lowest priority groups. Green text represents highest priority communities, orange text represents moderate priority, gray text represents lower priority, and black text (without corresponding color in the numbered cell) represents lowest priority. A * symbol represents possible monitoring during that year, based on analysis of previous monitoring years' data, and numbers in parentheses represent monitoring plots to be sampled if grassland monitoring plots can be read on a three year rather than annual basis (see Section II.6.A text).

Park and Vegetation Type	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12
PINN (continued)												
Chamisal or Dry Chaparral		12			12			12			12	
California Buckeye Woodlands					12			12			12	
Mixed Chaparral					12			12			12	
<i>Bushy spikemoss mats</i>					(12)			(12)			(12)	
<i>Juniper Woodlands</i>					(12)			(12)			(12)	
Stands per Year (excluding lowest priority communities)	74	80	71	77	78	72	74	78	72	74	78	54

For vegetation types with relatively high interannual variability and faster anticipated rates of change (i.e., grasslands), the panel design calls for annual sampling, at least initially. After an initial more-frequent sampling regime, SFAN staff will evaluate monitoring data to determine if a three-year return interval could be used to detect change or if annual variability is so high for the program's monitoring questions that more frequent monitoring is required (indicated with * in the schedule to represent the uncertainty of needing to sample those community types every year). If monitoring questions can be addressed with less frequent monitoring, the program will initiate monitoring of the lowest-priority communities in lieu of annual grassland monitoring. For vegetation types with lower interannual variability and expected rates of change (e.g., shrublands, forests) the panel calls for longer breaks between resampling events.

The proposed sampling schedule calls for 54 to 80 stands sampled per year in the first 12 years of implementation. The number of stands sampled per year is dependent on vegetation type. With a two-person crew, it is expected that approximately 5-6 stands per pay period could be sampled, which means that this amount of sampling can be realistically achieved.

In the event that future funding does not accommodate the proposed schedule, future vegetation managers of SFAN parks may consider reprioritizing vegetation types and either a) excluding some lower-priority vegetation types, and/or b) reducing the frequency of return sampling for some or all types. This decision making process will be guided by the amount of change seen in vegetation types to-date (e.g., vegetation types exhibiting slow rates of change may be sampled less frequently or be excluded from sampling if low priority). Dropping individual parameters from the sampling design will not achieve appreciable time savings, as much of the staff time commitment is in traveling to and between sites. In the event that the program is discontinued entirely, the data obtained and summarized through the program should nevertheless provide excellent baseline information regarding select vegetation types for future managers

II.6.B. Exceptions to the General Sampling Schedule

Natural and anthropogenic disturbances to vegetation can have profound impacts. Of high importance to land managers, disturbances can be associated with increased invasive species abundance (Hobbs and Huenneke 1992, Theoharides and Dukes 2007) and even type-conversion (Stylinski and Allen 1999, Talluto and Suding 2008). In some SFAN park units, historic human disturbances impacted park resources through logging, brush clearing for grazing (including chaining), and other activities. Some of the vegetation types being monitored in this protocol are still recovering from historic anthropogenic disturbances. If future disturbances to sample sites occur, especially natural disturbances like fire, this monitoring program will adjust the observation schedule to better understand recovery rates and to assess if interventions are required to assist in recovery. When a disturbance occurs at a study site, an assessment by I&M staff in consultation with park managers, and in light of available resources, should be performed to determine if supplemental monitoring should be conducted to understand recovery rates and post-disturbance vegetation dynamics. The recommended sampling schedule for post-disturbance situations is to sample annually for the first three years, then once at three years post-disturbance, then every additional three years afterwards up to 20 years post-disturbance.

II.6.C. Timing of Sampling

In coastal SFAN park units, the time of year when it is easiest to observe the maximum number of species per vegetation type may vary considerably between vegetation types. Furthermore, interannual variation in precipitation, temperature, and other climatic factors can cause interannual variation in the timing of phenological stages, especially for annual plants (Heady 1958). For some vegetation types, “peak flowering” may occur during the same time of the field season. And while observing plants in flower can be important for species identification, crews should also observe plots during the same phenological stage each sampling event, as the protocol depends on cover data, which is highly sensitive to seasonal timing for some species. In some years when precipitation is low or warmer temperatures have sped phenological stages, field crews may experience a “crunch-time” where many vegetation types are peaking at or near the same time. Field crews must exercise efficiency so that sampling can be accomplished during each community’s flowering and leaf-out period. Fortunately, not all of the vegetation types in the coastal parks unit typically experience phenological patterns in sync. The following monthly schedule (Table 6) prioritizes sampling times for the multiple vegetation types needed to be monitored.

Table 6. Timing of sampling by community type. Shaded bars represent the range of peak flowering and leaf-out for each community.

Mar	Apr	May	Jun	Jul	Aug
GOGA, MUWU, and PORE					
Bald Hills Prairie					
California Annual Grasslands					
	Northern Coastal Scrub				
	Coastal Dune Scrub				
		Coastal Terrace Prairie			
		Coast Live Oak Woodland			
		Bay Laurel Forest			
			Redwood Forest		
			Douglas-fir Forest		
			Red Alder Forest		
			Arroyo Willow Forest		
			Freshwater Wetlands		
				Coastal Salt Marsh	

Table 6 (continued). Timing of sampling by community type. Shaded bars represent the range of peak flowering and leaf-out for each community.

Mar	Apr	May	Jun	Jul	Aug
PINN					
Bushy Spikemoss Mats					
California Annual Grassland					
Blue Oak Woodland					
Southern Coastal Scrub					
	Chamisal or Dry Chaparral				
	Mixed Chaparral				
	California Buckeye Woodland				
	California Juniper Woodlands				

At PINN all of the vegetation types that will be surveyed are upland communities that contain a substantial proportion of native and exotic annual forbs, many of which are difficult to detect once senesced. Therefore, vegetation surveying should be done from mid-March through mid-June regardless of vegetation type. Further information on the timing of sampling is provided in Steers et al. 2016, SOP 5.

II.7. Location of Sampling Plots

The location of sampling plots has not been finalized since field verification of stands selected for monitoring is incomplete as of this time. No park contains vegetation map accuracy of 100% and since fine-scale vegetation types are being sampled it is of the highest importance to verify that mapped stands chosen for monitoring are accurately classified. Once the location of sampling plots has been finalized, instructions on the most efficient and safest way to access these sites will be added as a set of Sampling Plot Locator SOPs.

II.8. Detectable Level of Change

For the vegetation structure and composition parameters measured by this protocol, power analyses were conducted to assess the required number of sampling plots needed to detect a 20% change between sampling events based on varying levels of alpha (α) and beta (β) (see Steers et al. 2016, SOP 15 for details on the power analyses and vegetation types utilized). Alpha is the probability of rejecting the null hypothesis (e.g., no change) even though it is true, or wrongly concluding a change occurred when it really did not. Beta is the probability of accepting the null hypothesis even though it is false, or wrongly concluding no change occurred when it actually did. The acceptable level of α and β that were used to detect 20% changes in vegetation parameters under this protocol were 0.05 and 0.20, respectively; although varying levels of α and β are shown in Table 7 to demonstrate how variations in error probabilities can influence the required number of sampling plots.

Table 7. The required number of stands that must be sampled in order to detect a 20% change in a vegetation parameter given varying levels of alpha (α) and beta (β). These power analyses were based on untransformed data using a two-tailed, paired t-tests (NPS unpublished data).

Vegetation Type and Parameter	α 0.05	β 0.05	α 0.05	β 0.1	α 0.05	β 0.2	α 0.1	β 0.1	α 0.1	β 0.2	α 0.2	β 0.2
Grassland												
Species Richness												
All Species												
NAWMA plot (168 m ²)	6		5		5		4		3		2	
Quadrat (1 m ²)	6		5		5		4		3		2	
Native Species												
NAWMA plot (168 m ²)	10		9		7		7		5		3	
Quadrat (1 m ²)	11		9		7		7		5		3	
Exotic Species												
NAWMA plot (168 m ²)	6		5		4		4		3		2	
Quadrat (1 m ²)	11		9		7		7		5		3	
Cover (per quadrat)												
All Herbaceous Plants	6		5		4		4		3		2	
Native Herbaceous Plants	19		15		12		12		9		5	
Exotic Herbaceous Plants	9		8		6		6		5		3	
Shrubland												
Cover (per point line intercept)												
Shrubs	4		4		3		3		3		2	
Live Shrubs	4		4		3		3		3		2	
Dead Shrubs	12		10		8		7		6		4	
Forest												
Cover (per 1,012 m ² FIA plot)												
Trees	2		2		2		2		2		2	
Diameter at Breast Height (DBH) per FIA plot												
Large Trees (≥ 20 cm DBH)	6		5		5		4		3		2	
Small Trees (< 20 cm DBH)	12		10		8		7		6		4	
Density												
Live Trees (1012 m ²)	13		11		8		8		6		4	
Dead Trees (1012 m ²)	170		135		98		103		71		45	
Live Saplings (168 m ²)	44		36		26		27		19		12	
Dead Saplings (168 m ²)	37		29		22		22		16		10	
Tree seedlings (9 m ²)	173		137		99		105		73		46	

A 20% change in a parameter was used for these power analyses based on subjective reasons. First, a 20% change in one of the parameters is not so large that it would never take place. Second, this level of change is not too small that it would lack practical significance. It is clear that major disturbances, like wildfires, alter the majority of plant biomass and change vegetation parameters greatly. However, more subtle changes need to be detected by this protocol. On the central coast of California, physiognomic shifts in vegetation types over 25-year periods have been recorded (Hsu *et al.* 2012). We are not sure what the minimum time-scale for type conversion is; however, the ability to detect 20% changes every three years over a 25-year period would allow us to detect successional shifts before type-conversion takes places and in time for management actions to alter successional trajectories, if necessary. And, this level of detection is not so small that it forces an unachievable number of sampling plots to be utilized for each of the diverse vegetation types of interest.

These power analyses are based on pilot data collected from one type of grassland, shrubland, and forest using the methodologies described in this version of the protocol. Not every parameter listed in Table 7 was analyzed using data from each of the three vegetation types sampled. For example, the power analyses that assessed change in live tree density did not utilize the tree data collected from the shrubland or the grassland data sets since trees were extremely uncommon in these later types. Likewise, herbaceous plant parameters were not assessed using the shrubland or forest vegetation data because herbaceous species were less abundant and more infrequent in these types. Analyzing power in this way matched each vegetation type with its respective distinguishing parameters, which is reflected in the organization of Table 7. While land managers are still interested in tree density increases in grasslands, and herbaceous cover increases or decreases in the understory of forests, for example, no sample design that uses one sampling plot to measure multiple physiognomies is capable of performing excellently in every scenario. However, we accept this limitation given that our sampling plot performs well overall, is utilized by a number of other agencies and entities, and will be able to track physiognomic type-conversion without the need to utilize multiple types of sampling plots and reparameterize among them as communities convert.

Power analyses revealed that the sampling design can detect desired levels of changes at acceptable error probabilities for structure and species composition parameters. For example, many key parameters, such as native and exotic species richness; live cover of herbaceous, shrub, and tree species; density of live shrubs and trees; and diameter at breast height of live trees, all required a sample size of 12 or less to detect a 20% change using an α and β of 0.05. However, there were also parameters that did not perform well; mainly those that captured dead woody components of the vegetation and density of seedlings, which all had low abundances plus high variability and infrequency (data not shown). Overall, the structural and composition parameters assessed in the power analyses revealed that a minimum of 12 sampling plots were required per vegetation type to detect 20% changes based on an α and β of 0.05 and 0.20, respectively. The vegetation type being monitored and the number of sampling plots utilized per community are shown in Table 5.

III. Field Methods

III.1. Plot Design

Because this is a long-term study, we want to utilize a plot design that minimizes observer bias. We also desire a permanent plot design that can be easily found and reconstructed accurately over many site visits. Since we are interested in species richness, we want a plot design that can record richness at different spatial scales since this parameter is scale-dependent. Lastly, because vegetation plots can type-convert, we only want to utilize one plot design that can accurately capture vegetation parameters regardless of the physiognomy.

For constructing plot designs, there are many options available and many studies that compare multiple methods (reviewed in Mueller-Dombois and Ellenberg 1974, Elzinga et al. 1998, Barbour et al. 1999). The plot design chosen for this protocol is based on the USDA Forest Service (USFS) Forest Inventory and Analysis (FIA) program. However, instead of utilizing the entire FIA macroplot that contains four 17.95 m radius plots, we are only utilizing one 17.95 m radius plot as our sampling plot (Figure 9). Inside the sampling plot is a 7.32 m subplot that is identical to the North American Weed Management Association (NAWMA) standards sampling plot (Stohlgren et al. 2003). Thus our plot design will be comparable, in part, to at least two national standards that are implemented in a variety of vegetation types.

The plot design incorporates three main components that each focus on accurately capturing either herbaceous, shrub, or tree parameters. Detailed instructions on data collection in each component of the sampling plot, including survey forms, are provided in Steers et al. 2016, SOPs 6 through 12. Measured parameters and data collection are also briefly discussed in the following sections of this chapter. Other aspects of this protocol relating to field methods are not included in this narrative but are fully explained in separate appendixes or SOPs. These include: 1) setting up the electronic field equipment is described in Steers et al. 2016, SOP 4; 2) plot-setup, monumentation, and description are described in SOP 6; 3) photographing plots is described in Steers et al. 2016, SOP 7; and 4) creation of sample vouchers is described in Steers et al. 2016, SOP 17. Details regarding field work preparation, observer training, and procedures to be followed at the end of the field season are included in Chapter IV and Steers et al. 2016, SOPs 2, 3, and 18, respectively.

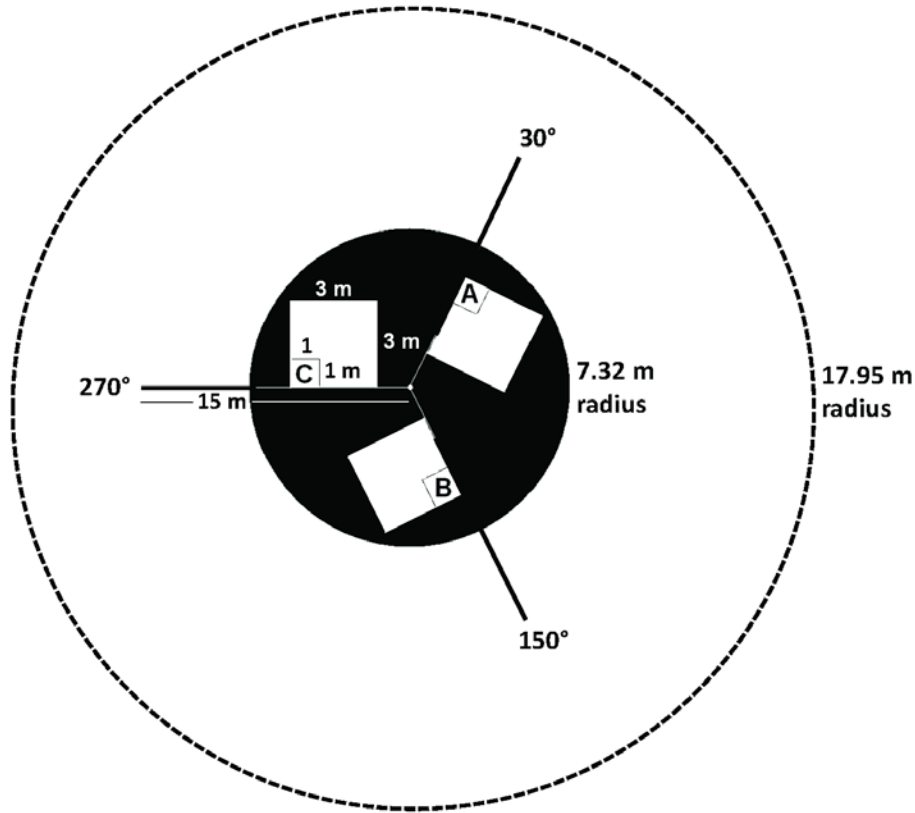


Figure 9. Sampling plot overview showing major components used for sampling vegetation.

III.1.A. Measured Parameters

The vegetation parameters associated with this program’s primary monitoring objective ([Section I.8.B](#); i.e., to document changes in species composition and structure over time within selected vegetation types) are the focus of the structural and species composition sampling methodology described below. However, other parameters associated with secondary monitoring objectives will also be sampled per plot. Regarding objectives related to processes, all tree species encountered that are known hosts of SOD or pine pitch canker, will be examined for signs of the pathogens. In addition, snags and coarse debris will be measured to aid the network fire ecology program and wildlife will be recorded when encountered as well as wildlife use of cavities and the presence of granary trees or snags. Regarding objectives related to the environment, we will measure aspect, slope, litter depth, and the cover of bare ground, rock, litter, bryophytes, and lichens. Methodologies for sampling all parameters measured per plot, in addition to example survey forms, are presented in Steers et al. 2016, SOPs 6 through 12 but are also outlined in Table 8 and the text that follows.

Table 8. Abiotic and biotic parameters measured per sampling plot.

Measured Parameter	How the Parameter Is Sampled per Sampling Plot	Steers et al. 2016 reference SOP
Environmental Variables		
Slope and Aspect	Slope is calculated twice with a clinometers: facing down- and up- slope; aspect taken at plot center	SOP 6
Disturbance	Descriptive notes on observations of disturbance	SOP 6
Cover of rock, bare ground, litter, lichen, moss, feces	Taken in three 1 m ² point quadrats using a point quadrat technique	SOP 8
Litter depth	Taken in five equidistant locations in all three 1 m ² quadrats	SOP 8
Disease	Signs of SOD or pine pitch canker on susceptible species will be recorded. Decay class and cause of death for snags will also be determined from a checklist	SOP 11
Forest Fuels (down and dead, litter plus duff height)	Recorded along three 12.5 m long line transects. Data utilized by the network fire program in fuels models for forested vegetation types	SOP 13
Vegetation Structure (Live and Dead)		
Cover of herbaceous plants by species	Taken in three 1 m ² quadrats using a point quadrat method	SOP 8
Cover of woody plants (shrubs and small trees) by species	Taken along three 12 m long point transects using a point line intercept method	SOP 10
Cover of large trees	Taken along three 12 m long point transects using a densitometer	SOP 12
Density of woody plants by species and life stage	Taken in three 3 m ² quadrats for seedlings, sprouts, saplings, and adults (SOP 9). Then, for only saplings and trees in the 7.32 m radius subplot, and lastly, only for trees ≥20-cm DBH in the 17.95-m circular plots	SOP 11
DBH of trees species	Recorded for all trees with a DBH ≥ 5 cm in the 7.32 m radius subplot, and then, only for trees ≥20-cm DBH in the 17.95-m circular plot	SOP 11
Vegetation Composition		
Total species richness	Taken in three 1 m ² quadrats plus within one 7.32 m radius circular plot	SOP 8
Woody plant richness	Taken in three 1 m ² point quadrats, in three 9 m ² quadrats, and in one 7.32 m radius circular plot	SOP 8, SOP 9, SOP 11

III.2. Taking Measurements

III.2.A. Use of 1 m² Quadrats to Measure Herbaceous Vegetation and Other Parameters

By use of the point quadrat method (Goodall 1952), 1 m² quadrats will capture herbaceous cover by species (Figure 10). Based on a pilot study where point quadrat methods with varying densities of points were compared with visual estimates of cover, a 50 point per quadrat method was found to be superior based on speed plus accuracy, over a 30 and a 100 point per quadrat method, and over a visual estimation method (data not shown). To this end, three 1 m² point quadrats will be placed 4.57 m from plot center along the following compass bearings, 30, 150, and 270 degrees (Figure 10). The FIA and NAWMA standards use visual estimates of cover in these quadrats; however, we determined that point quadrat was better suited to the long-term nature of this program since multiple observers would be involved in data collection over a long period of time, and observer bias can be a drawback of visual estimations (Kennedy and Addison 1987). Also, point quadrats have been very successful in accurately portraying diverse herbaceous vegetation assemblages (Stampfli 1991). While other life forms (e.g., shrubs, trees) will also be detected with the point quadrat technique, different sampling procedures described below address methods that are better suited to capture shrub and tree structural features of the vegetation.

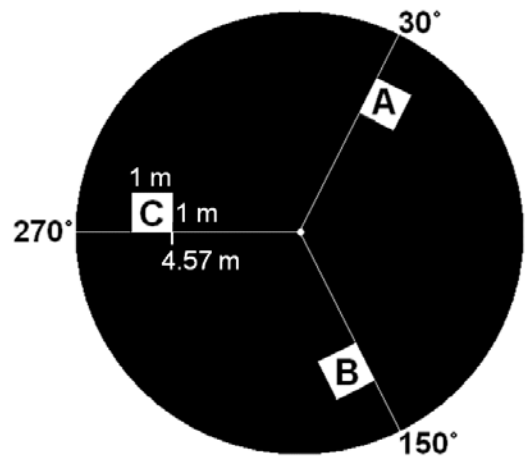


Figure 10. Graphical representation of the subplot, which is identical in dimension to the USFS FIA subplot and the modified-NAWMA sampling plot. The three 1 m² plot frames, A, B, and C, start 4.57 m from plot center along the indicated compass headings.

In addition to capturing herbaceous vegetation data, the cover of other parameters such as bare ground, rock, litter, lichen, and bryophyte will be recorded in the point quadrats. Lastly, within each quadrat, litter depth will also be recorded to aid in our understanding of herbaceous plant dynamics. Litter can be negatively correlated with native herbaceous species abundance and richness in California grasslands (Hayes and Holl 2003). Full details of the field methods are provided in Steers et al. 2016, SOP 8.

III.2.B. Use of 9 m² Quadrats to Measure Woody Plant Density

Woody plant density is measured in three 9 m² quadrats (3 m by 3 m) overlaid on the 1 m² quadrats, starting 2.57 m from plot center (Figure 11). These quadrats accurately capture woody plant density. Full details of the field methods are provided in Steers et al. 2016, SOP 9. Observers will use the list in Steers et al. 2016, SOP 21: Life Form Master List to determine whether a plant encountered should be considered a tree or a shrub. If an encountered plant does not occur on the list, observers will classify the species as either a tree or a shrub for the purpose of this monitoring program using field references.

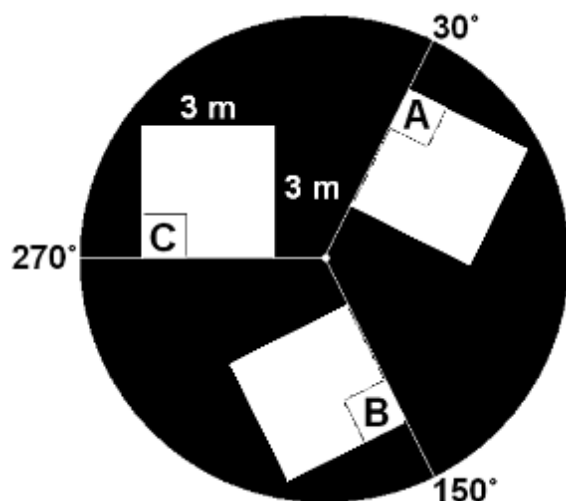


Figure 11. Three 9 m² quadrats placed along the three primary transects per subplot are used to measure woody plant density of shrubs and seedlings.

III.2.C. Use of 15 m Lines to Measure Woody Plant Cover and Other Parameters

Shrub and tree cover will not be accurately represented by the three 1 m² point quadrats per plot. Therefore, three 12 m point line intercept transects (Heady et al. 1959) per plot will be used to measure woody plant cover by species (Figure 12). The three transects will originate from the middle of the plot and extend in the same three compass headings used for the point quadrats. Measurements will start 3 m away from plot center and end 15 m away. The point line intercept transects will accurately measure shrub and sub-shrub cover. Pilot data that compared this point line intercept technique with 100 m long point line intercepts in patchy, coastal dune scrub vegetation revealed that the three point line intercepts per plot produced the same estimates of cover for

individual shrub species and for total shrub cover as an equal number of separate 100 m transects (Steers et al. 2011). Portions of trees that are 3 m or less in height will also be recorded by use of the point line intercept when encountered (see Steers et al. 2016, SOP 10 for full details of the field methods). However, canopy cover (closure) associated with overstory trees will primarily be measured with a densitometer along the 12 m transects (Figure 12). Lastly, fuels will also be recorded along the 15 m line transects (NPS 2003). Fuels less than 7.6 cm diameter will be recorded from short segments along one of the 15 m lines per plot. Fuels or down wood greater than 7.6 cm will be recorded when encountered from 2.5 m to 15 m along all three lines per plot (Figure 12). See SOP Steers et al. 2016, SOP 12 for full details of the fuel field methods.

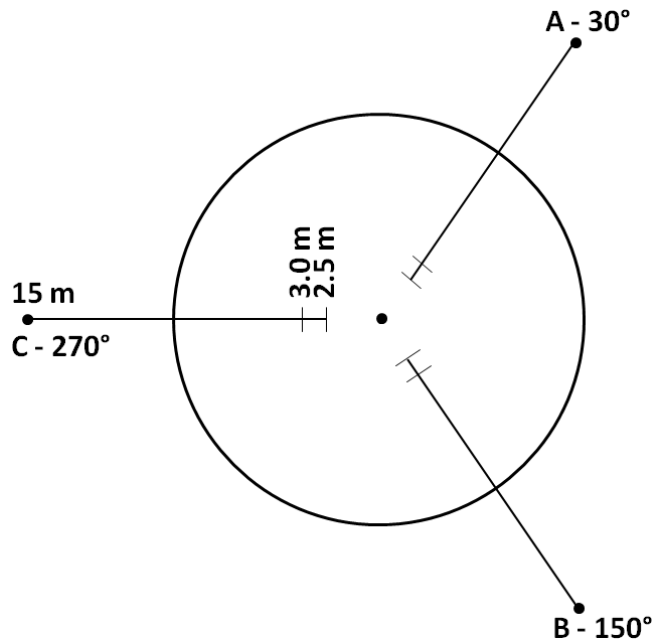


Figure 12. Graphical representation of the three 15 m lines used for measuring woody plant cover, canopy closure, and fuels. The orientation of the three lines follows the same compass bearings as shown in Figure 9. On each line, fuels are measured from the 2.5 to 15 m mark, vegetation and canopy cover are sampled following the point-line intercept method from the 3 m to 15 m mark.

III.2.D. Use of the Mod-NAWMA and FIA Plots to Measure Tree Density and Diameter at Breast Height

To adequately capture the density and diameter at breast height of trees, all saplings and trees were recorded by species within the entire mod-NAWMA subplot (7.32 m radius circle). Then, only trees ≥ 20 cm DBH were recorded in the rest of the FIA plot, out to a 17.95 m radius (Figure 13). Pilot vegetation sampling in bay laurel woodland in GOGA and old-growth redwood forest at MUWO revealed that trees smaller than a 20 cm DBH could be accurately scaled up from the mod-NAWMA plot to the FIA plot scale (data not shown). Therefore, saplings and trees less than 20 cm diameter were not measured throughout the entire 17.95 m radius FIA plot to improve time efficiency. Snags are also recorded similarly as live trees in terms to the size cut-offs. For snags encountered, cause of death and decay stage are recorded. For trees that are susceptible to SOD or pine pitch canker, symptoms are searched for and recorded. Full details of the field methods are provided in Steers et al. 2016, SOP 11.

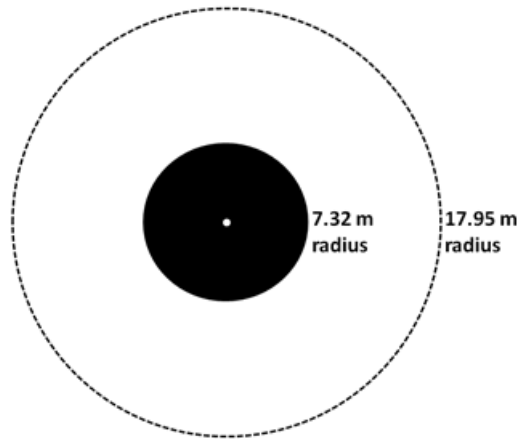


Figure 13. Saplings and tree DBH (taken at 1.37 m height) will be measured for all species within the 7.32 m radius subplot (black circle). Beyond the subplot and out to the 17.95 m radius plot edge (circle demarcated by dashed line), only tree species with a DBH at least 20 cm will be recorded.

III.2.E. Species Richness

Species richness will be captured at multiple spatial scales, allowing for examination of species-area relationships (Lomolino 2000) and for determining if richness responds differently to vegetation change at different scales. All plant species encountered will be recorded in the three 1 m² quadrats per subplot (Steers et al. 2016, SOP 8). At the next largest spatial scale, only woody plant species richness will be recorded in the 9 m² quadrats that enclose the smaller quadrats (Steers et al. 2016, SOP 9). Then within the entire subplot, every vascular plant species will be recorded (Steers et al. 2016, SOP 8). Overall, total and herbaceous species richness will be comparable at two spatial scales (1 m², and 168.3 m²); shrub species richness will be comparable at three spatial scales (1 m², 9 m², 168.3 m²); and tree species richness will be comparable at three to four spatial scales (1 m², 9 m², 168.3 m², and 1,012.2 m²), depending on tree size. It should be noted though, that a 1 m² area and maybe even a 9 m² area are not suitable in themselves for accurately reflecting tree species richness.

IV. Data Handling, Analysis, and Reporting

IV.1. Metadata Procedures

Metadata must be generated for all SFAN datasets, including geospatial data. For geospatial metadata, every federal agency is mandated to follow the Federal Geographic Data Committee (FGDC) standards (<http://www.fgdc.gov/metadata/>) by Executive Order 12906. In addition to spatial information, metadata include information about data format, collection and analysis methods, time of collection, originator, access/use constraints, and distribution. Metadata provide the means to catalog products, within Intranet and Internet systems, making them available to a broad range of potential users. See Steers et al. 2016, SOP 16 for further details.

IV.2. Data Life Cycle

Data take on different forms during various phases of a project, and are maintained in different places as they are acquired, processed, documented, analyzed, reported, and distributed. What is referred to as the data life cycle is characterized by a series of events as follows (Cook and Lineback 2008):

Event 1. *Acquire data* – Data are acquired in digital or analog form. Digital data can be recorded on handheld computers and PDAs, tablets, or laptop computers. Analog data are entered on field data sheets.

Event 2. *Archive raw data* – Copies of all raw data files are archived intact. Digital files are copied to the digital library (the set of LAN folders created for the project); hard copy forms are either scanned and placed in the digital library or are copied and placed in the archives. Archiving or scanning of hard copy data forms may occur at the end of a season as a means of retaining all marks and edits made during the verification and validation steps.

Event 3. *Enter/import data* – Analog data are entered manually and digital data files are uploaded to the working database.

Event 4. *Verify, process, and validate* – Accurate transcription of the raw data is verified; data are processed to remove missing values and other flaws; and data are validated through visual inspection and queries to capture missing data, out-of-range values, and logical errors.

Event 5. *Documentation and certification* – Develop or update project metadata and certify the data set. Certification is a confirmation by the project leader that the data has passed all quality assurance requirements and are complete and documented. It also means that data and metadata are ready to be posted and delivered.

Event 6. *Upload data* – Certified data are uploaded from the working database to the master project database. This step might be skipped for short-term projects where there is no need to distinguish working data for the current season from the full set of certified project data.

Event 7. *Archive versioned data set* – Copies of the certified data and metadata are placed in the digital library. This can be accomplished by storing a compressed copy of the working database or by exporting data to a more software-independent format (e.g., ASCII text).

Event 8. *Disseminate data and update national databases*– Certified data and metadata, and digital image products are posted to national repositories (the NPS Data Store, Biodiversity Data Store, NPS Focus) to make them more broadly available to others. National databases, including NPSpecies, NPSTORET, and ANCS+ are updated with data obtained from certified data sets.

Event 9. *Reporting and analysis* – Certified data are used to generate data products, analyses, and reports, including semi-automated annual summary reports for monitoring projects. Depending on project needs, data might be exported for analysis or summarized within the database.

Event 10. *Distribute information products* – Information products such as reports, maps, and checklists are disseminated to the public through the SFAN website and NPS Focus, and catalogued in NatureBib.

Event 11. *Share data and information* – Data, metadata, reports and other information products can be shared in a variety of ways – by FTP or mailing in response to specific requests, or by providing direct access to project records to park staff and cooperators.

Event 12. *Track changes* – All subsequent changes to certified data are documented in an edit log, which accompanies project data and metadata upon distribution. Significant edits will trigger reposting of the data and products to national databases and repositories.

Event 13. *Store products* – Reports and other data products are stored according to format and likely demand, either in the digital library, on off-line media, or in the document archives.

Event 14. *Catalog project products* – Catalog products and all information associated with a project, including results of analyses and paths of dissemination. Project tracking databases can be useful tools for this purpose.

IV.3. Overview of Database Design

Data collected by SFAN will be stored in the plant community monitoring database, which is based on the Natural Resources Database Template (NRDT). The SFAN database was developed in Microsoft Access 2007 (later updated to Microsoft Access 2010). The master plant list used in the database was created by the Jepson Herbarium at the University of California, Berkeley, using nomenclature in the Jepson Manual, 2nd edition (Baldwin et al. 2012). This species list represents all of the plant species found in the state of California. The Jepson Manual is an authoritative guide on species nomenclature. Its nomenclature can differ from other databases (e.g., USDA PLANTS database). However, since the Jepson Manual is so widely used in the state of California by field botanists, and since field techs will already be familiar with its nomenclature, using the Jepson Manual, 2nd edition will likely result in the least number of errors or synonyms. See Steers et al. 2016, SOP 13 for further details.

IV.4. Data Entry, Verification, and Editing

The success of the plant community monitoring protocol hinges on correctly recording, storing, entering, and validating data in the plant community database. Quality assurance and quality control (QA/QC) will be a priority during crew training and throughout the field season. During the field season, data will be entered on paper data sheets. Before leaving the study site, all data sheets will be checked to make sure all applicable sections are complete. Upon return from the field, the paper data sheets will be scanned into an Adobe Portable Document File (PDF), and paper data sheets will be filed in the cabinet until the data are entered into the plant community monitoring database, which will be no more than a week from date of collection. Typically, one day a week is set aside for data entry and other office tasks, though on shorter days data may be entered on the same day as collection. A detailed description of the data quality procedures are provided in Steers et al. 2016, SOP 14.

IV.5. Recommendations for Routine Data Summaries and Analysis

Data from the SFAN plant community monitoring program will be analyzed in three ways:

1. Summaries on the status of the vegetation in each park.
2. Analysis of trends in key parameters.
3. Determination of relationships between environmental parameters.

Following each field season, the structural and compositional metrics for each vegetation type sampled will be summarized (see Table SOP 15.1, Steers et al. 2016,). Once a plot has been revisited, analyses will be performed to assess trends in individual structural or compositional metrics. Analyses to be used are detailed in Steers et al. 2016, SOP 15.

With the data collected from environmental parameters regression analyses, ordination techniques, and other statistical tests can be used to assess relationships with key parameters of interest, like species richness or exotic plant abundance. Data collected for other SFAN vital signs, such as weather and climate (data gathered by other agencies and parks) and early detection of invasive plants, can also help us understand interannual variability and geospatial relationships between source populations of invasive plants along roads and trails and their abundance in vegetation types being monitored. Further details on analyses are included in Steers et al. 2016, SOP 15.

IV.6. Recommended Reporting Schedule and Format

Two types of reports will be produced for the SFAN plant community monitoring program, *annual reports* and *synthesis reports*. The annual report is a summary of the monitoring that was conducted that field season. The status of each vegetation type that was sampled will be reported and will include values of key metrics, such as the ones shown in Table SOP 15.1 (Steers et al. 2016, SOP 15.1). This report will be distributed to SFAN resource managers and also posted online at the IRMA Data Store. The synthesis reports will focus on trends and analyses of environmental parameters with vegetation metrics and draw upon data gathered from other vital signs and from published literature to illustrate observed changes, lack of change, and environmental relationships in the most complete and accurate context available. Synthesis reports will be completed after each vegetation type has

been resampled. Further details on the contents and schedule of reports are provided in Steers et al. 2016, SOP 15.

IV.7. Data Archival Procedures

Following each day in the field collecting monitoring data, and after error checking, data sheets will be scanned into an electronic PDF format and stored in a Google Drive folder for offsite backup during the field season. Another offsite option may be selected in the future as technology changes. At the end of the season, the full collection of PDFs will be grouped into one file for posting to IRMA for long-term digital archiving. The original paper data sheets will be stored in a file cabinet within a locked office at Fort Cronkhite, GOGA. See Steers et al. 2016, SOP 14 for more details.

V. Personnel Requirements and Training

V.1. Roles, Responsibilities, and Qualifications

The following personnel are involved in the plant community monitoring program:

V.1.A. Network Program Manager

The SFAN program manager is responsible for overseeing and coordinating the implementation of the plant community monitoring program. The SFAN program manager ensures that this monitoring program is contributing towards National and Regional I&M program goals, SFAN goals, and the goals of each park unit. The network program manager provides support in budget, personnel, and logistical matters.

V.1.B. Data Manager

The SFAN data manager is responsible for providing database and data management training to the plant ecologist and field crew members. Also, the data manager is responsible for providing any technical assistance with the database and GIS, as needed. Specific tasks that the data manager will be responsible for include:

- Create, update, and maintain the structure and functionality of the plant community monitoring database
- Ensure that the plant community monitoring database is compliant with the NRDT
- Review data products to ensure they contain at least the minimum required metadata
- Provide database and GIS training and support
- Supervise metadata, certification, and data archiving procedures

For further details, see information about the “certification form” in Steers et al. 2016, SOP 1 and information on metadata in Steers et al. 2016, SOP 16.

V.1.C. Vegetation Ecologist

The SFAN vegetation ecologist functions as the plant community monitoring program manager and is responsible for coordinating all aspects of the project, including field work, data management, and analysis/reporting. This person directly supervises the vegetation field crew. The vegetation ecologist must be skilled in field botany, with a strong knowledge of the flora of California’s central coast. Specific responsibilities of the ecologist include:

- Develop an annual field schedule
- Ensure safety measures are followed
- Coordinate with PORE law enforcement prior to field season in regard to potential marijuana cultivation areas
- Provide NPS Bay Area Network Fire Program with map of sampling sites, route, and visitation schedule (to ensure limited interference with fuel treatment projects)

- Acquire permission to pass through lessee property to access sampling sites (e.g., PORE rangelands)
- Coordinate with program manager regarding annual and seasonal budgets
- Hire seasonal field crew
- Prepare, repair, and/or purchase equipment
- Prepare database for the field season (review species lists, add crew members names, *etc.*)
- Conduct field crew training, including annual review of protocol SOPs
- Supervise field crew, providing logistic and administrative support
- Ensure vegetation sampling meets quality standards throughout the field season
- Ensure the correct monitoring sites are being sampled each season
- Ensure effective communication between park staff, field crew, and other SFAN staff
- Review and revise standard operating procedures as needed
- Ensure proper data QA/QC and data archival procedures are followed
- Data analysis and report writing
- Ensure that all field crew members are trained in proper data collection procedures
- Identify plants accurately and/or process unknown plants for later identification
- Conduct data verification on data entered into the database by checking against paper field forms

Approximately 10% of the field crew members' time will be dedicated to data management.

This position also oversees the SFAN early detection of invasive plants program. The position is typically furloughed for one pay period per year; its time is dedicated 50% to the early detection program and 50% to the plant community monitoring program.

V.1.D. SFAN Field Crew Members

The primary responsibility of the field crew members is to collect field data on sampling plots and enter those data into the project database. It is critical that crew members are able to identify plants of California's central coast prior to being hired. Below are specific tasks that the crew members are responsible for:

- Complete mandatory training
- Conduct all work in a safe manner provide prompt feedback to other team members regarding field conditions
- Collect field data accurately as described in the program SOPs (Steers et al. 2016)
- Identify plants accurately and/or process unknown plants for later identification
- Ensure plot work meets the desired standards of quality
- Enter data accurately into the project database from paper data sheets

- Complete timesheets and expense reimbursement forms accurately and in a timely manner
- Ensure all necessary equipment is assembled, clean, and functional prior to each trip

Approximately 10% of the field crew members' time will be dedicated to data management.

V.1.E. Other Network Vegetation Specialists

The SFAN I&M program coordinates a vegetation managers' group consisting of the vegetation specialists from GOGA, PINN, PORE, and John Muir National Historic Site, as well as the SFAN program manager and aquatic ecologist. This group meets biannually to provide oversight and technical guidance for this monitoring program and also the SFAN early detection of invasive plants program. Members of this group will be responsible for:

- Assisting the program vegetation ecologist with administration needs specific to individual parks
- Access and safety considerations for fieldwork
- Assisting the program vegetation ecologist with hiring and personnel management
- Training of field personnel
- Quality control and quality assurance for monitoring data
- Data analysis and reporting
- Review of reports and publications

V.2. Training Procedures

Prior to each field season, all field personnel must undergo a training period of one to two weeks where the full details of protocol implementation are covered, with specific emphasis on field monitoring techniques, risk management, and data entry. The training will be focused on making sure the field crew is ready to properly execute the monitoring protocol. Specific topics covered during training are detailed in Steers et al. 2016, SOPs 3 and 22.

VI. Operational Requirements

VI.1. Annual Workload and Field Schedule

Within a year, work will primarily consist of hiring and training two field crew members (Steers et al. 2016, SOPs 2 and 3), planning the field schedule (Steers et al. 2016, SOP 5), executing the field monitoring (Steers et al. 2016, SOPs 6 through 12), data entry and QA/QC (SOP 14), and data analysis and report writing (Steers et al. 2016, SOP 15, plus see Table SOP 1.1 for schedule of deliverables). Field work will begin in mid-March and extend through the end of August. The sampling schedule is based on the vegetation types that are to be monitored in any given year (Steers et al. 2016, SOP 5). Preparations for the upcoming field season should start as soon as the last field season ends (Steers et al. 2016, SOP 18).

VI.2. Facility and Equipment Needs

The logistical and equipment needs of the plant community monitoring crew are detailed in Steers et al. 2016, SOP 2. If available, government housing will be offered to the field crew. The vegetation ecologist should coordinate housing and transportation needs with park staff. The field crew will have access to several vehicles that are shared among other I&M and GOGA natural resources staff.

VI.3. Budget Considerations

The field season will be six months a year, March through August. The program GS-9 vegetation ecologist works year-round with the exception of a one pay period furlough and 50% of his/her time is dedicated to this program (12.5 pay periods). A two-person crew would need to start in March for training and begin sampling by the middle of the month in drier vegetation types (e.g., dry grasslands) or in relatively dry locales like PINN. The two-person crew would stay through August for a total of 13 pay periods per year. The current budget for this protocol is \$92,800 (Table 9). The majority of the funds will cover two field crew members (GS-5 employees). The remaining \$3,000 is for equipment, travel, and training. COLA and step increases will raise personnel costs over time.

Table 9. Estimated yearly cost to implement the plant community monitoring protocol.

Line Item	Cost (\$)
GS-9, term, 12.5pp/year*	40,600
GS-5, seasonal, 13pp/year	24,600
GS-5, seasonal, 13 pp/year	24,600
Equipment	800
Travel (including vehicle)	1,800
Training	400
Total	92,800

Assumptions: Budget is for GS-9 step 5 term and GS-5 step 1 seasonal employees.

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Appendix A. Methodology for selection of plant community types for monitoring.

Abstract

The San Francisco Bay Area Network of national parks (SFAN) is located in a region of high floristic diversity. Vegetation type diversity is also very high, which can overwhelm the utility of a monitoring program if not accounted for. Therefore, specific vegetation types were selected for monitoring under the plant community vital sign. Vegetation types were chosen on the basis of how well they represented each park, their spatial abundance, and management importance. Over 120 distinct vegetation types have been mapped in the SFAN parks. Based on previous mapping and classification projects in these parks, two sampling frames are utilized: the *coastal parks sampling frame* includes GOGA, MUWO, and PORE, which are adjacent to one another and had their vegetation classified and mapped simultaneously (Figure APP A.1); the *Pinnacles sampling frame* was mapped separately (Figure APP A.1). This appendix describes how different vegetation types were selected for these two sampling frames. Through the selection process, 13 vegetation types were chosen for monitoring at the coastal parks sampling frame, and 8 were chosen for monitoring at the Pinnacles sampling frame.

Introduction

Within SFAN, vegetation type diversity is high. Over 120 distinct vegetation types have been mapped and even more vegetation types have been identified through classification exercises associated with the mapping projects (Schirokauer et al. 2003, O'Neil and Egan 2004, URS 2009, Kittel et al. 2012). Vegetation type diversity is reflected in physiognomy, floristic composition, spatial patterning, and dynamics. In terms of physiognomy, forests, shrublands, and grasslands can each be found in every SFAN park unit that contains open space.

Multiple variations of the major physiognomies exist in each park unit. For example, grasslands can be dominated by annual exotics, annual natives, perennial exotics, perennial natives, or various combinations that affect overall appearance. Forests can be dominated by tall, evergreen coastal redwoods (*Sequoia sempervirens*), hardwoods like oak (*Quercus* spp.) and bay laurel (*Umbellularia californica*), relatively short willows (*Salix* spp.), or many other tree species. Forests also include mixed assemblages of tree species and can vary greatly in terms of tree density. In terms of floristic diversity, the high number of plant species in this region translates to a diverse assortment of vegetation types and also high variation in composition among similar types, depending on how fine- or broadly they were classified.

In terms of spatial patterning, all park units exhibit a mosaic complex where multiple vegetation types, often with differing physiognomies, intermix across the landscape. Lastly, in terms of vegetation dynamics, multiple factors influence resiliency, recovery, or rates of change. Similar vegetation types in a park unit can change at different rates based on local-scale differences in resources or perturbations, among other factors.

Given the diversity of vegetation types, it is expected that future changes in structure and species composition will be dissimilar and even divergent among all the different types. A monitoring plan that does not account for this diversity will be overwhelmed and will underperform. Thus, for the sake of maximizing trend detection, vegetation type diversity must be accounted for. Due to monetary constraints, it is not possible to sample over 120 distinct vegetation types that have been mapped in all SFAN park units. Therefore, a prioritization process was implemented to reduce the number of vegetation types that would be monitored in the plant community protocol. By only selecting a sub-set of vegetation types, data variability is reduced to the extent that trend detection is possible.

Methods

Vegetation maps that have been created for each park unit were utilized to determine which vegetation types are monitored. For the purposes of selecting vegetation types, the SFAN park units were divided into two units based on how their vegetation types were classified and mapped. GOGA, MUWO, PORE, and surrounding lands (e.g., Tomales Bay State Park, Mt. Tamalpais State Park) had their vegetation classified and mapped consecutively as part of the same project (Schirokauer et al. 2003). Therefore, GOGA, MUWO, and PORE are treated as one sampling frame for selecting vegetation types to monitor and for choosing where the permanent monitoring sites are. PINN vegetation was mapped separately (Kittel et al. 2012) so this park is a separate sampling frame. Descriptions of the mapped vegetation for each of these two sampling frames can be found in Appendixes B, C, D, E, and F.

The vegetation type prioritization process was a two-tiered exercise. First, for each of the two sampling frames, we selected broadly-classified vegetation types that would be monitored based on abundance and resource management priorities. Then, for each broadly classified vegetation type that was chosen, one finer-scale vegetation type that would be representative of each broadly classified type was selected. The finer-scale vegetation type was usually an association or alliance, which respectively, are the finest and second finest classifications available. Narrowing the vegetation type to a finely-classified type, like an alliance or association ensures that variability will be minimized since these classifications are based on identifying vegetation types with similar floristic composition, physiognomy, and repeatability across the landscape (Barbour et al. 1999). Using this two-step process, 21 vegetation types were chosen for monitoring.

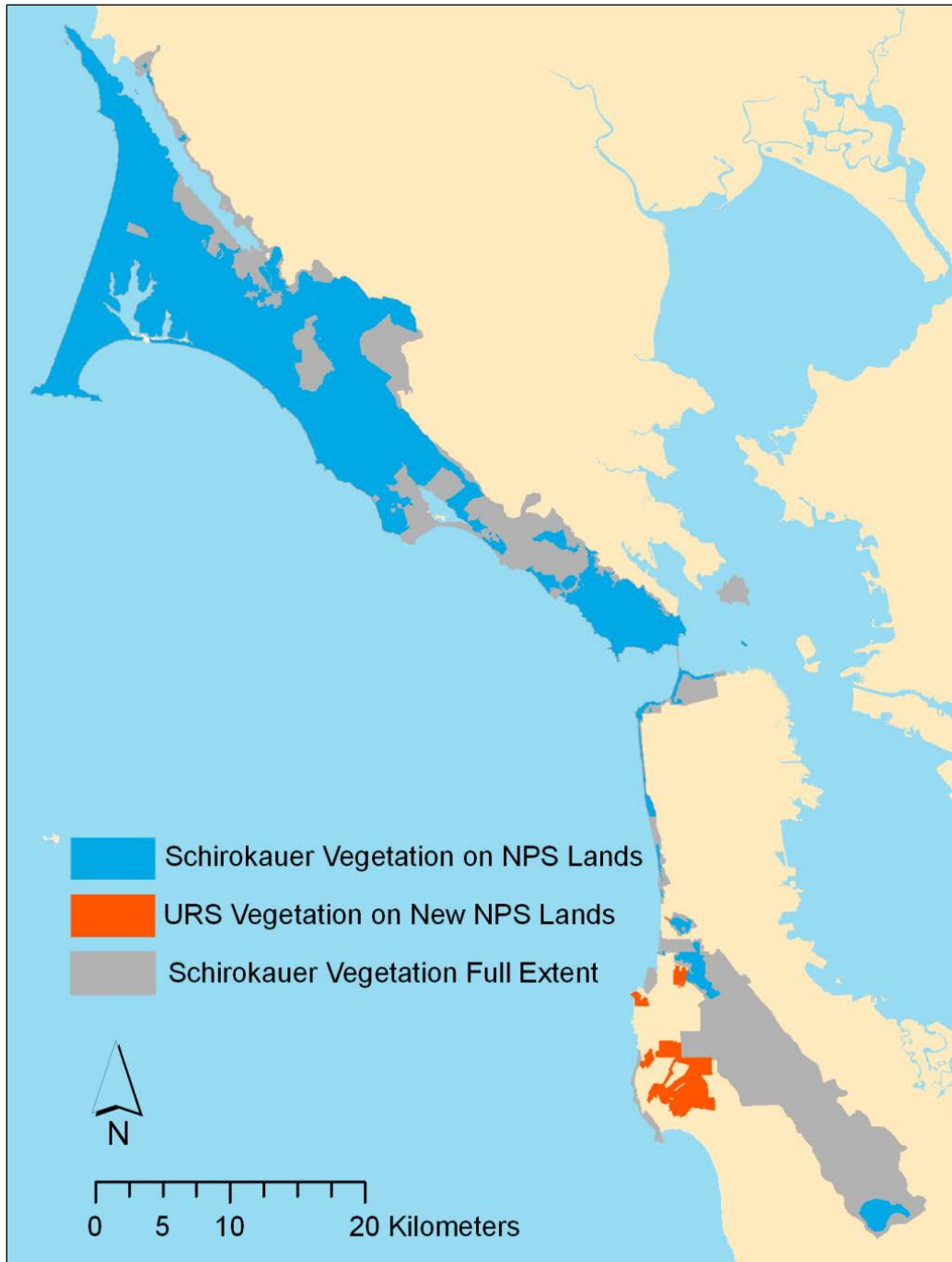


Figure APP A.1. The largest vegetation classification and mapping project was completed by Schirokauer et al. (2003). This project mapped all lands colored dark blue and grey. The dark blue colored lands are only those places mapped by Schirokauer et al. (2003) that overlap with NPS property. Only vegetation mapped on dark blue colored lands were used to determine which vegetation types would be monitored for the coastal parks sampling frame ([Appendix B](#)). The lands colored orange were mapped by URS, Inc. and May and Associates, Inc. (URS 2009) using a different classification system than the NVC system ([Appendix E](#)). These vegetation stands were not used to determine which vegetation types will be sampled but they are used for monitoring where they are found to correspond with the target vegetation.

Step One: Coarse-Scale Vegetation Type Selection

Vegetation types were examined at a coarse-level of classification (*sensu* Holland 1986, Holland and Keil 1995). This classification system was based on a combination of habitat characteristics (e.g., dune, riparian, montane), physiognomy, and species composition. It was used in the coarse-level selection process because that level of classification was more familiar to the National Park Service staff than the mesocluster and super alliance names provided by the National Vegetation Classification (NVC) standards, which are based solely on floristics. When necessary, a cross-walk was used to bridge the mapped NVC units for each park with the naming conventions used by Holland and Keil following an existing template (Holland and Keil 1995). An exception was made for the coarse-level classification of forests and woodlands, which used the NVC standard alliance names (e.g., redwood forest) following Sawyer et al. (2009).

The general criteria for prioritizing a broadly-classified community type for inclusion in this monitoring protocol during this stage included these factors:

Abundance and Distribution of the Community

- Near the edge of its range in SFAN parks
- Formerly more extensive in the Bay Area
- Rare elsewhere
- High spatial coverage in SFAN parks

Susceptibility of the Community to Degradation

- Climate change (including changes in temperature, rainfall, and fog regimes) may cause change in structure and composition
- Susceptible to invasions of exotic species or a high proportion of exotic species of management concern or populations of invasive species may cause change in structure and composition
- Moderate amount of change in species structure and composition expected in a 10-20 year time frame or ability to collect baseline data for communities that may change quickly
- Susceptible to pathogens of concern
- Fire or fire-induced sediment loads may cause sudden change in structure and composition
- Susceptible to trampling
- Highly vulnerable to erosion or sea level rise

Ecology of the Community

- Includes many special-status species
- High species richness
- High proportion of native species
- Has distinctive species composition in SFAN parks compared with this community elsewhere

- High habitat value for many species
- Dominant plants with special adaptations to dynamic fire regime
- Early colonizer of disturbed areas
- Relatively dynamic structure and composition
- Slow recruitment of species of interest

Transferability of Information Gathered to Other Agencies, Universities, NGOs, etc.

- Trend data would be of state-wide interest
- Compliments other SFAN monitoring protocols
- Specific monitoring question of concern that could be addressed by this protocol

Conversely, the authors of this protocol ranked some communities as lower priority for inclusion in this monitoring protocol due to factors including:

- Existing studies or other protocols already provide structure and composition data
- Remote sensing tools can better track questions of interest about the community
- Difficulty of obtaining highly reliable data with this protocol due to dense vegetation cover or steepness of slopes
- Extensive management of dominant vegetation in the community (e.g., non-native trees)
- Very stable community not likely to show signal of change in management-relevant timeframes

Communities were not included in the monitoring protocol if the monitoring plot design described here would not be suitable for tracking change over time in these communities (e.g., Bishop pine forest). Also, managers attempted to select a suite of communities to be monitored that includes a diversity of physiognomic types and balanced between the northern and southern network parks.

For herbaceous communities, a vegetation type was not excluded due to dominance of non-native species in the vegetation type (e.g., many grassland communities).

Step Two: Fine-Scale Vegetation Type Selection

Most of the coarse-scale vegetation types mapped in SFAN parks contain multiple associations. Thus, on a floristic basis alone, the different associations contain variations that could affect trajectories and rates of change due to differences in species traits. For example, the dense coyote brush and related scrub mesocluster in the coastal parks sampling frame, contains five superalliances, 10 alliances, and 15 associations in the mapped area (Keeler-Wolf et al. 2003). While *Baccharis pilularis* is either dominant or co-dominant in almost all of these associations, other co-dominant or associated species can differ greatly. For example, some associations are characterized by the prevalence of *Ceanothus thyrsiflorus*, an obligate seeding shrub while others are characterized by *Rhamnus californica*, an obligate sprouting shrub. Thus, response to fire or the long-term absence of fire will vary considerably between these two associations. If these differences are not accounted for, they could diminish the ability of the monitoring program to detect real trends. In another example from PORE and GOGA, California bay / coast live oak super alliance contains bay laurel

(*Umbellularia californica*) dominated woodlands and separate coast live oak (*Quercus agrifolia*) dominated woodlands. Because of Sudden Oak Death, oak dominated communities would be expected to change much more rapidly and in different ways compared with stands dominated by bay laurel (Brown and Allen-Diaz 2009).

Selection Criteria

To minimize variability, for each coarse-scale vegetation type chosen for monitoring, the most spatially abundant fine-scale vegetation type within that coarse-level was chosen as the vegetation type that would be sampled.

Ideally, for every coarse-level type chosen, one association was selected for monitoring. However, that was not always possible and some exceptions were applied. For example, in the coastal parks sampling frame, there was a case where two fine-scale vegetation types were chosen to be sampled separately because they were substantially different yet equally important for management (see alder riparian woodland and willow riparian woodland). There was also another case in the coastal parks sampling frame where two fine-scale vegetation types were so similar, they were lumped together and treated as one fine-scale vegetation type since field reconnaissance revealed that there were no consistent differences between them (see purple needlegrass alliance and the California annual grassland with native component mapping unit). At PINN, for one coarse-scale type there was no fine-scale type that was representative and feasible to sample, so the coarse-scale type was selected and north facing stands were used to represent one desired vegetation type while south facing stands were used to represent another desired vegetation type (see mixed chaparral and chamisal or dry chaparral). Also, for both the coastal sampling frame and for PINN, sometimes mapping units or alliances had to be selected if no associations were available. However, priority during the fine-scale selection process was given to the finest-scale vegetation type available to minimize floristic and environmental variability, especially if it was relatively abundant and spatially widespread. All fine-scale vegetation types were examined with a GIS to assess their spatial spread in each sampling frame before being selected.

Only vegetation mapped on NPS property using NVC standards are included in this decision making process. Also, the coastal parks sampling frame (GOGA, MUWO, and PORE) and the PINN sampling frame had vegetation mapped that was outside park boundaries. All mapped vegetation outside of park boundaries was excluded. For the coastal parks sampling frame, the largest and most complete vegetation mapping project was conducted by Schirokauer et al. (2003). After this vegetation mapping project was completed, GOGA acquired new lands in San Mateo County. These lands were mapped by May and Associates, Inc. and URS, Inc., using a classification system that May and Associates, Inc. created called the Vegetation Management Community (VMC) classification system. This system differs from the NVC in that it is based on classifying vegetation by treatment regimes for vegetation management purposes (URS 2009). It can only be cross-walked with NVC types mapped by Schirokauer et al. (2003) at a very coarse-scale. This newly mapped vegetation was excluded from the spatial statistics used to determine which vegetation types would be monitored. However, vegetation types in these new lands were incorporated into the sample design and monitored if they met the required criteria during field visits.

Results

Through the coarse- and fine-scale selection process, 13 vegetation types were chosen to be sampled at the coastal parks frame (GOGA, MUWO, and PORE; Appendix B) and 8 were chosen for PINN (Appendix C).

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Appendix B. Vegetation types selected for monitoring in the coastal parks sampling frame.

Thirteen coarse-level vegetation types were chosen for monitoring in the coastal parks sampling frame. Thirteen fine-scale vegetation types will be utilized to represent each coarse-level type (Table APP B.1). One of the coarse-level vegetation types chosen (riparian forest) was split into two vegetation types (willow riparian forest and alder riparian forest) that will be sampled separately. Another coarse-level vegetation type chosen (bald hills prairie) combines two fine-scale vegetation types into one vegetation type that will be sampled since there was no apparent or consistent difference between them based on field observations. Thus, thirteen unique vegetation types will be sampled separately. The spatial abundance, rank based on area, and justifications for selecting the coarse-scale and fine-scale vegetation types are presented below.

Table APP.B.1. The vegetation types chosen for monitoring in the coastal parks sampling frame (GOGA, MUWO, and PORE) based on the most recent mapping and classification campaign using NVC standards (Schirokauer et al. 2003). Blue underlined text represents what the sampling unit is referred to as in this monitoring protocol.

Physiognomic Groupings

Coarse-scale vegetation type chosen for sampling by SFAN Vegetation Working Group

- Corresponding Coarse-scale vegetation type based on NVC standards
 - *The fine-scale NVC vegetation type or mapping unit that will be sampled during protocol execution to represent the broad vegetation type chosen by the working group.*

Forests

Redwood Forest

- Redwood - Tanoak Superalliance
 - *Sequoia sempervirens - Pseudotsuga menziesii - Umbellularia californica Association*

Douglas-fir Forest

- Douglas-fir Superalliance
 - *Pseudotsuga menziesii / Umbellularia californica / Polystichum munitum Association*

Coast Live Oak Woodlands

- California Bay - Coast Live Oak Superalliance
 - *Quercus agrifolia - (Arbutus menziesii) - Umbellularia californica Association (preliminary)*

Riparian Forest

- Red Alder Superalliance
 - *Alnus rubra / Salix lasiolepis Association*
- Arroyo, Red, Black, and Yellow Willow Superalliance
 - Arroyo Willow Alliance

Table APP.B.1 (continued). The vegetation types chosen for monitoring in the coastal parks sampling frame (GOGA, MUWO, and PORE) based on the most recent mapping and classification campaign using NVC standards (Schirokauer et al. 2003). Blue underlined text represents what the sampling unit is referred to as in this monitoring protocol.

Physiognomic Groupings

Coarse-scale vegetation type chosen for sampling by SFAN Vegetation Working Group

- Corresponding Coarse-scale vegetation type based on NVC standards
 - *The fine-scale NVC vegetation type or mapping unit that will be sampled during protocol execution to represent the broad vegetation type chosen by the working group.*

Shrub Dominated Communities

Northern Coastal Scrub

- Dense Coyote Brush and Related Scrub Mesocluster
 - *Baccharis pilularis -Artemisia californica - Toxicodendron diversilobum / Monardella villosa* Association

Shrub Dominated Communities (continued)

Coastal Dune Scrub

- Dune Vegetation Mesocluster
 - Dune Sagewort - Goldenbush Complex Mapping Unit

Herbaceous Dominated Communities

California Annual Grassland

- California Annual Grassland Mapping Unit
 - California Annual Grassland Mapping Unit

Bald Hills Prairie

- California Annual Grassland (CAG) with Native Component Mapping Unit
 - Purple Needlegrass Alliance plus CAG with Native Component Mapping Unit

Coastal Terrace Prairie

- Moist Coastal Grassland Mesocluster
 - Tufted Hairgrass Alliance

Freshwater Wetlands

- Freshwater Wetland Herb Mesocluster
 - Pacific Rush Freshwater Wetland Mapping Unit

Salt Marsh Communities

Coastal Salt Marsh

- Salt Marsh Mesocluster
 - Pickleweed Tidal Wetlands Mapping Unit

Vegetation Type Descriptions

This section includes basic descriptions of each vegetation type selected for inclusion in this monitoring program. First, the coarse-scale vegetation type chosen for sampling by SFAN Vegetation Working Group is listed. Then, the corresponding coarse-scale vegetation type(s) based on NVC standards are written below. For the coastal parks sampling frame, all summary statistics represent the coarse-scale vegetation type and are based on mapped polygons produced by the classification and mapping project for GOGA, MUWO, and PORE (Schirokauer et al. 2003). Spatial statistics for all fine-scale vegetation types can be found in [Appendix D](#). An additional paragraph that explains how the fine-scale vegetation type that represents the coarse-scale type was chosen for sampling is also presented: the default approach to determine the fine-scale vegetation type was to select the most spatially abundant association or alliance that adequately represented the coarse-scale type. For situations where this was obvious, little additional explanation for why the fine-scale type was chosen is provided. Lastly, monitoring questions pertaining to that coarse-scale vegetation type are included.

Redwood Forest

Description

This alliance (Sawyer et al. 2009) consists of conifer stands dominated by coast redwood (*Sequoia sempervirens*) with both Douglas-fir (*Pseudotsuga menziesii*) and California bay laurel (*Umbellularia californica*) present in significant cover (Keeler-Wolf et al. 2003, Sawyer et al. 2009). In some stands tanoak (*Lithocarpus densiflorus*) is well represented; Pacific madrone (*Arbutus menziesii*) can also be present. Some stands have strong dominance by redwood with very little other tree cover. Other trees found in this community include *Quercus chrysolepis* and *Q. wislizeni*. California hazel (*Corylus cornuta*) and huckleberry (*Vaccinium ovatum*) are common understory shrubs, with shrub cover usually sparse to moderate. Sword fern (*Polystichum munitum*) can dominate the herbaceous layer. Other herbaceous species commonly found in this community include *Clintonia andrewsiana*, *Oxalis oregano*, *Viola sempervirens*, *Iris douglasiana*, *Lonicera hispidula*, *Smilacina* sp., *Galium* sp., *Pteridium aquilinum*, *Stachys ajugoides*, and *Toxicodendron diversilobum*. This association may be differentiated from the *S. sempervirens* / *Lithocarpus densiflorus* / *Vaccinium ovatum* association by the presence of tree-size *Pseudotsuga menziesii* and the general absence of *Vaccinium ovatum* in the understory.

Coast redwood trees attain a height of up to 120 meters and an age of over 2,000 years. These trees produce high seed counts annually, but seeds have poor dispersal and viability. Seedlings are somewhat shade tolerant; growth is improved in areas with greater light levels as long as the substrate (bare soil, duff, or logs) is moist. Coast redwoods are well adapted to fire disturbance, with protective bark and the ability to sprout vigorously after damage to trunks, branches, and roots. Since coast redwoods are relatively resistant and resilient to fire and other physical disturbances compared to other SFAN vegetation types, monitoring may be useful for future comparisons with other forested types in light of future perturbances or environmental change.

The primary conservation concern for coast redwood forests is severe habitat alteration due to logging. Stands of this forest type at Point Reyes are second-growth, having been logged in the late 19th and early 20th centuries. Current threats to coast redwood stands in the park include changes in precipitation and fog regimes, especially as the parks are near the southernmost distribution of the dominant species, and accelerated hillslope erosion associated with increased storm severity due to climate change. Highly visited stands of this community type (e.g., at Muir Woods NM) are potentially susceptible to foreign diseases and novel invasive species. A frequently co-dominant tree in this community type, tan oak, is particularly susceptible to Sudden Oak Death mortality.

In addition to monitoring questions addressed by this protocol, general research questions about this community include:

- Will climate change impacts effect coast redwood communities more or less severely dependent on co-factors such as latitude, slope, aspect, soil type?

- How will redwood-associated understory species respond to any changes in redwood forest structure?
- How is Sudden Oak Death (SOD) contributing to changes in forest structure?
- How resilient is this forest type to changes in hydrology and fire regimes compared with other forest communities? How resilient is it to invasions of novel plants, animals, and pathogens?

Reasons that SFAN vegetation managers included this type in the monitoring program include:

- High spatial coverage in coastal parks sampling frame.
- Coast redwoods are climatic relicts that have persisted along the relatively mesic California coast through past warm and dry climatic periods of the Quaternary. Future changes in climate along the coast, such as alterations to fog, precipitation, hydrology, and other factors related to water availability could have large impacts, especially since we are near the southernmost distribution of this species.
- Tanoak, an important component of the type, is highly susceptible to SOD mortality.
- The type may exhibit increased fuel accumulation and vegetation change due to fire suppression and/or SOD.
- Coast redwoods are relatively resistant and resilient to fire and other physical disturbances compared to other SFAN vegetation types. Monitoring would be useful for future comparisons with other forested types in light of future perturbations, disturbances, or changes in the environment.
- Highly visited (e.g., MUWO) and potentially susceptible to foreign diseases and invasive species.

Coarse-Scale Vegetation Type Selected

The following classification unit in Schirokauer et al. (2003) was selected as the coarse-scale vegetation type that crosswalks to redwood forest (Sawyer and Keeler-Wolf 1995):

- Redwood\Tanoak Superalliance

Number of mapped polygons: 154

Area (Ha): 1,042

Rank based on area: 7

This forest type has high spatial coverage within the coastal parks in the network. Roughly 60% of redwood forest in NPS lands managed by PORE and GOGA occurs in southern portion of this area, much of it found in Muir Woods and on the Phleger Estate. The *Sequoia sempervirens* - *Pseudotsuga menziesii* - *Umbellularia californica* Association is found only at PORE within SFAN parks. Coast redwood forests rely on heavy summer fog to maintain moist soils year-round, and are generally found below 600 meters in elevation. Stands can occur at higher elevations if supported by shallow groundwater.

Fine-Scale Vegetation Type Selected

- *Sequoia sempervirens* - *Pseudotsuga menziesii* - *Umbellularia californica*

This is the most spatially-abundant fine-scale type available to represent redwood forests in SFAN parks.

Monitoring Questions

- What are the trends in abundance of all species in the sampling area?
- What are the trends in overall species richness?
- What are the trends in the ratio of invasive plants to native plants?
- What is the rate of invasion of novel plant species?
- What are the trends in diameter of trees?
- What are the causes of death of tree species and is that changing over time?
- What are the trends in cover of rock, bare ground, litter, lichen, and moss?
- What are the trends in fuel abundance?
- What is the trend in SOD incidence?

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Douglas-fir Forest

Description

This alliance (Sawyer et al. 2009) is dominated by Douglas-fir (*Pseudotsuga menziesii*), usually less than 35 meters in height with a highly patchy canopy cover. The lower tree canopy is dominated by *Umbellularia californica*, although *Lithocarpus densiflorus*, *Quercus agrifolia* and/or *Aesculus californica* may constitute minor cover. The shrub layer is open with minor cover contributed by *Vaccinium ovatum*, *Rhamnus californica* ssp. *californica*, *Rubus ursinus*, and/or *Rubus parviflorus*. *Polystichum munitum* is the dominant understory species. Other common herbaceous associates may include *Pteridium aquilinum*, *Iris douglasiana*, and/or *Stachys ajugoides* (Sawyer et al. 2009).

The dominant tree in this community, Douglas-fir, matures at about 20 years in age and may live over 500 years. Heavy seed production occurs every 5-7 years and seeds are viable for up to two years with a short-range of dispersal. Seedlings persist best in moderate shade and moderately well-drained soils. Douglas-fir and co-dominants in this association are adapted to a short to medium fire-return interval of 5 to 120 years. Seedling and sapling Douglas firs are more susceptible to fire-related mortality than older trees. Other influences on Douglas fir forests include fungi, insect pathogens, and windstorms.

Most of the Douglas-fir stands in the lands managed by GOGA and PORE have been logged over the past 150 years. The Mount Vision fire of November 1995 affected numerous stands of this association in the central Inverness Ridge area of PORE. Post-fire monitoring in this area will provide useful information on the transition states of vegetation formerly of this association. Fire return intervals and logging history may have a significant role to play in the determination of whether a stand is a member of the *Pseudotsuga menziesii* alliance or the *Umbellularia californica* alliance.

In addition to monitoring questions addressed by this protocol, general research questions about this community include:

- What will be the impacts of changing hydrology or fire regimes associated with climate change be on this forest type? Will that vary dependent on co-factors such as latitude, slope, aspect, soil type?
- Is understory composition or structure different under lighter tree canopy in this community? Or near forest edges?
- How is SOD contributing to changes in forest structure?
- How resilient is this forest type to changes in hydrology and fire regimes compared with other forest communities? How resilient is it to invasions of novel plants, animals, and pathogens?

Reasons that SFAN vegetation managers included this type in the monitoring program include:

- High spatial coverage in the coastal parks sampling frame.
- In this region, Douglas-fir forests are found in the most mesic upland locales (Evens 2008). They are representative of the Pacific Northwest and therefore, are near their southern latitudinal distribution in our SFAN national parks. In fact, although Douglas-fir can be found along the coast south to Santa Barbara County, the Douglas-fir forests found at PORE could be the largest southernmost stands south of Sonoma County in the Coast Ranges.
- Forests in PORE lack the typical associated tree species, like *Abies grandis*, *Picea sitchensis*, and *Tsuga heterophylla* that are characteristic of north coast coniferous Douglas-fir forests. Other differences may also become apparent with monitoring and will contribute to a more complete understanding of the floristic range and variability of Douglas-fir forests throughout the state.
- Douglas-fir is a known colonizer of undisturbed and disturbed vegetation (Evens 2008, etc.). This species may transform some of the other vegetation types being monitored and it would be useful to have data on mature stands for comparison purposes.

Coarse-Scale Vegetation Type Selected

The following classification unit in Schirokauer et al. (2003) was selected as the coarse-scale vegetation type that crosswalks to Douglas-fir forest (Sawyer and Keeler-Wolf 1995):

- Douglas-fir Superalliance

Number of mapped Polygons: 888

Area (Ha): 5,694

Rank based on area: 2

The large range of the *Pseudotsuga menziesii* Forest Alliance stretches from Washington State to the central California Coast Ranges and the northern Sierra Nevada. Douglas-fir forest is the most common forest type in the NPS lands managed by PORE and GOGA, and roughly 70% of Douglas-fir forest occurs in the northern portion of this area, much of it concentrated to the west of Highway One from Inverness to Bolinas. The remaining 30% or so is found in the southern portion of the study area, with a large occurrence in the Montara Mountain area. In SFAN parks, Douglas-fir forests are found in the most mesic upland locales (Evens 2008).

Fine-Scale Vegetation Type Selected

- *Pseudotsuga menziesii* / *Umbellularia californica* / *Polystichum munitum* Association

This is the most spatially-abundant fine-scale association available to represent Douglas-fir forests in SFAN parks.

Monitoring Questions

- What are the trends in abundance of all species in the sampling area?
- What are the trends in overall species richness?
- What are the trends in the ratio of invasive plants to native plants?

- What is the rate of invasion of novel plant species?
- What are the trends in diameter of trees?
- What are the causes of death of tree species and is that changing over time?
- What are the trends in cover of rock, bare ground, litter, lichen, and moss?
- What are the trends in fuel abundance?
- What is the trend in SOD incidence?

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Coast Live Oak Woodland

Description

Coast live oak woodlands (Sawyer et al. 2009) support either dominant or co-dominant canopies of coast live oak (*Quercus agrifolia*). This woodland type is often found with co-dominant canopies of bay laurel (*Umbellularia californica*). Other co-dominant species can include *Acer macrophyllum*, *Arbutus menziesii*, and *Salix lasiolepis*. Associated herbaceous and shrub species are numerous, although these layers are often sparse. Trees in this community are generally <30 m in height.

Quercus agrifolia is a long-lived, highly drought tolerant evergreen oak well adapted to well drained hill slopes, canyons, and alluvial terraces. Individuals may exceed 200 years old. Mature trees are supported by both a deep root tapping groundwater and an extensive network of shallow roots utilizing near-surface water (Calloway 1990). The tree's minute female flowers and pendulous male catkins are wind-pollinated in spring, with acorns maturing in fall. Acorn production varies greatly each year, with seeds dropping in the fall and reliant on birds and small mammals for dispersal. Forage value of acorns is high for wildlife, and much of each crop is lost to seed predation. Acorns germinate with winter rains and quickly produce deep roots and the tree's characteristic spinose leaves. Seedlings are subject to browse by livestock, deer, small mammals, and invertebrates (Steinberg and Howard 2002).

Conservation concerns for this community type include limited oak seedling reproduction due to livestock browse and changing hydrology. However, some climate change modeling efforts show potential expansion of this habitat type at the expense of coniferous types under future climate scenarios (e.g., Loarie et al. 2008, Lenihan et al. 2003). Mature coast live oaks and bay laurel are fire resistant. Natural fire return intervals in this community range from 30 to over 100 years (Steinberg and Howard 2002, Sugihara et al. 2006).

In addition to monitoring questions addressed by this protocol, general research questions about this community include:

- Are these woodlands expanding in spatial extent as suggested by successional models from the Bay Area? If so, then which vegetation types are being displaced?
- Are there differences in recruitment rates of woody species based on slopes, soils, climatic conditions, etc.? Are canopy gaps important for the recruitment or persistence of certain species within existing stands? What conditions are optimal for tree colonization into other vegetation types?
- What are the long-term effects of SOD? Will gaps caused by SOD be filled in by exotic species or will other natives fill in gaps?
- How does fire suppression affect structure and composition? Why might some stands experience changes while others would not? How has fire suppression affected the abundance

of madrone? Where in the parks do we see madrones persisting and where do madrones appear to be more of an early-mid successional species that phases out over time?

- What understory species are characteristic of bay laurel woodlands, oak woodlands, mixed evergreen hardwood forests, oak forests or woodlands, and madrone forests? Does understory species composition differ greatly within and between these vegetation types?

Reasons that SFAN vegetation managers included this type in the monitoring program include:

- High spatial coverage in coastal parks sampling frame.
- There is high potential for this vegetation type to undergo major changes in the future based on impacts from SOD. Stands in certain portions of the park have already been highly impacted.
- Oak woodlands are of high conservation importance throughout the state (Integrated Hardwood Range Management Program; CA State Laws: AB 242, SB 1334).
- High habitat value for numerous species.
- Seedling recruitment and establishment have been a state-wide concern. While regeneration does not appear to be limiting in the parks, future interference by SOD, invasive plants, and/or drier conditions due to climate change could pose problems for recruitment.

Coarse-Scale Vegetation Type Selected

The following classification unit in Schirokauer et al. (2003) was selected as the coarse-scale vegetation type that crosswalks to coast live oak woodland (Sawyer and Keeler-Wolf 1995):

- California Bay - Coast Live Oak Superalliance

Number of mapped Polygons: 704

Area (Ha): 2,687

Rank based on area: 5

This vegetation grows along valley margins on moderate slopes. Locally, stands can be found on the lower to upper third of a slope on any aspect. Most of the stands are small. However the few large stands tend to occur on upper or mid slopes. Soils are coarse to fine sandy loams. This is a drier forest than the *Umbellularia* - *Q. agrifolia* / *Toxicodendron* association, with a more open xerophytic understory, usually missing mesophytic species such as *Polystichum munitum*, and *Vaccinium ovatum* (from Schirokauer et al. 2003)

Fine-Scale Vegetation Type Selected

- *Quercus agrifolia* - (*Arbutus menziesii*) - *Umbellularia californica* Association (preliminary)

This is the most spatially-abundant fine-scale type available to represent coast live oak woodlands in SFAN parks. This association was not more spatially abundant than similar associations dominated by *U. californica*, however, due to concern for community change due to SOD, the *Quercus agrifolia* - (*Arbutus menziesii*) - *Umbellularia californica* Association was prioritized as it is expected to be more susceptible to the pathogen than *U. californica* communities.

Monitoring Questions

- What are the trends in abundance of all species in the sampling area?
- What are the trends in density of seedling *Quercus agrifolia* and does that correlate with climate parameters?
- What are the trends in overall species richness?
- What are the trends in the ratio of invasive plants to native plants?
- What is the rate of invasion of novel plant species?
- What are the trends in diameter of trees?
- What are the causes of death of tree species and is that changing over time?
- What are the trends in cover of rock, bare ground, litter, lichen, and moss?
- What are the trends in fuel abundance?
- What is the trend in SOD incidence?

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Red Alder Forest

Description

Red alder forests (Sawyer et al. 2009) are dominated or co-dominated by *Alnus rubra* in the tree canopy. Co-dominant trees and shrubs include *Salix lasiolepis* and *Rubus ursinus*. Trees in this community type are generally less than 40 meters in height, with a continuous canopy. Sub-canopy layers, particularly *S. lasiolepis*, can also be very dense. Associated *Salix* species typically grow along and over stream channels, while *Alnus* dominate the slightly higher and less-frequently disturbed ground farther from the channel. *Urtica dioica*, *Artemisia douglasiana*, *Scirpus microcarpus*, and *Vinca major* are commonly-associated herbaceous species, while ferns such as *Polystichum munitum* are also found in the sub-shrub layer.

This community type inhabits low-elevation stream banks, bottomlands, and floodplains with shallow water tables (at least seasonally). Soil types are generally young, sands or loams. The dominant species are disturbance tolerant, re-colonizing open habitat after flood disturbance and newly deposited sediment. These habitats generally do not have frequent fire-return intervals, however the dominant species can recolonize open habitat quickly.

Alder trees are long-lived (up to 100 years) and produce copious minute seeds beginning at about 10 years of age. Seed production is episodic, with large pulses about every 4 years. Flowers are wind-pollinated, and seeds are wind-dispersed. Germination rates are high on moist, mineral soils in unshaded habitat. Seedlings establish long water-seeking roots quickly and can attain a height of one meter in three years. Willow trees, similarly, establish best on moist exposed mineral soils and grow quickly in good conditions. *Salix* species also propagate well through downstream dispersal and sprouting of woody material from parent plants.

This community type provides critical cover habitat for many species of birds and mammals, as well as nesting habitat for migratory song birds. Conservation concerns include susceptibility to habitat conversion to conifer forest types due to changing hydrographs and lowered water tables. Stands of this association can be heavily invaded by non-native species such as *Vinca major*, *Rubus discolor*, *Delairea odorata*, and *Conium maculatum*.

In addition to monitoring questions addressed by this protocol, general research questions about this community include:

- What environmental features of the landscape are associated with the presence of certain types of riparian forests? For example, are stands of the arroyo willow alliance consistently found in the same type of environmental setting (e.g., same soils, slopes, land formations)?
- How does the structure and species composition of riparian forests change in relation to scouring, sediment loading, fire, or release from grazing?
- How will riparian communities change with altered climatic conditions?

Reasons that SFAN vegetation managers included this type in the monitoring program include:

- Sensitive to climate change and hydrologic regime change.
- Important for wildlife.
- Sensitive to management changes.
- Sensitive to sedimentation loads that result from large scale disturbances like wildfires.
- Relatively dynamic ecosystems.
- Long-term dynamics are virtually unknown for many of the riparian woodland types in the parks.

Coarse-Scale Vegetation Type Selected

The following classification unit in Schirokauer et al. (2003) was selected as the coarse-scale vegetation type that crosswalks to red alder forest (Sawyer and Keeler-Wolf 1995):

- Riparian Forest Mesocluster

Number of mapped Polygons: 416

Area (Ha): 993.12

Rank based on area: 8

This Schirokauer NVC type includes two alliances targeted by this protocol for monitoring: alder riparian forests which are represented by the *Alnus rubra* / *Salix lasiolepis* association and willow riparian forests which are represented by the arroyo willow alliance. These two vegetation types are assumed to differ substantially based on differences in species composition and both are equally important based on resource management priorities. Hence, they were both chosen for monitoring. These vegetation types will be sampled separately.

Fine-Scale Vegetation Type Selected

- *Alnus rubra* / *Salix lasiolepis* forest association

Stands of this association are found on low gradient streams and their banks, including upper terraces. Soil textures range from moderately fine sandy clay loam to medium sand of gravelly alluvium. All stands inventoried occurred along permanent streams.

The less spatially abundant *Alnus rubra* / *Salix lasiolepis* association was chosen for monitoring over the more spatially abundant *Alnus rubra* / *Rubus spectabilis* / *Sambucus racemosa* association because the former is more widespread and safer to access. Most of the *Alnus rubra* / *Rubus spectabilis* / *Sambucus racemosa* association's stands are found farther up-stream from *Alnus rubra* / *Salix lasiolepis* associations and are often surrounded by slopes 30 degrees or greater.

Monitoring Questions

- What are the trends in abundance of all species in the sampling area?
- What are the trends in overall species richness?

- What are the trends in the ratio of invasive plants to native plants?
- What is the rate of invasion of novel plant species?
- What are the trends in diameter of trees?
- What are the trends in cover of rock, bare ground, litter, lichen, and moss?
- What is the temporal pattern of disturbance and succession? How does this correlate with flow measurements?

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Arroyo Willow Forest

Description

Arroyo willow thickets (Sawyer et al. 2009) are dominated or co-dominated by *Salix lasiolepis* in the tree canopy. The National Vegetation Classification (NVC) considers this to be a shrub alliance, however Schirokauer et al. (2003) classified local associations as forest because these stands of *S. lasiolepis* are taller than typical shrub height, and grow in relatively dense stands. Canopy cover in the tree layer is continuous to intermittent. Co-dominant trees and shrubs include other willows such as *S. exigua*, *S. lucida*, *S. gooddingii*, and *S. scouleri*. Sub-canopy layers are also typically dominated by willow species, but may be joined by *Rubus ursinus*, *Toxicodendron diversilobum*, *Sambucus racemosa*, and *Scrophularia californica*. *Oenanthе sarmentosa* may occur in patches of open canopy. The herbaceous layer is open to intermittent, and may include *Equisetum arvense*, *Urtica dioica*, *Conium maculatum*, *Juncus patens*, and *J. effusus* (Schirokauer et al. 2003).

This community type inhabits low-elevation stream banks, bottomlands, and floodplains with shallow water tables and seasonal flooding. Soil types are generally recently-deposited sands or loams. The dominant willows are disturbance tolerant, re-colonizing open habitat after flood disturbance on newly deposited sediment. These habitats generally do not have frequent fire-return intervals, however willows can recolonize open habitat quickly.

The riparian willows found in this community type grow as tall shrubs or trees up to 10 meters in height, with *S. lasiolepis* among the tallest of these. The shrub and tree canopies in these stands can be very dense. Willows can establish from seed dispersal on moist exposed mineral soils, however *Salix* species also propagate well through downstream dispersal and sprouting of woody material from parent plants.

This community type provides critical riparian cover habitat for many species of birds and mammals, as well as nesting habitat for migratory song birds. Stands of this association can be invaded by non-native species such as *Vinca major*, *Rubus discolor*, *Delairea odorata*, and *Conium maculatum*.

General research questions about this community and reasons that SFAN vegetation managers included this type in the monitoring program are equivalent to those described for red alder forest above.

Coarse-Scale Vegetation Type Selected

The following classification unit in Schirokauer et al. (2003) was selected as the coarse-scale vegetation type that crosswalks to arroyo willow thickets (Sawyer et al. 2009):

- Riparian Forest Mesocluster

Number of mapped Polygons: 416

Area (Ha): 993.12

Rank based on area: 8

This Schirokauer NVC type includes two alliances targeted by this protocol for monitoring: alder riparian forests which are represented by the *Alnus rubra* / *Salix lasiolepis* association and willow riparian thickets which are represented by the arroyo willow alliance. These two vegetation types are assumed to differ substantially based on differences in species composition and both are equally important based on resource management priorities. Hence, they were both chosen for monitoring. These vegetation types will be sampled separately.

Fine-Scale Vegetation Type Selected

- Arroyo Willow Alliance

Stands of this association are found on low gradient streams and their banks, including upper terraces. Soil textures range from moderately fine sandy clay loam to medium sand of gravelly alluvium. All stands inventoried occurred along permanent streams. The NVC types this as a scrub alliance. In Marin County, the habitat is typed as a forest, however, as the *S. lasiolepis* canopy in these stands is greater than shrub height.

The arroyo willow alliance will be sampled since it was the most spatially abundant fine-scale vegetation type and adequately represents the target vegetation.

Monitoring Questions

- What are the trends in abundance of all species in the sampling area?
- What are the trends in overall species richness?
- What are the trends in the ratio of invasive plants to native plants?
- What is the rate of invasion of novel plant species?
- What are the trends in diameter of trees?
- What are the trends in cover of rock, bare ground, litter, lichen, and moss?
- What is the temporal pattern of disturbance and succession? How does this correlate with flow measurements?

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Northern Coastal Scrub

Description

Northern coastal scrub (Holland and Keil 1995) is dominated by soft-leaved evergreen shrubs from one to two meters tall. Coyote brush (*Baccharis pilularis*) is dominant in the shrub layer, or co-dominant with other shrubs such as *Artemisia californica*, *Ceanothus thyrsiflorus*, *Frangula californica*, or *Toxicodendron diversilobum*. The coyote brush alliance is endemic to California, found primarily in the outer coast ranges from Humboldt to San Diego County, but best represented in central coastal California. Northern coastal scrub intergrades with southern coastal sage scrub in the central Coast Ranges over a very broad latitudinal gradient of increasing temperature and aridity. Moving southward, drought deciduous shrubs such as *Artemisia californica* and *Salvia* species become increasingly dominant in coastal scrub vegetation types. In the coastal parks unit, *Artemisia Californica* is an important component of northern coastal scrub, but reaches the northern limit of its range in PORE.

Structure and composition show a great range of variation depending on local environmental conditions and disturbance history. The coyote brush alliance contains the greatest diversity of associations defined in Schirokauer et al. (2003). The shrub layer may be continuous to open, and the herbaceous layer is typically well developed. On exposed coastal bluffs, the shrub layer is open and exhibits prostrate growth as low as 25 cm. In sheltered locations, the shrub canopy is more continuous, and shrubs can reach 2 m. height. Species richness varies widely along environmental gradients, and tends to be higher where the shrub canopy is more open, and the herbaceous layer is more continuous.

Northern coastal scrub is a dynamic, disturbance-mediated vegetation. Disturbance factors include fire, drought, salt spray, grazing, and anthropogenic clearing. In the absence of disturbance, stands may be colonized by tree species such as *Pseudotsuga menziesii*, *Quercus agrifolia*, and *Umbellularia californica*. Small-scale gap dynamics affect composition and structure at local scales, with herbaceous species colonizing canopy gaps created by shrub dieback (Baxter and Parker 1999). Small mammal density is high under the shelter of shrub canopies, and herbivory by species such as brush rabbit (*Sylvilagus bachmani*) strongly regulates vegetation structure in coastal scrub (McBride 1964, Bartholomew 1970). Small mammal herbivory suppresses the growth of understory herbaceous species, and promotes invasion resistance in coastal scrubs with continuous canopies (Lambrinos 2002).

Northern coastal scrub provides important habitat for a high number of special status plant and animal species, and is important breeding habitat for many songbirds. Coastal scrub habitats in California are threatened by habitat loss, fragmentation, degradation, and successional change. Local declines in white-crowned Sparrows (*Zonotrichia leucophrys*) have been linked to loss of northern coastal scrub habitat through forest succession at PORE (Chase et al. 2005).

In addition to monitoring questions addressed by this protocol, general research questions about this community include:

- Why are some coastal scrub stands high in species diversity while others are less so? What factors control species diversity?
- What are appropriate management targets for conservation of biodiversity in coastal scrub and coastal prairie mosaics?
- How resilient is northern coastal scrub to type-conversion by increased fire frequency?
- How common or important are "fire followers" in northern coastal scrub?

Reasons that SFAN vegetation managers included this type in the monitoring program include:

- Coastal scrub is one of the most abundant vegetation types in the coastal parks sampling frame.
- This type is highly dynamic vegetation and prone to type-conversion to grassland or woodland/forest depending on disturbance or lack thereof.
- Much of the coastal scrub in the parks is considered "northern coastal scrub" or at least contains "northern" elements that are at or near their southern limit in the coastal parks sampling frame. It has potential to be sensitive to future climate change.

Coarse-Scale Vegetation Type Selected

The Holland and Kiel (1995) definition of northern coastal scrub crosswalks to the following coarse-scale vegetation type selected for monitoring, from the classification of Schirokauer et al. (2003):

- Coastal Scrub Supercluster (excluding Coastal Dune Scrub, Coastal Bluff Scrub, and Shrubland / Grassland [Transitional] Vegetation Types)

Number of mapped Polygons: 1739

Area (Ha): 6417.43

Rank based on area: 1

The coastal scrub supercluster is one of the most abundant vegetation types in the coastal parks unit. Extensive stands occur throughout PORE and GOGA in almost all settings. Northern coastal scrub is the predominant vegetation type of southwestern coastal slopes in Marin County from Drakes Estero to the Marin headlands. It also predominates on GOGA lands in San Mateo County, at Milagra Ridge, Sweeney Ridge, and Rancho Corral de Tierra.

Fine-Scale Vegetation Types Selected

- *Baccharis pilularis* / *Artemisia californica* / *Toxicodendron diversilobum* / *Monardella villosa* Association
- Coyote Brush - Coastal Sagebrush - Pacific Poison Oak /Coyote Mountain balm Shrubland

For northern coastal scrub, the *Baccharis pilularis* / *Artemisia californica* / *Toxicodendron diversilobum* / *Monardella villosa* (BATM) association will be sampled. The *Baccharis pilularis* / *Toxicodendron diversilobum* association was the most spatially abundant fine-scale vegetation type available and adequately represents the target vegetation ([Appendix D](#)). However, pilot vegetation sampling revealed that severe exposure to poison oak (*T. diversilobum*) was unpreventable; leading to unsafe conditions, crew members needing to take leave, and low morale that could jeopardize a field season. Although the BATM association contains poison oak, it does so at much lower levels, is often a shorter stature community, and can be sampled with much lower incidence of poison oak.

The BATM association was also chosen over the slightly more abundant *Baccharis pilularis* / *Rhamnus californicus* / *Rubus parviflorus* association since it is easier to move throughout and sample, plus it matches more of the “coastal scrub” vegetation in new park lands within San Mateo County (URS 2009) based on field reconnaissance. Thus, it is likely to actually be greater in spatial abundance, which could be validated if these new park lands were ever classified using NVC standards.

Monitoring Questions

- What are the trends in native species presence and abundance?
- What are the trends in invasive species presence and abundance?
- What are the trends in presence and abundance of physiognomic guilds (e.g. woody plants, annuals, perennials)?
- What are the trends in shrub species mortality following drought?
- What are typical successional trajectories at the landscape-scale, and the patch-scale, and what span of time is required to observe these changes?
- What are the correlations between shrub cover and herbaceous cover in northern coastal scrub?
- If the future climate becomes drier, will more "southern" coastal scrub species like, *Artemisia californica* and *Eriogonum fasciculatum*, increase at the expense of more northern coastal scrub species, like *Rhamnus californica*, *Heracleum maximum*, and *Toxicodendron diversilobum*?

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Coastal Dune Scrub

Description

Coastal dune scrub (Holland and Kiel 1995) refers to a diverse set of shrub communities occupying backdunes from southern California to Sonoma County. Dune scrub is dominated by salt-tolerant, mostly evergreen shrubs from 1 – 2 meters tall. Compared to nearshore environments such as beach and foredune, backdunes offer enough relative shelter from wind and salt spray to allow colonization by shrubs, which stabilize and enrich the sandy soils (Pickart and Barbour 2007). Shrub cover is patchy and can be open to continuous. A rich mixture of herbaceous annuals and perennials occupy the interstices between the shrubs. Approaching the shoreline, dune scrub intergrades with pioneer plant communities of the beach and foredune. With increasing distance from the beach, dune scrub vegetation is less impacted by disturbance from wind, salt spray, and shifting sand, supporting greater species richness and variety of life forms. Characteristic dune scrub species include *Acemispn glaber*, *Artemisia pycnocephala*, *Baccharis pilularis*, *Camissoniopsis cheiranthifolia*, *Dudleya farinosa*, *Ericameria ericoides*, *Fragaria chiloensis*, and *Lupinus chamissonis*. Coastal dune scrub provides habitat for numerous special status species, including the federally endangered Tidestrom's lupine (*Lupinus tidestromii*) and beach layia (*Layia carnosa*).

Native coastal dune vegetation is threatened and much of it has been lost to development along the Pacific coast. Dune systems are highly dynamic, and the disturbance regime (especially wind disturbance) can encourage invasive plant species (Lortie and Cushman 2007). Invasive species such as *Ammophila arenaria* and *Carpobrotus edulus* have altered the physical setting of native dune systems throughout coastal California (Pickart and Sawyer 1998). Coastal dune scrub may also be vulnerable to erosion and inundation associated with sea level rise.

In addition to monitoring questions addressed by this protocol, general research questions about this community include:

- Which areas are most vulnerable to erosion or inundation from sea level rise?
- Which dunes have the least and the most abundance of invasive species? Why?
- Is the ecotone between backdunes and inland non-dune vegetation stable? Are dunes encroaching inland, shrinking towards the coast, or are they stable?
- Is sand being depleted from dunes, increasing, or is the amount not changing? What are the implications of more and less sand input? What is the origin of the dune sand?
- What processes maintain and build-up dune scrub hummocks? What processes destroy hummocks?

Reasons that SFAN vegetation managers included this type in the monitoring program include:

- Vulnerable to erosion, sea level rise, and invasive species.

- Highly dynamic ecosystem. The disturbance regime (especially wind disturbance) can encourage invasive plant species (Lortie and Cushman 2007).
- Original extent of dune vegetation was historically much more prevalent, but like coastal bluff scrub, human land-use (i.e., coastal development) has greatly reduced its extent in the Bay Area.
- European dunegrass (*Ammophila arenaria*) and iceplant (*Carpobrotus edulis*) may locally extirpate some native plant species. Other potential invaders (e.g., *Ehrharta calycina*) could increase in the future at expense of native plants.
- Habitat for numerous special status species.
- Dune vascular plant assemblages were ranked 22nd among all SFAN vital signs (Adams et al. 2006).

Coarse-Scale Vegetation Type Selected

The Holland and Keil (1995) definition of coastal dune scrub crosswalks to the following coarse-scale vegetation type selected for monitoring, from the classification of Schirokauer et al. (2003):

- Dune Sagewort – Goldenbush Complex Mapping Unit

Number of mapped Polygons: 269

Area (Ha): 832.25

Rank based on area: 10

Extensive stands in the dune sagewort – Goldenbush complex mapping unit occur in the backdunes along the entire length the Great Beach at PORE, and smaller stands occur at Tomales Point and Limantour Spit. In GOGA, small stands are mapped at Fort Funston.

Dune scrub has been restored in the Presidio on the bluffs above Baker Beach, and at Crissy Field. In the Marin Headlands, dunes at the southern end of Rodeo Beach mapped in the iceplant (*Carpobrotus edulis*) alliance in Schirokauer (2003), contain remnant dune scrub species such as *Ericameria ericoides*, and probably supported historic native dune scrub vegetation.

Fine-Scale Vegetation Type Selected

- Dune Sagewort – Goldenbush Complex Mapping Unit

For coastal dune scrub vegetation, the less spatially abundant dune sagewort – goldenbush alliance was chosen over the other dune vegetation alliances (i.e., European dunegrass and iceplant). The dune sagewort – goldenbush alliance was selected because it is the only vegetation type in this coarse-level class that is primarily composed of native vegetation and representative of coastal dune scrub.

Monitoring Questions

- What are the trends in invasive species presence and abundance?
- What are the trends in native species presence and abundance?

- What are the trends in presence and abundance of physiognomic guilds (e.g., woody plants, annuals, perennials)?
- How stable or dynamic is species composition in dune scrub?
- Do state changes occur, in which relatively stable species composition at a site transitions to a different stable state?
- Are there successional trends between dune scrub and pioneer foredune communities?

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California Annual Grassland

Description

California annual grassland (Sawyer and Keeler-Wolf 1995) is dominated by introduced annual grasses and forbs in the ground layer. Dominants vary by site and may include *Festuca perennis*, *Avena* spp., *Brachypodium distachyon*, *Bromus hordeaceus*, *B. diandrus*, or *Vulpia bromoides*. Associated herbaceous species are numerous. The herbaceous layer is typically less than 1 meter in height, and is continuous to open. Although native species usually contribute a low percentage of herbaceous cover, native species richness can be high in some stands. Emergent shrubs and trees may be present, and woody plant succession often occurs in the absence of disturbances such as grazing or fire (Keeley 2005). These grasslands exhibit high temporal variability in species composition, abundance, and biomass both intra-annually and inter-annually, driven by variation in precipitation and temperature within and between years, and also exhibits high spatial variability at multiple scales (Bartolome et al. 2007). California annual grasslands provide habitat for a number of special status plant and animal species, and also contains a high proportion of non-native species, some of which are invasive, and management concerns.

California annual grassland occurs throughout cismontane California in all topographic settings, in foothills, waste places, and rangelands below 2200 meters. Stands may occur on shallow rocky soils that once supported native scrub, chaparral, or annual forb communities, or stands may occur on deep, fine - textured soils that originally supported native grasslands or forblands.

European annual grasses were first introduced to California with Spanish colonization in the 18th century. Widespread conversion of native herbaceous plant communities to those dominated by introduced annual grasses coincided with expansion of cattle grazing throughout the state in the 19th century (Bartolome et al. 2007), and continued into the 20th century with type conversion of shrublands and forests for pasture and agriculture.

In addition to monitoring questions addressed by this protocol, general research questions about this community include:

- How much interannual variability in species composition and abundance exists? Does seasonality and amount of rainfall have a strong influence on composition? How do weather conditions in the previous year or previous two years influence species composition in the current year?
- Are native components of these herbaceous communities persisting?
- What is the impact of nitrogen deposition on vegetation and soils, and at what level of deposition is it meaningful?
- What is the role of small scale disturbances, like from gophers, on grassland vegetation?

- Is there an order in germination timing among the annual species? If so, do we see presumably more competitive species, like exotic annual grasses, germinating prior to native annuals within a season?
- How can fire or grazing be used to manage exotic plant species?
- How much of the potential vegetation is actually grassland?

Reasons that SFAN vegetation managers included this type in the monitoring program include:

- Can contain high native species richness.
- Is habitat for numerous special status plant and animal species.
- Has a high proportion of exotic species, some of which are of high management concern.

Coarse-Scale Vegetation Type Selected

The following classification unit in Schirokauer et al. (2003) was selected as the coarse-scale vegetation type that crosswalks to California annual grassland (Sawyer and Keeler-Wolf 1995):

- California Annual Grassland Mapping Unit

Number of mapped Polygons: 223

Area (Ha): 5650.32

Rank based on area: 3

Stands are widespread in the Coastal sample frame. Annual grasslands comprise much of the grazed rangelands in PORE from Drakes Estero westward. In GOGA extensive stands occur on Bolinas ridge and Nicasio Ridge, and scattered stands occur throughout the Marin Headlands. In San Mateo County, stands occur at Mori Point, Sweeney Ridge, Milagra Ridge, Rancho Corral de Tierra, and Phleger Estate. Composition varies along a continuum of coastal to inland types. Stands dominated by *Festuca perennis* are more common towards the coast, in more mesic settings, and tend to have higher native species richness. Stands dominated by *Brachypodium distachyon* and *Bromus* species are more common inland, in drier locales, and tend to have lower native species richness and lower richness of perennial species.

Fine-Scale Vegetation Type Selected

- California Annual Grassland Mapping Unit

The California annual grassland mapping unit was the only mapped vegetation type available that represents the target vegetation ([Appendix D](#)).

Monitoring Questions

- What are the trends in cover of woody plants?
- Do trends in woody plant cover correlate with trends in herbaceous species cover?
- Do trends in woody plant cover correlate with climatic parameters?
- How much interannual variability in species composition and abundance exists?

- Does seasonality and amount of precipitation have a strong influence on species composition?
- How do weather conditions in the previous year or previous two years influence species composition in the current year?
- Are native plant species increasing, declining, or stable?
- Do state changes occur, in which relatively stable species composition at a site transitions to a different stable state?

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Bald Hills Prairie

Description

Bald hills prairie is one of the two phases of coastal prairie defined by Holland (1986). The bald hills prairie phase occurs further inland from the coast on exposed coastal ridges and hilltops. It is often dominated by introduced annual grasses, but contains a rich mixture of native grasses and forbs. The second phase, coastal terrace prairie, occurs on uplifted marine terraces near the coast, and is dominated by native and introduced perennial grasses. These two phases intergrade along water availability gradients, with bald hills prairies occupying the drier end of the water availability gradient, and coastal terrace prairies on the moister end of the gradient. Coastal prairies occur along the California coast and into southern Oregon in areas where the maritime climate ameliorates drought stress somewhat during the summer dry season (Holland 1986, Sawyer et al. 2009). California's coastal prairies are known to be the most diverse grasslands in North America (Stromberg et al. 2001). Grasslands which contain a significant component of native grasses, such as coastal prairies, are rare throughout the state, but some investigators believe they were much more prevalent in the past (reviewed by Minnich 2008).

Bald hills prairies occur in the outer Coast Ranges from Santa Barbara County to Southern Oregon. Stands represent coastal associations of the purple needlegrass and Idaho fescue grassland alliances. The range of both alliances extends far into interior foothills and valleys. Stands of these alliances occurring closer to the coast tend to have higher species richness than interior stands (Stromberg et al. 2001).

Bald hills prairies typically occur on soils that have adequate winter and spring moisture to support shallowly rooted grasses and forbs, but become too dry in the summer to support woody plants (Holland and Keil 1995). Soils in these grasslands often contain shallow hardpans or claypans that prevent deep percolation of water. Bald hills prairies often form a patchy vegetation mosaic with coastal scrub, coast live oak woodland, and Douglas fir forest. On deeper clay soils that can support both woody and herbaceous vegetation, coastal grasslands are maintained by disturbances such as anthropogenic clearing, fire, grazing, and exposure to salt aerosols. California coastal grasslands often succeed to shrublands in the absence of disturbance (Keeley 2005). In the Coastal Parks Unit, bald hills prairies are dominated by introduced annual grasses such as *Brachypodium distachyon*, *Briza maxima*, *Festuca bromoides* and *Festuca perennis*. Native grasses and herbs are diagnostically present with over 10% relative cover. Native perennial grasses include *Festuca idahoensis*, *Stipa pulchra*, *Festuca rubra*, *Danthonia californica*, and *Agrostis hallii*. Common native perennials include *Achillea millefolium*, *Calystegia purpurata*, *Carex brevicaulis*, *Chlorogalum pomeridianum*, *Heterotheca sessiliflora*, and *Wyethia angustifolia*.

This vegetation type provides habitat for a high number of special status plant and animal species, including the federally listed endangered mission blue butterfly (*Icaricia icarioides missionensis*). It also has a high proportion of exotic species, some of which are of management concern.

In addition to monitoring questions addressed by this protocol, general research questions about this community include:

- How much interannual variability in species composition and abundance exists? Does seasonality and amount of rainfall have a strong influence on composition? How do weather conditions in the previous year or previous two years influence species composition in the current year?
- Are native components of these herbaceous communities persisting?
- What is the impact of nitrogen deposition?
- What is the role of small scale disturbances, like from gophers, on grassland vegetation?
- Is there an order in germination timing among the annual species? If so, do we see presumably more competitive species, like exotic annual grasses, germinating prior to native annuals within a season?
- How can fire or grazing be used to manage exotic plant species?
- How much of the park's potential vegetation is actually grassland?
- How important are biological soil crusts for resisting invasive species? How might grazing or other soil disturbances damage crusts and increase the susceptibility of grasslands to invasive plant species?
- What are the effects of different land use histories on contemporary composition of coastal prairies?

Reasons that SFAN vegetation managers included this type in the monitoring program include:

- Can contain high native species richness
- Native bunchgrass grasslands are rare throughout the state but some investigators believe they were much more prevalent in the past.
- Contains a high number of special status species.
- Has a high proportion of exotic species, some of which are of high management concern.

Coarse-Scale Vegetation Types Selected

The following classification units in Schirokauer et al. (2003) were selected as the coarse-scale vegetation types that crosswalk to bald hills prairie (Holland 1986):

- California Annual Grassland with Native Component Mapping Unit (native component MU)
- Purple Needlegrass Alliance

Number of mapped Polygons: 328

Area (Ha): 1453.17

Rank based on area: 6

Bald hills prairies are located on ridgelines and slopes throughout the Coastal Parks Unit. Locations in GOGA include the Marin Headlands, Mori Ridge, and Rancho Corral de Tierra. Locations in PORE include the hills facing Drakes Bay and Drakes Estero.

Fine-Scale Vegetation Types Selected

- *Festuca idahoensis* - *Stipa pulchra* Provisional Association
- Idaho Fescue - Purple Needlegrass Provisional Association

For bald hills prairie, there were two mapped vegetation types that represented the target vegetation type. These were the California annual grassland with native component mapping unit (native component MU) and the purple needlegrass alliance. Instead of choosing just one of these two fine-scale vegetation types, both of them were selected and combined into one composite vegetation type. The purple needlegrass alliance only included 8 stands, which were mostly all found in the Marin headlands. The native component MU included 320 stands, ranging from coastal portions of PORE to ridgelines in San Mateo County. This broadly classified mapping unit had a high degree of environmental and compositional variability between stands. In order to select relatively xeric stands, and reduce the variability in other environmental factors, a subset of the two fine-scale grassland types was selected that overlapped soils derived from Franciscan complex chert in the Marin Headlands (Niven et al. 2009).

Field verification of the purple needlegrass alliance and the native component MU revealed that there is no consistent difference between these two types where they overlay Franciscan chert in the Marin Headlands; they both can contain similar amounts of purple needlegrass (*Stipa pulchra*) (Steers and Spaulding 2013). Furthermore, analysis of pilot data collected for this protocol in 2013 indicates that these grasslands actually belong to the Idaho fescue (*Festuca idahoensis*) alliance, with purple needlegrass as an associate. In the 12 sample plots selected for this protocol, Idaho fescue had greater constancy and higher cover in more plots than purple needlegrass (SFAN I&M, unpublished data). A separate sampling effort in coastal Marin and Sonoma counties also recently classified and mapped the Marin Headlands chert grasslands under the Idaho fescue alliance (Ayzik Solomeshch, UC Davis, personal communication). Stands of the Idaho fescue alliance associated with purple needlegrass were also described by Evans and Kentner (2006) from Mount Tamalpais in Marin County.

Monitoring Questions

- What are the trends in cover of woody plants?
- Do trends in woody plant cover correlate with trends in herbaceous species cover?
- Do trends in woody plant cover correlate with climatic trends?
- How much interannual variability in species composition and abundance exists?
- Does seasonality and amount of precipitation have a strong influence on species composition?
- How do weather conditions in the previous year or previous two years influence species composition in the current year?

- Are native plant species increasing, declining, or stable?
- What are the trends in presence or abundance of Mission Blue butterfly host plants (*Lupinus albifrons* var. *collinus*, *L. formosus*, *L. variicolor*)?
- Are precipitation patterns correlated with litter depth, and is litter depth positively correlated with non-native annual grass cover, or negatively correlated with native species richness or cover?

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Coastal Terrace Prairie

Description

Coastal terrace prairie is one of the two phases of coastal prairie defined by Holland (1986). The coastal terrace prairie phase occurs on uplifted marine terraces and stabilized dunes near the coast, and is dominated by sod and tussock-forming perennial grasses associated with a rich mixture of herbaceous annuals and perennials. The second phase, bald hills prairie, occurs further inland from the coast on exposed coastal ridges and hilltops, and is often dominated by introduced annual grasses, mixed with native perennial grasses and forbs. These two phases intergrade along water availability gradients, with coastal terrace prairies occupying the moister end of the water availability gradient, and bald hills prairies occupying the drier end of the gradient. Coastal terrace prairies occur along the California coast from Santa Cruz County north into southern Oregon in areas where the maritime climate ameliorates drought stress somewhat during the summer dry season (Holland 1986, Sawyer et al. 2009). California's coastal prairies are known to be the most diverse grasslands in North America (Stromberg et al. 2001). Grasslands which contain a significant component of native grasses, such as coastal prairies, are rare throughout the state, but some investigators believe they were much more prevalent in the past (reviewed by Minnich 2008).

Coastal terrace prairies typically occur on moderate slopes close to the coast, on sandy loam and sandy clay soils. They acquire a significant amount of water from frequent summer fogs (Corbin et al. 2005), and can occur on steeper slopes at higher elevations, where inversions layers concentrate fog precipitation. The fog regime may change in the future due to climate change (Johnstone and Dawson 2010), which would have a significant effect on coastal terrace prairies. Coastal prairie and scrub mosaics are dynamic, and native shrubs may invade prairie vegetation in the absence of disturbance such as grazing, fire, and anthropogenic clearing. Deposition of maritime salt aerosols is also an important disturbance factor that maintains herbaceous dominance in coastal terrace prairies. Deposited salts cause cell embolism and death of plant tissues, suppressing upright growth of woody plants, and favoring low-growing herbaceous perennials (Keeler-Wolf 2009). Coastal terrace prairies are characterized by the tufted hairgrass (*Deschampsia caespitosa*) alliance, the pacific reedgrass (*Calamagrostis nutkaensis*) alliance, the (*Festuca rubra*) alliance, and the (*Danthonia californica*) alliance. Common associates include *Achillea millefolium*, *Chlorogalum pomeridianum*, *Erigeron glaucus*, *Elymus glaucus*, *Horkelia marinensis*, *Pteridium aquilinum*, *Plantago lanceolata*, *Iris douglasiana*, *Viola adunca*, and *Dudleya farinosa*. Emergent shrubs may be present at low cover, including *Rubus ursinus*, *Baccharis pilularis*, *Gaultheria shallon*, and *Vaccinium ovatum*.

Coastal terrace prairies provide habitat for a high number of special status plant and animal species, including the federally listed endangered Myrtle's silverspot butterfly (*Speyeria zerene myrtleae*), and showy indian clover (*Trifolium amoenum*). Coastal prairies currently occupy a much smaller area in California than they historically did. Loss of coastal prairie has been due to development, agriculture, overgrazing, and fire suppression. Coastal terrace prairies are also highly susceptible to plant invasions, and many coastal prairies are now dominated by introduced perennial grasses such as

Holcus lanatus, *Anthoxanthum odoratum*, *Festuca arundinacea*, *Phalaris aquatica* and *Rytidosperma penicillatum*.

General research questions about this community and reasons that SFAN managers included this type in the monitoring program are equivalent to those described for bald hills prairie above.

Coarse-Scale Vegetation Type Selected

The Holland (1986) definition of coastal terrace prairie crosswalks to the following coarse-scale vegetation types selected for monitoring, from the classification of Schirokauer et al. (2003):

- Introduced Perennial Grassland – *Deschampsia* Superalliance

Number of mapped Polygons: 208

Area (Ha): 781.20

Rank based on area: 11

In the Coastal Parks Unit, coastal terrace prairies are concentrated in the northwestern portion of the Point Reyes peninsula. Here, stands of the tufted hairgrass alliance occur in the hills and dunes east of the Great Beach, and Pacific reedgrass stands are concentrated in wet bottomlands on mesic, north-facing coastal bluffs. Coastal terrace prairie stands dominated by introduced perennial grasses are also commonly found in this area. In GOGA stands dominated by introduced perennial grasses occur on the headlands above Stinson and Muir Beaches, in wet meadows in Tennessee Valley and Rodeo Valley, on Milagra and Mori Ridges, and on the lower slopes of Rancho Corral de Tierra.

Fine-Scale Vegetation Types Selected

- Tufted Hairgrass Alliance
- *Deschampsia caespitosa* Alliance

The tufted hairgrass alliance is represented locally by two associations. The *Deschampsia cespitosa* – *Danthonia californica* association is found on moist coastal terraces and slopes, while the *Deschampsia cespitosa* -*Horkelia marinensis* Grassland Association occurs on sandy soils adjacent to stabilized dunes. This is a very wide - ranging alliance occurring in mountains and cool coastal strips throughout much of North America.

The less spatially abundant tufted hairgrass alliance was chosen over the introduced coastal perennial grassland alliance because the tufted hairgrass alliance is dominated by native species and best characterizes coastal prairie vegetation. Another vegetation type, the *Calamagrostis nutkaensis* / *Carex* / *Juncus* association, had a coastal prairie phase but was not included in the coarse scale vegetation type that represents coastal prairie. Although the *Calamagrostis nutkaensis* / *Carex* / *Juncus* association was more spatially abundant than the tufted hairgrass alliance, many of its stands were in depressions and wetland-like habitats that resembled freshwater marsh communities more so than coastal prairies. Once these marsh-like stands were removed, there were not as many upland coastal prairie stands left in the *Calamagrostis nutkaensis* / *Carex* / *Juncus* association compared to the tufted hairgrass alliance.

Monitoring Questions

Monitoring questions about this community are equivalent to those described for bald hills prairie above, and also include the following:

- What are the trends in presence or abundance of western dog violet (*Viola adunca*) the larval host plant for Myrtle's silverspot butterfly?
- How do cattle-grazed and elk-grazed sites differ?
- Are there detectable differences in vegetation dynamics between the *Deschampsia cespitosa* – *Danthonia californica* association and the *Deschampsia cespitosa* -*Horkelia marinensis* associations?

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Freshwater Wetlands

Description

Freshwater wetlands as defined by Holland and Kiel (1995) encompass a broad range of plant communities adapted to extended periods of inundation. Pacific Reed Grass meadows (Sawyer et al. 2009) are among the best represented types of freshwater wetlands in the Coastal Parks Unit. These wetlands support a diverse herbaceous community with Pacific reed grass (*Calamagrostis nutkaensis*), a native perennial bunchgrass, as dominant or co-dominant in the ground layer. Co-occurring herbaceous species include a mix of native and non-native species such as *Anthoxanthum odoratum*, *Elymus glaucus*, *Festuca arundinacea*, *F. rubra*, *Heracleum maximum*, *Holcus lanatus*, and *Pteridium aquilinum*. While tree and shrub species may occur in this community type, particularly in ecotonal space, these comprise low foliar cover. Shrub species can include *Rubus ursinus*, *Baccharis pilularis*, and *Vaccinium ovatum*; tree species bordering habitat polygons can include *Alnus rubra* and *Salix* spp.

For the purposes of this monitoring program, SFAN botanists will be joining this type with the Bulrush–Cattail Super Alliance and the Rush Super Alliance. These more mesic graminoid communities support co-dominants *Scirpus microcarpus* / *Typha latifolia* and *Juncus effusus* / *J. patens*, respectively. In some polygons *Typha latifolia* may be replaced by and/or crossed with exotic invasive *T. angustifolia*.

These target communities are typically found in swales and flats, and are supported by seasonal or semi-permanent shallow groundwater. Where found on low-gradient slopes, water sources for these communities may include mid-slope seeps and springs. Like *C. nutkanensis*, co-dominant species in this community are generally obligate or facultative wetland plants. With reliable moisture *C. nutkaensis* grows up to a meter in height and forms a deep layer of litter that may slow encroachment and spread of competing species (Ripley 1983). This community may be vulnerable to change in species composition, such as woody plant invasions, with changes in precipitation and fog regimes.

In addition to monitoring questions addressed by this protocol, general research questions about this community include:

- How do wetland species sort along soil moisture or inundation gradients?
- Are graminoid dominated wetlands becoming invaded by woody species? Are natural communities that surround wetlands encroaching? If so, why?
- How stable are freshwater wetlands? Are some more stable than others, and why?
- Which wetlands are most diverse and why?
- Are invasive species displacing wetland vegetation? Where and why?
- Are there any wetland types that are unique to the coastal parks or are at least very uncommon elsewhere?

Reasons that SFAN vegetation managers included this type in the monitoring program include:

- Potentially dynamic depending on environmental setting.
- Sensitive to hydrologic changes.
- Sensitive to water quality change.

Coarse-Scale Vegetation Type Selected

The following classification unit in Schirokauer et al. (2003) was selected as the coarse-scale vegetation type that crosswalks to Pacific reed grass meadows (Sawyer et al. 2009):

- *Calamagrostis nutkaensis* / *Carex* / *Juncus* Association plus the Rush Super Alliance and the Bulrush – Cattail Super Alliance

Number of mapped Polygons: 327

Area (Ha): 740.73

Rank based on area: 12

Fine-Scale Vegetation Type Selected

- *Calamagrostis nutkaensis* / *Carex* / *Juncus* Association plus the Rush Super Alliance and the Bulrush – Cattail Super Alliance

Stands of this type are generally small – less than 2 hectares.

Monitoring Questions

- What are the trends in abundance of obligate and facultative wetland species?
- Is there strong correlation between amount of precipitation and species composition?
- Do trends in woody plant abundance correlate with trends in herbaceous species cover?
- Do trends in woody plant abundance correlate with climatic parameters?
- Do weather conditions in the previous year or previous two years influence species composition in the current year?
- Are native plant species increasing, declining, or stable?
- Do state changes occur, in which relatively stable species composition at a site transitions to a different stable state?

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Coastal Salt Marsh

Description

Coastal salt marshes (Holland and Kiel 1995), or pickleweed tidal wetlands (Sawyer and Keeler-Wolf 1995) are dominated by the native perennial subshrub *Sarcocornia pacifica* - also known under the names *Salicornia pacifica* (Ball 2003) and *Salicornia virginica* (Hickman 1993). Common co-occurring species include *Distichlis spicata*, *Jaumea carnosa*, *Triglochin maritima*, *Cordylanthus maritimus*, *Schoenoplectus maritimus*, *Grenelia stricta*, and *Spartina foliosa*.

This community type occurs on regularly inundated tidal flats. Within network parks it is found along the margins of Tomales Bay, Bolinas Lagoon, and Drakes Bay. Plant species present are specialized for tolerance to brackish soils and are typically wetland obligates. Generally *S. pacifica* is strongly dominant in this community type. This short evergreen woody succulent has green to red stems which shed periodically to remove salts. Salt marshes often exhibit zonal patterns by elevation representing high marsh, marsh plain, and cordgrass habitat (Zedler et al. 1999) with distinct co-dominant communities. Disturbance to this community occurs through flooding and invasions of exotic species. Sea level rise associated with climate change may put this community at risk of conversion to sub-tidal habitat, however, some models suggest that sediment deposition and isostatic rebound along the San Andreas Fault Zone may counteract this effect.

In addition to monitoring questions addressed by this protocol, general research questions about this community include:

- How will structure and composition change as sea-level rises?
- How is sedimentation altering these communities?
- Where are nutrient inputs highest and what are the consequences in terms of vegetation change?
- Where do invasive species have the greatest abundance and/or richness?
- How are wetlands changing in response to invasive *Spartina* hybrids or other invasive plants? What are the long-term consequences?

Reasons that SFAN vegetation managers included this type in the monitoring program include:

- Includes regionally significant salt marsh ecosystems.
- Susceptible to rising sea level.
- Susceptible to invasion by numerous species, some of which can alter ecosystem services and trophic dynamics (Brusati and Grosholz 2006).

Coarse-Scale Vegetation Type Selected

The following classification unit in Schirokauer et al. (2003) was selected as the coarse-scale vegetation type that crosswalks to coastal salt marsh (Holland and Kiel 1995):

- Salt Marsh Mesocluster

Number of mapped Polygons: 114

Area (Ha): 170.08

Rank based on area: 14

Fine-Scale Vegetation Type Selected

- Pickleweed Tidal Wetlands Mapping Unit

Monitoring Questions

- How will structure and composition change as sea-level rises?
- How is sedimentation altering these communities?
- Where are nutrient inputs highest and what are the consequences in terms of vegetation change?
- Where do invasive species have the greatest abundance and/or richness?
- How are wetlands changing in response to invasive *Spartina* hybrids or other invasive plants? What are the long-term consequences?

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Appendix C. Vegetation types selected for monitoring in the Pinnacles sampling frame.

Eight vegetation types were chosen for monitoring in PINN (Table APP C.1). The spatial abundance, rank based on area, and justifications for selecting the coarse-scale and fine-scale vegetation types are presented below.

Table APP C.1. The vegetation types chosen for monitoring at PINN based on the most recent mapping and classification campaign using NVC standards and the Park Specific PI classifications found in the VegPoly_Joined_PostAA_Park_Specific_10_2_09 layer (Kittel et al. 2012). Blue underlined text represents what the sampling unit is referred to as in this monitoring protocol.

Physiognomic Groupings

Coarse-scale vegetation type chosen for sampling by SFAN Vegetation Working Group

- Corresponding Coarse-scale vegetation type based on NVC standards
 - *The fine-scale NVC vegetation type or mapping unit that will be sampled during protocol execution to represent the broad vegetation type chosen by the working group.*

Forests and Woodlands

California Buckeye Woodland

- California Buckeye Woodland Alliance
 - California Buckeye Woodland Alliance (PI - 2220)

Blue Oak Woodland

- Blue Oak Woodland Alliance
 - Blue Oak/Mixed Herbaceous Woodland Association (PI - 2212)

California Juniper Woodland

- California Juniper Woodland Alliance
 - California Juniper Woodland Alliance (PI – 1220)

Shrublands

Mixed Chaparral

- Californian Xeric Chaparral Shrubland Group
 - Chamise Shrubland Alliance (PI - 3110 - north facing slopes only)

Chamisal or Dry Chaparral

- Californian Xeric Chaparral Shrubland Group
 - Chamise Shrubland Alliance (PI - 3110 - south facing slopes only)

Southern Coastal Scrub

- California Coastal Scrub Shrubland Macrogroup
 - California Coastal Scrub Shrubland Macrogroup (PI - 3300)

Table APP C.1 (continued). The vegetation types chosen for monitoring at PINN based on the most recent mapping and classification campaign using NVC standards and the Park Specific PI classifications found in the VegPoly_Joined_PostAA_Park_Specific_10_2_09 layer (Kittel et al. 2012). Blue underlined text represents what the sampling unit is referred to as in this monitoring protocol.

Physiognomic Groupings
Coarse-scale vegetation type chosen for sampling by SFAN Vegetation Working Group - Corresponding Coarse-scale vegetation type based on NVC standards <i>The fine-scale NVC vegetation type or mapping unit that will be sampled during protocol execution to represent the broad vegetation type chosen by the working group.</i>
Herbaceous Dominated Communities
<u>California Annual Grassland</u> - Mediterranean California Naturalized Annual and Perennial Grassland and Herbaceous Vegetation Macrogroup - Mediterranean California Naturalized Annual and Perennial Grassland and Herbaceous Vegetation Macrogroup (PI - 4300)
<u>Bushy Spikemoss Mats</u> - Open to Sparse Grass on Thin Substrate Herbaceous Vegetation Mapping Unit - Open to Sparse Grass on Thin Substrate Herbaceous Vegetation Mapping Unit (PI - 4003)

Vegetation Type Descriptions

This section includes basic descriptions of each vegetation type selected for inclusion in this monitoring program. First, the coarse-scale vegetation type chosen for sampling by SFAN Vegetation Working Group is listed. Then, the corresponding coarse-scale vegetation type(s) based on NVC standards are written below. For the PINN sampling frame, all summary statistics represent the coarse-scale vegetation type and are based on mapped polygons produced by the classification and mapping project (Kittel et al. 2012) bound by the 2006 PINN property line. Similar spatial statistics for each finer-scale vegetation type can be found in Appendix F, which shows the spatial properties of all mapped vegetation for the PINN sampling frame. An additional paragraph that explains how the fine-scale vegetation type that represents the coarse-scale type was chosen for sampling is also presented: the default approach to determine the fine-scale vegetation type was to select the most spatially abundant association or alliance that adequately represented the coarse-scale type. For situations where this was obvious, little additional explanation for why the fine-scale type was chosen is provided. Lastly, monitoring questions pertaining to that coarse-scale vegetation type are included.

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Kittel, G., E. Reyes, J. Evens, J. Buck and D. Johnson. 2012. Vegetation classification and mapping project report, Pinnacles National Monument. Natural Resource Report NPS/SFAN/NRR—2012/574. National Park Service, Fort Collins, Colorado.

California Buckeye Woodland

Description

California buckeye woodland (Sawyer et al. 2009) is dominated or co-dominated by California buckeye (*Aesculus californica*) in the sparse to intermittent tree canopy. *Pinus sabiniana*, *Quercus wislizenii*, and *Umbellularia californica* may also occur in the tree layer at lower cover. Species present in the shrub layer may include *Prunus ilicifolia*, *Mimulus aurantiacus*, *Keckiella breviflora*, and *Toxicodendron diversilobum*. The herbaceous layer is typically sparse and is generally dominated by non-native summer senescent grasses such as *Bromus diandrus*, *B. hordeaceus*, and *Festuca myuros*. The herb layer can also include non-gramminoids such as *Anthriscus caucalis*, *Clarkia unguiculata*, *Galium porrigens* var. *porrigens*, and *Pentagramma triangularis* ssp. *triangularis* (Kittel et al. 2012).

Aesculus californica grows up to 7 meters tall as a tree or large shrub with bright green foliage. These trees can be summer deciduous, with leaves drying and dropping in locales with dry soils in late-summer and early-fall. Although the tree produces many-flowered insect pollinated racemes on terminal branches, each raceme results in up to one large “buckeye” seed. These are dispersed by gravity or water (Howard 1992). Prehistorically these were pulverized and used for stunning stream fish and, after tannin leaching, as a food starch by native Californians for years with poor acorn crops. Nectar from the flowers is utilized by native butterflies, although toxic to non-native honey bees.

California buckeye woodland stands are small and also only a very limited acreage of habitat occurs within the park (<35 Ha). This community type typically occurs on moderate to steep north-facing slopes with thin, well-drained soils. California buckeye woodland can transition into chaparral community types in drier margins. This community type is not prone to carry wildfire, due to *Aesculus californica*’s open canopy and summer-deciduous leaves, which allows for the canopy to attain tree height.

In addition to monitoring questions addressed by this protocol, general research questions about this community include:

- Are woody plant components regenerating?
- Is regeneration spatially localized and why might some areas have higher recruitment while other areas have less?
- How different is understory species composition among all stands in the park? Are there large differences and if so, why?

Reasons that SFAN vegetation managers included this type in the monitoring program include:

- Relatively rare and understudied vegetation type in the South Coast Range with little understanding of composition and structure.

- Seedling recruitment and establishment of buckeye is unknown but could be compromised by exotic annual grasses, similar to oak seedlings.
- Consist of a high proportion of native herbaceous vegetation in the understories of the trees, which elsewhere in the state is uncommon due to grazing disturbance or for other reasons. Sampling provides opportunity to document the relatively high abundance of native herbaceous plant components and learn more about this vegetation type in general.

Coarse-Scale Vegetation Type Selected

The following classification unit in Kittel et al. (2012) was selected as the coarse-scale vegetation type that crosswalks to California Buckeye Woodland (Sawyer and Keeler-Wolf 1995):

- California Buckeye Woodland Alliance

Number of mapped Polygons: 35

Area (Ha): 34.28

Rank based on area: 9

Fine-Scale Vegetation Type Selected

- California Buckeye Woodland Alliance

The California Buckeye Woodland Alliance was the only mapped vegetation type available that represents the target vegetation ([Appendix F](#)).

Monitoring Questions

- What are the trends in abundance of all species in the sampling area?
- What are the trends in overall species richness?
- What are the trends in the ratio of invasive plants to native plants?
- What is the rate of invasion of novel plant species?
- What are the trends in diameter of trees?
- What are the causes of death of tree species and is that changing over time?
- What are the trends in cover of rock, bare ground, litter, lichen, and moss?
- What are the trends in fuel abundance?
- What is the trend in SOD incidence?

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Sawyer, J.O., T. Keeler-Wolf, and J.M. Evens. 2009. A manual of California vegetation, 2nd edition. California Native Plant Society, Sacramento, California.

Blue Oak Woodland

Description

Blue oak woodland (Sawyer et al. 2009) support an intermittent to continuous tree canopy is dominated or co-dominated by blue oak (*Quercus douglasii*). Other co-dominants in the tree layer can include *Aesculus californica*, *Juniperous californica*, *Pinus sabiniana*, *Quercus agrifolia*, and *Quercus wislizeni*. In the sparse to intermittent shrub layer co-occurring species can include *Cercocarpus montanus* var. *glaber* (= *Cercocarpus betuloides*), *Ceanothus cuneatus*, *Lonicera subspicata* var. *denudata*, and *Rhamnus ilicifolia*, and *R. crocea*. The herbaceous layer is often dominated by non-native annual grasses such as *Bromus diandrus*, *Bromus hordeaceus*, and *Bromus madritensis* ssp. *rubens* but can also include minor components of non-graminoids such as *Amsinckia menziesii* var. *intermedia*, *Erigeron foliosus* var. *foliosus*, *Galium porrigens* var. *porrigens*, *Marah fabaceus*, *Pentagramma triangularis* ssp. *triangularis*, and *Phacelia distans*.

This community type occurs on sloping to steep north- and west-facing slopes, but occasionally found on toes of hillslopes. Soils range from gravel to clay, generally well drained and shallow.

Blue oaks form a patchy canopy less than 20 meters tall, with small irregularly-lobed blue-green leaves. These trees grow on dry slopes with poor and frequently rocky soils, and develop deep root structures, up to 25 meters deep to access soil moisture. Trees reproduce at approximately 10 years of age and can continue acorn production for over 200 years. Acorn production is episodic, with distribution by birds and mammals. Seedlings may be subjected to high rates of mortality from deer browse and fossorial mammal activity and fungal infection. However, as a member of the white oak group, blue oaks are considered not susceptible to the Sudden Oak Death pathogen. Regional variation is high in this species, with both high genetic diversity and high variation in co-located associate species. State-wide conservation concerns for blue oak woodlands focus on loss of habitat to development and agriculture. Blue oak woodlands can support a short fire-return interval of 5 to 15 years.

In addition to monitoring questions addressed by this protocol, general research questions about this community include:

- What is the structure and species composition of these oak woodlands?
- Are oaks and other trees regenerating? Is regeneration spatially localized and why might some areas have higher recruitment while other areas have less?
- How does rainfall variability influence the herbaceous component of this vegetation type?
- How different is understory species composition among all of the oak woodland stands in the monument? Are there large differences and if so, why?

Reasons that SFAN vegetation managers included this type in the monitoring program include:

- Oak woodlands are species of high conservation importance throughout the state (Integrated Hardwood Range Management Program; CA State Laws: AB 242, SB 1334).
- Seedling recruitment and establishment of oaks are of state-wide concern. Regeneration trends in PINN are unknown but invasive plants and drier conditions due to climate change could negatively affect recruitment rates.
- These woodlands contain a high proportion of native herbaceous vegetation. This is in contrast to many oak woodlands in South Coast Range, whose herbaceous component is typically dominated by exotic annual grasses. Sampling PINN oak woodlands will provide an opportunity to document a less invaded representation of this vegetation type, which may be useful for restoration purposes.
- Oak woodlands were ranked 38th out of all SFAN vital signs (Adams et al. 2006).

Coarse-Scale Vegetation Type Selected

The following classification unit in Kittel et al. (2012) was selected as the coarse-scale vegetation type that crosswalks to California Buckeye Woodland (Sawyer et al. 2009):

- Blue Oak Woodland Alliance plus Foothill Pine Woodland Alliance

Number of mapped Polygons: 615

Area (Ha): 970.25

Rank based on area: 2

Fine-Scale Vegetation Type Selected

- Blue Oak Woodland Alliance plus Foothill Pine Woodland Alliance

For foothill woodland vegetation, foothill pine communities and blue oak communities were combined to represent the coarse-scale vegetation type that was to be monitored. Then, the most spatially abundant association, the *Quercus douglasii* / mixed herbaceous woodland association was selected for monitoring. Other alliances and associations dominated by foothill pine (*Pinus sabiniana*) were excluded because they either were intermediate between foothill woodland and other vegetation types, like chaparral, were in difficult to access areas, or were in stream reaches that are already being monitored by the PINN wetlands monitoring protocol (Denn and Ryan 2011). The *Quercus douglasii* / mixed herbaceous woodland association adequately represents the target vegetation.

Monitoring Questions

- What are the trends in abundance of all species in the sampling area?
- What are the trends in overall species richness?
- What are the trends in the ratio of invasive plants to native plants?
- What is the rate of invasion of novel plant species?
- What are trends in seedling and sapling abundance?

- What are the trends in diameter of trees?
- What are the causes of death of tree species and is that changing over time?
- What are the trends in cover of rock, bare ground, litter, lichen, and moss?
- What are the trends in fuel abundance?

References

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California Juniper Woodland

Description

At Pinnacles NP California juniper woodland (Sawyer et al. 2009) support an intermittent tree canopy that is dominated by California juniper (*Juniperus californica*). *Quercus douglasii* may also occur in the tree layer, although not as a dominant. The shrub layer typically includes *Prunus ilicifolia* ssp. *ilicifolia*. The sparse herbaceous layer can include *Galium aparine*, *Galium porrigens* var. *porrigens*, *Marah fabaceus*, *Pentagramma triangularis* ssp. *triangularis*, *Bromus hordeaceus*, *Bromus madritensis* ssp. *rubens*, *Melica torreyana*, and *Festuca myuros* (Kittel et al. 2012).

This community type occurs on dry, rocky steep north- and northeast-facing slopes with elevations between 473 and 596 m (Kittel et al. 2012). Parent material for the shallow well-drained soils includes volcanic breccia, general volcanic extrusives, and rhyolite.

California juniper is a stout shrub or tree generally growing less than 4 meters tall. Bark of mature individuals is ropy and reddish in hue, contrasting with the sparse, scale-like blue-green foliage. Fruits of this tree are berrylike cones, dispersed by birds and mammals (Sawyer and Keeler-Wolf 1995). The tree does not resprout after fire, instead wholly depending on seed for reproduction. It is not well fire-adapted, and its sparse habitat is subject to infrequent fire with long return intervals (100-200 years). Stands may be at risk of type conversion if fuel accumulation or spread of annual exotic grasses shortens fire return intervals. Elsewhere in the state this tree may form communities with other co-dominant trees, however at PINN California juniper is the sole dominant in the tree layer where it occurs (Kittel et al. 2012). In the Central California Coast Ranges this community type may be suppressed by cattle grazing and/or disturbance from feral pigs.

In addition to monitoring questions addressed by this protocol, general research questions about this community include:

- What is the structure and species composition of these stands? How do vegetation parameters change with time in disturbance-free contexts and in the face of disturbances, like wildfires?
- Initial field observations suggest that some stands contain California junipers with unusually large DBH measures. What is the significance of these large individuals?
- How will a drier future climate influence this vegetation type compared to other types being monitored at PINN?

Reasons that SFAN vegetation managers included this type in the monitoring program include:

- California juniper woodlands are common further to the east in the inner South Coast Range. However, they are relatively in low abundance in PINN but may represent some of the most western stands of this vegetation type in this part of the South Coast Range (specifically, the Gabilan Range).

- The dominant species, California juniper, is killed by fire and does not resprout so changes in the fire regime, like increased fire frequency, may have profound impacts on this vegetation type. Could be a very useful indicator for changes to the fire regime.
- Comparing the response of this vegetation type to future fire disturbance with other vegetation types will improve our understanding of fire ecology in this part of SFAN.
- There is high interest in the future response of this vegetation type to climate change since it is associated with relatively drier or less productive environments.

Coarse-Scale Vegetation Type Selected

The following classification unit in Kittel et al. (2012) was selected as the coarse-scale vegetation type that crosswalks to California Juniper Woodland (Sawyer et al. 2009):

- California Juniper Woodland Alliance
Number of mapped Polygons: 13
Area (Ha): 16.02
Rank based on area: 11

Fine-Scale Vegetation Type Selected

- California Juniper / Hollyleaf Cherry / Moss Woodland

This is the only fine-scale type available at PINN to represent this alliance.

Monitoring Questions

- What are the trends in abundance of all species in the sampling area?
- What are the trends in overall species richness?
- What are the trends in the ratio of invasive plants to native plants?
- What is the rate of invasion of novel plant species?
- What are trends in seedling and sapling abundance?
- What are the trends in diameter of trees?
- What are the causes of death of tree species and is that changing over time?
- What are the trends in cover of rock, bare ground, litter, lichen, and moss?
- What are the trends in fuel abundance?

References

- Kittel, G., E. Reyes, J. Evens, J. Buck and D. Johnson. 2012. Vegetation classification and mapping project report, Pinnacles National Monument. Natural Resource Report NPS/SFAN/NRR—2012/574. National Park Service, Fort Collins, Colorado.
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Chamise Chaparral and Mixed Chaparral

Description

Chaparral is an evergreen, sclerophyllous (leather-leaved) shrubland that dominates the California Coast Ranges and the Sierra Nevada foothills. In the Coast Ranges, chaparral predominates from the San Francisco Bay Area south to northwestern Baja, Mexico. The shrub layer is continuous to open, with a very sparse herbaceous understory. Small mammal density is high under the shelter of shrub canopies, and herbivory strongly regulates the structure of the herbaceous layer (Bartholomew 1970).

Chaparral communities form a mosaic on the landscape with woodlands, sage scrublands, and grasslands depending on aspect, local climatic differences, soil moisture, and fire regimes. In the Coast Ranges, chaparral is closely associated with southern coastal scrub, which occurs on more xeric slopes (Keeley and Davis 2007). On more mesic slopes chaparral is replaced by forests and woodlands. Chamise (*Adenostoma fasciculatum*) is the most common chaparral shrub species throughout this range.

Chaparral is adapted to stand replacing crown fires with very little ground involvement. Fire return intervals vary widely by region, from 30-150 years (Keeley and Davis 2007). Fire adaptations for regeneration in chaparral shrub species fall into two categories: obligate-sprouters, and obligate-seeders. Resprouting shrubs can regenerate vegetatively by sending up new shoots from burned root crowns, while obligate-seeding species are killed by fire and regenerate from dormant seeds in the soil seedbank. Species richness is greatest in areas that have recently burned. Native forb species known as “fire followers” germinate from dormant seedbanks following stand replacing fires. A fire return interval that is shorter than approximately twenty years can cause chaparral to type convert to grassland by killing off resprouts or seedlings of all shrub cohorts (Keeley 2005).

Chamise chaparral (Holland and Kiel 1995) is found from Washington to Baja, Mexico, and inland as far as southern and central Arizona (Keeley and Davis 2007). The chamise chaparral alliance is differentiated from other chaparral alliances by the near total dominance of chamise (Kittel et al. 2012). This alliance can be found in California at elevations ranging from 10 to 1800 meters, with a lower elevation range in the south and higher elevations in the north (Keeley and Davis 2007, Sawyer et al. 2009). Chamise chaparral is found on relatively xeric exposures within its range. It intergrades with mixed chaparral, which occurs on more mesic northerly exposures (Holland and Kiel 1995). Chamise is capable of resprouting following a fire, so the chamise alliance is slightly more resistant to type conversion than chaparral communities dominated by obligate seeding species (Holland and Kiel 1995). In the absence of fire, chamise chaparral has been documented to be a relatively stable plant community in areas with moderate to long fire return intervals (Keeley and Davis 2007).

Mixed chaparral (Holland and Kiel 1995) is a broadly defined vegetation type, characterized by co-dominance of two or more chaparral shrub species. It consists of an assortment of alliances and associations that occur on more mesic exposures than pure chamise chaparral, although chamise is often an important component of mixed chaparral stands. Co-dominant species at PINN include

chamise, *Arctostaphylos glauca*, *Ceanothus cuneatus*, *Heteromeles arbutifolia*, and *Prunus ilicifolia*. Associate species found in both broad chaparral types at PINN include *Keckiella antirrhinoides*, *Bromus rubens*, *Cerastium glomeratum*, *Hypochaeris glabra*, *Logfia gallica*, and *Festuca myuros* (Kittel et al. 2012).

In addition to monitoring questions addressed by this protocol, general research questions about this community include:

- What are the impacts of fire suppression?
- What will be the response to future climate change? Will this vegetation type experience species die-offs within stands? Will it take longer to recover from fire disturbance? Will mesic chaparral, typically found on north facing slopes be more or less resistant to climate change effects than dry, south facing stands?
- Will floristic surveys in post-fire environments add additional species to the monument's list?
- What is the 'natural' fire return interval? What could happen if fire frequency is too high or too low?
- Do invasive species interfere with post-fire recovery? When, where, why, and how?
- How does chaparral vegetation change with decreasing water availability?

Reasons that SFAN vegetation managers included this type in the monitoring program include:

- Chaparral is the most abundant vegetation type in PINN and mixed chaparral is an important phase that is typically associated with mesic conditions. It typically contains relatively high shrub species richness. It will likely respond differently to disturbances and climate change compared to other chaparral phases or types that can be found in drier or more exposed locales.
- Chaparral shrub species associated with mesic environments may be a good indicator of climate change impacts, especially when comparisons can be made to chaparral species in relatively xeric conditions in the park (e.g., chamisal chaparral on south facing slopes).

Coarse-Scale Vegetation Type Selected

The Holland and Keil (1995) definitions of chamise chaparral and mixed chaparral crosswalk to the following coarse-scale vegetation type selected for monitoring, from the classification of Kittel et al. (2012):

- *sensu lato* California Chaparral Shrubland Macrogroup

Number of mapped Polygons: 1700

Area (Ha): 7252.14

Rank based on area: 1

The California chaparral shrubland macrogroup (chaparral macrogroup) has the greatest spatial extent of mapped vegetation units at PINN, and encompasses a number of chaparral alliances.

Chamise chaparral is the most widespread alliance within the chaparral macrogroup, and occurs between 388 and 737 meters elevation (Kittel et al. 2012).

Fine-Scale Vegetation Types Selected

- Chamise chaparral
 - Chamise Shrubland Alliance (southern exposure)
- Mixed Chaparral
 - Chamise Shrubland Alliance (northern exposure)

For chamise chaparral, only south facing stands of the chamise shrubland alliance will be utilized. All other stands on different aspects will be excluded. Restricting the target vegetation to south facing slopes adequately represents the target vegetation. Furthermore, this allows for comparisons between north and south facing chaparral vegetation, which will be useful for understanding how aspect influences species composition, fuel properties, fire recovery, response to climate change, and other ecological questions that could inform management. Lastly, all other dry or chamise shrubland types that were mapped, those being the chamise - coastal sage scrub shrubland mapping unit and the chamise - California wild buckwheat shrubland mapping unit did not represent the target vegetation well. Instead they represented more of a chaparral – coastal scrub transitional vegetation type. Thus, the chamise alliance was the most spatially abundant fine-scale vegetation type that was available for monitoring.

For mixed chaparral, north facing stands of the chamise shrubland alliance will be utilized. The chamise shrubland alliance is by far, the most spatially abundant vegetation type in PINN (Appendix F). Other, more indicative mixed chaparral communities, specifically the dry - mesic chaparral shrubland mapping unit and the hollyleaf cherry shrubland alliance, were not utilized to represent mixed chaparral because of the difficulty associated with sampling them. These other two mixed chaparral communities are very dense and nearly impenetrable. The chamise shrubland alliance on north facing slopes is also thick and difficult to sample, but relatively much more feasible. North facing stands of the chamise shrubland alliance contain other chaparral shrub species besides chamise (*Adenostoma fasciculatum*) and will still represent mixed species stands.

Monitoring Questions

- How stable is chaparral vegetation in the absence of fire?
- What are the trends in shrub species mortality following drought?
- What are the local patterns of woody and herbaceous post-fire succession in chaparral?
- What are the differential responses of chamise chaparral and mixed chaparral to changes in precipitation, temperature, or fire regimes?
- What are the trends in invasive species presence and abundance?
- What are the trends in native species presence and abundance?

- What are the trends in presence and abundance of physiognomic guilds (e.g. woody plants, annuals, perennials)?

Management and research questions

- What are the impacts of fire suppression?
- At what low threshold of fire return does type conversion to grassland occur?
- Do invasive species interfere with post-fire recovery?
- How does chaparral vegetation change with decreasing water availability?

References

- Bartholomew, B. 1970. Bare zone between California shrub and grassland communities, the role of animals. *Science* 170:1210–1212.
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Southern Coastal Scrub

Description

Southern coastal scrub (Holland and Keil 1995), also known as coastal sage scrub, is dominated by soft-leaved, summer-deciduous shrubs from one to two meters tall. It occurs in the coast ranges from the San Francisco Bay Area to northwestern Baja, Mexico (Westman 1981). There is a broad latitudinal gradient of increasingly drought-tolerant species assemblages in coastal scrubs from north to south. This corresponds with the broad gradient of increasing aridity from north to south. Coastal scrub composition also varies similarly from east-to-west along a steeper climatic gradient of increasing aridity moving inland from the coast. Southern coastal scrub often occurs in ecotonal associations with grassland, chaparral, forest and woodland communities, in xeric sites on a variety of soil types which tend to be relatively shallow and infertile (Holland and Kiel 1995).

Southern coastal scrub alliances at PINN include *Artemisia californica*, *Eriogonum fasciculatum*, *Salvia mellifera* and *Mimulus aurantiacus*. The shrub layer may be more-or-less continuous to open, and the understory is sparsely vegetated. However, the interstices between shrubs may be rich in annual herbs, including *Cryptantha* spp., *Camissonia* spp., *Camissiniopsis* spp., *Dichelostemma capitatum*, *Erodium* spp., *Bromus* spp., and *Avena* spp. Occasionally there is an emergent tree layer, with species such as *Juniperus californica*, *Pinus sabiniana*, and *Quercus douglasii* found at trace cover (Kittel et al. 2012).

Southern coastal scrub is dynamic, disturbance-mediated vegetation. Disturbance factors include fire, drought, salt spray, grazing, and anthropogenic clearing. Invasions of introduced annual grasses can carry fire more effectively between shrubs, creating a feedback loop of increasing fire return intervals, leading to type conversion of southern coastal scrub to annual grassland (Keeley 2005). Small mammal density is high under the shelter of shrub canopies, and herbivory strongly regulates vegetation structure in coastal scrub (Bartholomew 1970). Small mammal herbivory suppresses the growth of understory herbaceous species, and stabilizes shrub – grassland ecotones.

Southern coastal scrub provides important habitat for a high number of special status plant and animal species, containing nearly 40 percent more rare plant taxa than predicted by its statewide areal extent (Keeley 2005). Southern coastal scrub has been greatly reduced from its historic extent in California, and is threatened by multiple interacting factors including habitat loss, fragmentation, degradation, type conversion by increased fire frequency, and nitrogen deposition.

In addition to monitoring questions addressed by this protocol, general research questions about this community include:

- Do fossorial mammals colonize recently burned shrublands? If so, what is their impact on shrubland recovery?
- What is the amount of nitrogen deposition in PINN and how does this pollutant affect coastal scrub vegetation here?

Reasons that SFAN vegetation managers included this type in the monitoring program include:

- High spatial abundance at Pinnacles NP.
- In general, this type is threatened by frequent fire, nitrogen deposition, and invasive annual grasses and forbs.
- Can contain high vascular plant species richness elsewhere in the state.

Coarse-Scale Vegetation Type Selected

The Holland and Keil (1995) definition of southern coastal scrub crosswalks to the following coarse-scale vegetation type selected for monitoring, from the classification of Kittel et al. (2012):

- California Coastal Scrub Shrubland Macrogroup plus Coyote Brush Shrubland Macrogroup

Number of mapped Polygons: 346

Area (Ha): 423.59

Rank based on area: 4

Southern coastal scrub stands are scattered throughout PINN on flat to steep slopes on most aspects, at elevations between 250 and 675 meters.

Fine-Scale Vegetation Type Selected

- California Coastal Scrub Shrubland Macrogroup

For southern coastal scrub vegetation, the California Coastal Scrub Shrubland Macrogroup was selected for sampling. This level of classification is coarse but had to be selected since all other mapped coastal scrub vegetation types are not spatially abundant enough, are not dispersed as well throughout the park, or they are not indicative or representative of typical coastal scrub vegetation (e.g., alluvial scrub found in stream reaches).

Monitoring Questions

- Do introduced annual grasses displace shrub species?
- How do introduced annual grasses and fire interact to influence coastal scrub vegetation?
- Are post-fire native herbaceous species similar to those found in chaparral vegetation types? How do they differ and why?
- Do coastal scrub communities in relatively drier places or harsher soils recover from disturbance at a slower rate than coastal scrub in relatively mesic locales?
- What are the trends in shrub species mortality following drought?
- What are the correlations between shrub cover and herbaceous cover in southern coastal scrub?
- How stable or dynamic is species composition in southern coastal scrub?
- Are native plant species increasing, declining, or stable?
- What are the trends in invasive species presence and abundance?

- What are the trends in native species presence and abundance?
- What are the trends in presence and abundance of physiognomic guilds (e.g., woody plants, annuals, perennials)?

References

- Bartholomew, B. 1970. Bare zone between California shrub and grassland communities, the role of animals. *Science* 170: 1210-1212.
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California Annual Grassland

Description

See ([Appendix B](#): Coastal Parks Unit – Herbaceous Vegetation – California Annual Grassland) for the description of this vegetation type.

In addition to monitoring questions addressed by this protocol, general research questions about this community include:

- What kind of interannual variability in species composition and abundance do communities' exhibit? Does seasonality and amount of rainfall have the most explanatory power in observed differences between years? Does the previous year's or previous two years' weather conditions more strongly influence species composition than weather conditions in the current year?
- Are native components of these herbaceous communities persisting?
- Is the nitrogen deposition level close to or exceeding a critical threshold of change?
- What is the role of small scale disturbances, like from gophers, on individual species in grassland ecosystems?
- What order of germination do the annual species typically follow? Based on this order, do we see presumably more competitive species, like exotic annual grasses, germinating prior to native annuals?
- How does herbaceous vegetation respond to fire and can fire be used to manage exotic plants?

Reasons that SFAN vegetation managers included this type in the monitoring program include:

- Spatially abundant.
- Can contain high native plant species richness.
- Important as wildlife habitat.
- Native dominated grasslands or forblands are increasingly rare throughout the state.
- Due to history of relatively low grazing duration at PINN, some herbaceous communities have relatively 'pristine' assemblages that would be valuable as references for restoration efforts within and outside of PINN.

Coarse-Scale Vegetation Type Selected

The following classification unit in Kittel et al. (2012) was selected as the coarse-scale vegetation type that crosswalks to California annual grassland (Sawyer and Keeler-Wolf 1995):

- Mediterranean California Naturalized Annual and Perennial Grassland and Herbaceous Vegetation Macrogroup

Number of mapped polygons: 201
Area (Ha): 323.67
Rank based on area: 5

The Mediterranean California Naturalized Annual and Perennial Grassland and Herbaceous Vegetation Macrogroup (CAG Macrogroup) was the finest scale unit mapped in Kittel et al. (2012) for all upland herbaceous vegetation except for the *Muhlenbergia rigens* alliance. The CAG Macrogroup encompasses 19 herbaceous annual and perennial vegetation types as defined in the vegetation classification (*ibid.*). Five of these vegetation types correspond to California annual grassland. Stands of the CAG Macrogroup are widespread throughout PINN.

Fine-Scale Vegetation Type Selected

The CAG Macrogroup will be used for stand selection following the guidelines in SOP 5. Field validation will be used to select upland stands within the CAG Macrogroup that are dominated by exotic annual species belonging to the *Avena*, *Bromus*, *Festuca* or *Erodium* genera. Stands at elevations below 400 meters will be excluded from the selection process to avoid historically cultivated alluvial bottomlands.

Monitoring Questions

- What are the trends in cover of woody plants?
- Do trends in woody plant cover correlate with trends in herbaceous species cover?
- Do trends in woody plant cover correlate with climatic trends?
- How much interannual variability in species composition and abundance exists?
- Does seasonality and amount of precipitation have a strong influence on species composition?
- How do weather conditions in the previous year or previous two years influence species composition in the current year?
- Are native plant species increasing, declining, or stable?
- Do state changes occur, in which relatively stable species composition at a site transitions to a different stable state?

References

- Kittel, G., E. Reyes, J. Evens, J. Buck and D. Johnson. 2012. Vegetation classification and mapping project report, Pinnacles National Monument. Natural Resource Report NPS/SFAN/NRR—2012/574. National Park Service, Fort Collins, Colorado.
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Bushy Spikemoss Mats

Description

Bushy spikemoss mats (Sawyer et al. 2009) are found on rock outcrops or extremely thin soils throughout the Central and Southern California Coast Ranges. Bushy spikemoss (*Selaginella bigelovii*), also known as resurrection plant, is a low-growing rhizomatous perennial that is able to dry down completely and go dormant during hot dry summers, and rapidly rehydrate when precipitation returns during the fall and winter months.

Kittel et al. (2012) identified one association belonging to the bushy spikemoss herbaceous alliance at PINN, the *Eriogonum fasciculatum* / *Selaginella bigelovii* Sparse Herbaceous Vegetation Association. *Bromus madritensis ssp. rubens* typically codominates in the herbaceous layer, and the emergent shrub layer includes *Eriogonum fasciculatum*.

Little is known about vegetation dynamics in rock outcrop plant communities. Bushy spikemoss establishes clonal mats on gently to moderately sloping rock faces. Over time, these mats capture enough particulates to form thin soils, allowing other herbaceous species to colonize (Sawyer et al. 2009). Stressors may include airborne pollutants, physical damage from foot traffic, and invasive plant species. Rock outcrop vegetation provides habitat for unique plant and animal communities.

In addition to monitoring questions addressed by this protocol, general research questions about this community include:

- Most of the species associated with barrens are adapted to low soil moisture or ephemeral periods of water availability. Could species adapted to this environment be especially vulnerable or resistant to the effect of future climate change?
- How does N-deposition or disturbances, like from rock climbing or foot-traffic, impact barrens?
- Due to the harsh conditions found in barrens, how long-lived are the plant species? How do they differ from grassland communities? Also, do they have relatively slow growth rates? If so, then will these communities be more susceptible or sensitive to disturbances than non-barren vegetation types?
- How important are lichens and bryophytes for resisting invasive species in barren habitats? For example, intact biological soil crusts are better capable of resisting invasive annual plants than broken crusts in coastal scrub vegetation (Hernandez and Sandquist 2011). Could the soil crusts in barren communities act similarly or is the relatively low amount of exotic species in this habitat more of a function of the shallow, undeveloped soils?

Reasons that SFAN vegetation managers included this type in the monitoring program include:

- This plant community is not well-studied outside of PINN

- Contains unique species and combinations of species that are adapted to harsh soil conditions, and are not found in other communities in PINN
- Thin, low productivity soils suggest that nitrogen addition or acidification from atmospheric deposition could have major impacts on this habitat.
- Vegetation adapted to this extreme environment is expected to respond differently to climate change, and may be an early indicator of change in other communities.

Coarse-Scale Vegetation Type Selected

The following classification unit in Kittel et al. (2012) was selected as the coarse-scale vegetation type that crosswalks to bushy spikemoss mats (Sawyer et al. 2009)

- Open to Sparse Grass on Thin Substrate Herbaceous Vegetation Mapping Unit

Number of mapped Polygons: 66

Area (Ha): 172.25

Rank based on area: 7

The Open to Sparse Grass on Thin Substrate Herbaceous Vegetation Mapping Unit is the finest scale mapping unit that contains stands of the *Selaginella bigelovii* alliance. This mapping unit is a park-specific subset of the Cliffs, Rock Outcrops and Steep Eroded Slopes Mapping Unit, which maps rocky exposures with low to no vegetative cover. Stands may be dominated by a variety of herbaceous species. *Selaginella bigelovii* may be present at low to high cover. It does not have a discernable photo signature, and was not mapped as a separate vegetation type.

Fine-Scale Vegetation Type Selected

- Open to Sparse Grass on Thin Substrate Herbaceous Vegetation Mapping Unit

Field validation will be used to select stands that belong to the bushy spikemoss alliance. The open to sparse grass on thin substrate herbaceous vegetation mapping unit will be used for stand selection following the guidelines in SOP 5. Selection criteria will be used in the field to accept only those stands that belong to the bushy spikemoss alliance. Acceptable stands shall have no less than 10% cover by all plant species based on visual estimation after walking throughout the entire stand, and shall be dominated by *Selaginella bigelovii* in the herbaceous layer.

References

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Appendix D. Table of mapped vegetation types in the coastal parks units.

Table APP D.1. Mapped vegetation from GOGA, MUWO, and PORE produced by Schirokauer et al. (2003). All non-NPS lands are excluded; vegetation only reflects types and amounts found on NPS property ([Appendix B](#)). Nomenclature and classification structure follows National Vegetation Classification (NVC) standards reported by Keeler-Wolf et al. (2003). Double daggers (§) indicate the mapped vegetation types that will be sampled. Single daggers (†) indicate mapped vegetation types that will be combined as one for sampling. Non-wildlands are excluded; spatial calculations only reflect wild vegetation types.

Supercluster	Superalliance	Alliance/Mapping Unit	Association	Total Area (ha)	Relative Cover (%)	Rank Based on Cover	No. of Mapped Polygons
Evergreen Forests and Woodlands							
		California Bay - Coast Live Oak					
		California Bay					
			<i>Umbellularia californica</i> / <i>Lithocarpus densiflorus</i>	30	0.09	56	17
			<i>Umbellularia californica</i> / <i>Polystichum munitum</i>	25	0.08	60	12
			<i>Umbellularia californica</i> / <i>Quercus agrifolia</i> / <i>Toxicodendron diversilobum</i>	935	2.99	9	194
			<i>Umbellularia californica</i> / <i>Quercus agrifolia</i> / <i>Toxicodendron diversilobum</i>	984	3.15	8	226
		Coast Live Oak					
			3	0.01	69	4	
	‡	<i>Quercus agrifolia</i> / (<i>Arbutus menziesii</i>) / <i>Umbellularia californica</i> (preliminary)					
			594	1.90	15	206	
		<i>Quercus agrifolia</i> / <i>Toxicodendron diversilobum</i> / (<i>Corylus cornuta</i>)					
			116	0.37	37	45	
		Douglas-fir					
		Douglas-fir					
			2399	7.67	3	318	
	‡	<i>Pseudotsuga menziesii</i> / <i>Umbellularia californica</i> / <i>Polystichum munitum</i>					
			2213	7.08	4	242	
		<i>Pseudotsuga menziesii</i> / <i>Baccharis pilularis</i>					
			307	0.98	23	142	
		<i>Pseudotsuga menziesii</i> / <i>Quercus agrifolia</i>					
			316	1.01	22	49	
		<i>Pseudotsuga menziesii</i> / <i>Umbellularia californica</i> / <i>Rhamnus californica</i>					
			448	1.43	18	131	
		<i>Pseudotsuga menziesii</i> / <i>Lithocarpus densiflorus</i> / <i>Rhamnus californica</i>					
			11	0.03	65	5	
		Hazel					
			1	0.00	73	1	
		Redwood - Tanoak					

Supercluster	Superalliance	Alliance/Mapping Unit	Association	Total Area (ha)	Relative Cover (%)	Rank Based on Cover	No. of Mapped Polygons
		Coast Redwood		279	0.89	27	59
		<i>Sequoia sempervirens</i> / <i>Lithocarpus densiflorus</i> / <i>Vaccinium ovatum</i>		300	0.96	25	35
	‡	<i>Sequoia sempervirens</i> / <i>Pseudotsuga menziesii</i> / <i>Umbellularia californica</i>		414	1.32	19	51
		Tanoak		50	0.16	48	9
		Bishop Pine – Chinquapin					
		Bishop Pine		814	2.60	10	195
		<i>Pinus muricata</i> / <i>Arbutus menziesii</i> / <i>Vaccinium ovatum</i>		101	0.32	40	22
		Giant Chinquapin		7	0.02	66	11
		Monterey Pine –Monterey Cypress					
		Monterey Cypress or Monterey Pine		110	0.35	39	77
		Eucalyptus					
		Eucalyptus		168	0.54	31	96
Winter Deciduous Forest / Scrub							
		Red Alder					
		Red Alder		1	0.00	70	2
		<i>Alnus rubra</i> / <i>Rubus spectabilis</i> / <i>Sambucus racemosa</i>		305	0.98	24	55
	‡	<i>Alnus rubra</i> / <i>Salix lasiolepis</i>		243	0.78	28	53
		Wax Myrtle - Salmonberry					
		California Wax Myrtle		45	0.14	52	42
		Salmonberry		26	0.08	58	16
		Arroyo, Red, Black, and Yellow Willow					
		Willow Mapping Unit		55	0.18	46	40
	‡	Arroyo Willow		319	1.02	21	208
Chaparral							
		Chamise - Manzanita					
		Chamise		25	0.08	59	9
		<i>Adenostoma fasciculatum</i> / <i>Arctostaphylos glandulosa</i> / <i>Quercus wislizenii</i>		25	0.08	61	20

Supercluster	Superalliance	Alliance/Mapping Unit	Association	Total Area (ha)	Relative Cover (%)	Rank Based on Cover	No. of Mapped Polygons
‡		Mixed Manzanita		91	0.29	41	25
		Eastwood Manzanita					
		<i>Arctostaphylos glandulosa</i> / <i>Quercus wislizenii</i>		50	0.16	49	38
		Sensitive Manzanita					
		Sensitive Manzanita		24	0.08	62	13
Coastal Scrub							
		Coyote Brush (in part)					
		<i>Baccharis pilularis</i> / <i>Lupinus arboreus</i> / <i>Lupinus chamissonis</i>		803	2.57	11	253
		<i>Baccharis pilularis</i> / <i>Corylus cornuta</i>		32	0.10	55	8
		<i>Baccharis pilularis</i> / <i>Carex obnupta</i> / <i>Juncus patens</i>		228	0.73	29	109
		Dune Lupine - Dune Sagewort - Dunegrass					
‡		Dune Sagewort – Goldenbush		285	0.91	26	105
		European Dunegrass		332	1.06	20	82
		Iceplant		214	0.69	30	82
		Coyote Brush - California Sagebrush					
		California Sagebrush		36	0.11	54	9
		Coyote Brush (in part)		1	0.00	71	1
‡		<i>Baccharis pilularis</i> / <i>Artemisia californica</i> / <i>Toxicodendron diversilobum</i> / <i>Monardella villosa</i>		672	2.15	13	154
‡		<i>Baccharis pilularis</i> / <i>Eriophyllum staechadifolium</i>		125	0.40	36	40
		Coyote Brush - Blue Blossom					
		Coyote Brush (in part)					
		<i>Baccharis pilularis</i> / <i>Ceanothus thyrsiflorus</i>		39	0.12	53	14
		Blue Blossom		45	0.14	51	19
		Mature Coyote Brush - Coffeebery - Poison Oak					
		Coyote Brush (in part)					
		<i>Baccharis pilularis</i> / <i>Rhamnus californicus</i> / <i>Rubus parviflorus</i>		747	2.39	12	224
		<i>Baccharis pilularis</i> / <i>Polystichum munitum</i>		1509	0.48	34	25
		<i>Baccharis pilularis</i> / <i>Toxicodendron diversilobum</i>		3497	11.19	2	834

Supercluster	Superalliance	Alliance/Mapping Unit	Association	Total Area (ha)	Relative Cover (%)	Rank Based on Cover	No. of Mapped Polygons
		Coffeeberry		135	0.43	35	71
		Poison Oak		28	0.09	57	17
		Holly-leaved Cherry – Coyote Brush					
		Coyote Brush (in part)					
		<i>Baccharis pilularis</i> / <i>Prunus illicifolia</i> (preliminary)		3	0.01	68	1
		Open Grassy - Yellow Bush Lupine - Coyote Brush					
		Coyote Brush (in part)					
		<i>Baccharis pilularis</i> / Non-native grassland (preliminary)		1299	4.15	6	252
		<i>Baccharis pilularis</i> - <i>Nassella pulchra</i>		84	0.27	42	34
		<i>Baccharis pilularis</i> / <i>Rubus ursinus</i> / Weedy		1053	3.37	7	247
		<i>Baccharis pilularis</i> / Native Grassland (preliminary)		651	2.08	14	155
		Yellow Bush Lupine		113	0.36	38	38
		Mixed Broom		61	0.19	45	60
Grassland-Herbaceous							
		Pacific Reedgrass - <i>Carex</i> - <i>Juncus</i>					
		Pacific Reedgrass					
		<i>Calamagrostis nutkaensis</i> / <i>Baccharis pilularis</i>		52	0.17	47	34
		<i>Calamagrostis nutkaensis</i> / <i>Carex</i> / <i>Juncus</i>		168	0.54	32	46
		Rush		523	1.67	17	249
		<i>Juncus effusus</i>		1	0.00	72	1
		Introduced Perennial Grassland - <i>Deschampsia</i>					
	‡	Tufted Hairgrass		165	0.53	33	29
		Introduced Coastal Perennial Grassland		564	1.80	16	145
		Native-Weedy Grassland					
	‡	California Annual Grassland Mapping Unit		5650	18.07	1	223
	†	California Annual grassland with Native Component Mapping Unit		1433	4.58	5	320
	†	Purple Needlegrass		21	0.07	63	8
		Bulrush - Cattail					
		Bulrush - Cattail - Spikerush Marsh Mapping Unit		49	0.16	50	31

Supercluster	Superalliance	Alliance/Mapping Unit	Association	Total Area (ha)	Relative Cover (%)	Rank Based on Cover	No. of Mapped Polygons
Salt Marsh							
		Pickleweed - Saltgrass					
		Saltgrass		68	0.22	44	43
	‡	Pickleweed		78	0.25	43	53
		<i>Salicornia virginica</i> / <i>Distichlis spicata</i> / <i>Jaumea carnosa</i>		18	0.06	64	10
		Cordgrass					
		Cordgrass		6	0.02	67	8

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Appendix E. Table of mapped vegetation types in San Mateo County on new NPS lands.

Table APP E.1. Mapped vegetation on newly acquired GOGA property in San Mateo County as mapped by May and Associates, Inc. and URS, Inc. Nomenclature and classification follow the Vegetation Management Classification (VMC) scheme, which was created by May and Associates, Inc. (URS 2009). Vegetation types and their spatial properties only reflect mapped areas that occur on NPS property ([Appendix B](#)). All nomenclature and spatial statistics were summarized from the GIS layer titled, "URS_Veg_NPSonly_PCC". Neither of these vegetation types nor their spatial abundance were factored into the selection process for determining which vegetation type to monitor in the coastal parks sampling frame ([Appendix A](#)). Non-wildlands are excluded; spatial calculations reflect only wild vegetation types.

General Physiognomy				
VMC Vegetation Type	Total Area (ha)	Relative Cover (%)	Rank Based on Cover	No. of Mapped Polygons
Forest and Woodland				
Eucalyptus	70	3.99	4	46
Monterey Cypress/Pine	42	2.38	5	157
Redwood Forest	1	0.03	12	3
Riparian Forest/Shrub	131	7.43	2	82
Shrubland				
Coastal Bluffs	10	0.54	9	3
Coastal Scrub	1351	76.54	1	221
Dune Scrub	<1	0.00	13	1
French Broom	2	0.14	10	11
Herbaceous Vegetation				
Cape Ivy*	14	0.81	7	65
Grassland	105	5.96	3	208
Herbaceous Wetland	14	0.78	8	19
Iceplant	1	0.04	11	14
Pampas Grass	24	1.36	6	80

*Cape ivy is often draped over shrubs or other woody plants.

Literature Cited

United Research Services (URS). 2009. Results of the 2009 vegetation and Cowardin wetland mapping for the Golden Gate National Recreation Area (GGNRA) newly acquired and expansion lands in San Mateo County, CA. Unpublished Report, URS Corporation, Oakland, California.

Appendix F. Table of mapped vegetation types at PINN.

Table APP F.1. Mapped vegetation from PINN based on Kittel et al. (2012) and taken from the GIS layer titled, "PINN_Veg_ParkSpecific." The corresponding park specific codes (from the "Park_Specific_PI" field) for each mapped type are also shown in parentheses. Nomenclature and classification is based on National Vegetation Classification (NVC) standards (Kittel et al. 2012). Double daggers (‡) indicate the vegetation types that will be sampled. A bullet symbol before the chamisal chaparral alliance indicates that this vegetation type will be split by north and south facing slopes and sampled separately. North facing stands will be sampled as mesic chaparral and south facing stands will be sampled as chamisal chaparral. This division is not reflected in the original GIS data. Non-wildlands are excluded; spatial calculations only reflect wild vegetation types.

General Physiognomy	Macrogroup / Group	Alliance	Association / Mapping Unit	Total Area (ha)	Relative Cover (%)	Rank Based on Cover	No. of Mapped Polygons
Forest and Woodland							
			Foothill Pine Woodland (1210)	39	0.37	20	41
			Foothill Pine/Chaparral Woodland Mapping Unit (1211)	157	1.50	13	126
			Foothill Pine/California Wild Buckwheat Alluvial Woodland Mapping Unit (1212)	18	0.17	31	17
			Foothill Pine/California Wild Buckwheat Thin Substrate Woodland Mapping Unit (1213)	12	0.11	35	8
	‡		California Juniper Woodland (1220)	16	0.15	33	13
			Coast Live Oak Woodland (2110)	271	2.59	8	214
			<i>Quercus agrifolia</i> / Annual Grass - Herb Woodland (2112)	19	0.19	30	13
			Coast Live Oak Alluvial Woodland Mapping Unit (2114)	58	0.55	18	47
			Interior Live Oak Woodland (2120)	1	0.01	44	1
			Blue Oak Woodland (2210)	24	0.22	26	20
			Blue Oak / Chaparral / Grass Woodland Mapping Unit (2211)	168	1.61	12	116
	‡		<i>Quercus douglasii</i> / Mixed Herbaceous Woodland (2212)	100	0.95	15	74
			<i>Quercus douglasii</i> – <i>Juniperus californica</i> Woodland (2213)	89	0.85	16	40
			Blue Oak - California Buckeye Woodland Mapping Unit (2216)	23	0.22	27	18
			Blue Oak - Foothill Pine Woodland Mapping Unit (2217)	334	3.19	4	146
			Blue Oak / Coastal Sage Scrub Woodland Mapping Unit (2218)	7	0.06	39	9
	‡		California Buckeye Woodland (2220)	34	0.33	21	35
Shrubland							
			California Chaparral Shrubland Macrogroup				
			Dry - Mesic Chaparral Shrubland Mapping Unit (3102)	270	2.58	9	197
	•		Chamise Shrubland (3110)	5845	55.81	1	948
			Chamise - Coastal Sage Scrub Shrubland Mapping Unit	724	6.92	2	332

General Physiognomy	Macrogroup / Group	Alliance	Association / Mapping Unit	Total Area (ha)	Relative Cover (%)	Rank Based on Cover	No. of Mapped Polygons
			(3114)				
			Chamise - California Wild Buckwheat Shrubland Mapping Unit (3115)	17	1.11	14	73
			Hollyleaf Cherry Shrubland (3150)	275	2.63	7	129
			California Scrub Oak Shrubland (3160)	21	0.20	29	21
			Coyote Brush Shrubland Macrogroup				
			Coyote Brush Shrubland (3210)	3	0.02	42	2
‡			California Coastal Scrub Shrubland Macrogroup (3300)	294	2.81	6	251
			California Wild Buckwheat Shrubland (3330)	58	0.55	19	42
			California Wild Buckwheat Alluvial Shrubland Mapping Unit (3331)	8	0.08	36	7
			California Wild Buckwheat Thin Substrate Shrubland Mapping Unit (3332)	25	0.23	24	18
			Silver Lupine Shrubland (3350)	17	0.16	32	9
			Black Sage Shrubland (3360)	14	0.13	34	12
			California Sagebrush - California Wild Buckwheat Shrubland (3370)	5	0.05	40	5
Herbaceous Vegetation							
		‡	Open to Sparse Grass on Thin Substrate Herbaceous Vegetation Mapping Unit (4003)	172	1.64	11	66
			Alluvial Herb and Shrub Vegetation Mapping Unit (4004)	25	0.24	23	20
‡			Mediterranean California Naturalized Annual and Perennial Grassland and Herbaceous Vegetation Macrogroup (4300)	324	3.09	5	201
			Post Burn and Post Disturbance Vegetation				
			Post Burn and Post Disturbance Undifferentiated Shrub and Grass-Herb Regeneration Mapping Unit (9700)	250	2.39	10	110
			Post Burn and Post Disturbance Californian Chaparral Shrubland Mapping Unit (9710)	23	0.22	28	17
			Post Burn and Post Disturbance Californian Xeric Chaparral Shrubland Mapping Unit (9720)	501	4.78	3	115
Riparian-Wetland Forest and Woodland							
			Southwestern N. American Riparian Evergreen and Deciduous Forest Group (1300)	61	0.58	17	39
			California Sycamore Temporarily Flooded Woodland (1310)	<1	0.00	46	2
			<i>Platanus racemosa</i> - <i>Quercus agrifolia</i> Woodland (1311)	8	0.08	37	4
			Valley Oak Woodland (2230)	2	0.02	43	2
			<i>Quercus lobata</i> – <i>Q. agrifolia</i> / Grass Woodland (2231)	28	0.27	22	17
			Valley Oak - Coast Live Oak / Mesic Grass Woodland Mapping Unit (2232)	7	0.06	38	2
			Riparian-Wetland Shrubland				

General Physiognomy	Macrogroup / Group	Alliance	Association / Mapping Unit	Total Area (ha)	Relative Cover (%)	Rank Based on Cover	No. of Mapped Polygons
	Southwestern North American Riparian / Wash Scrub Shrubland Group (3400)			24	0.23	25	23
	California Rose Shrubland (3410)			1	0.01	45	1
Riparian-Wetland Herbaceous Vegetation							
	Western North American Wet Meadow and Low Shrub Carr Herbaceous Vegetation Macrogroup (4500)			3	0.03	41	4
	Deergrass Herbaceous Vegetation (4510)			<1	0.00	47	1

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