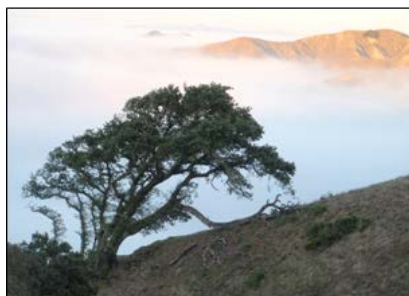




Terrestrial Vegetation Monitoring Protocol for the Mediterranean Coast Network—Cabrillo National Monument, Channel Islands National Park, and Santa Monica Mountains National Recreation Area

Narrative, Version 1.0

Natural Resource Report NPS/MEDN/NRR—2016/1296



ON THE COVER

Top: A view of Castro Crest from Gillette Ranch, Santa Monica Mountains. Marine fog has entered the valley, 7 km from the coast, through the Malibu Creek drainage. (T. Sagar)

Middle left: *Cupressus macrocarpa* on eastern Santa Cruz Island. Marine fog shrouds the canyons below the tree. (D. Rodriguez)

Middle right: Coastal terraces above tidepools on Point Loma. Marine fog has withdrawn to ocean. (K. Lombardo)

Bottom left: Federally threatened *Dudleya verityi* growing on the lichen *Niebla ceruchoides* in the western end of the Santa Monica Mountains. (T. Sagar)

Bottom right: First spring after a fire in Solstice Canyon, Santa Monica Mountains. (T. Sagar)

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John Tiszler¹, Dirk Rodriguez², Keith Lombardo³, Tarja Sagar¹, Luis Aguilar¹, Lena Lee⁴, Timothy Handley⁴, Kathryn McEachern⁵, Leigh Ann Harrod Starcewich⁶, Marti Witter¹, Tom Philippi⁷, Stacey Ostermann-Kelm⁴

¹National Park Service
Santa Monica Mountains NRA
401 W. Hillcrest Drive
Thousand Oaks, CA 91360

²National Park Service
Channel Islands National Park
1901 Spinnaker Drive
Ventura, CA 93001

³National Park Service
Cabrillo National Monument
1800 Cabrillo Memorial Drive
San Diego, CA 92106

Editor
Sonya Daw
National Park Service
Inventory and Monitoring Program
Flagstaff, AZ 86001

⁴National Park Service
Inventory and Monitoring Program
Mediterranean Coast Network
401 W. Hillcrest Drive
Thousand Oaks, CA 91360

⁵U.S. Geological Survey
Western Ecological Research Center
Channel Islands Field Station
1901 Spinnaker Drive
Ventura, CA 93001

⁶Statistical Consultant
PO Box 1032
Corvallis, OR 97339

⁷National Park Service
Inventory and Monitoring Program
c/o Cabrillo National Monument
1800 Cabrillo Memorial Drive
San Diego, CA 92106

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National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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Change History

Version numbers will be incremented by a whole number (e.g., Version 1.3 to Version 2.0) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.6 to Version 1.7) when there are minor modifications that do not affect requirements or procedures for publication in the series. Minor modifications to SOPs are recorded within individual SOPs.

The following revisions have occurred to this protocol since August 2016.

Previous Version #	Date	Revised by	Changes	Justification	New Version #

- Record the previous version number, date of revision, author of the revision, paragraphs and pages where changes were made, the reason for making the changes, and the new version number.
- Notify the MEDN Data Manager of any changes to the protocol narrative or SOPs so that the new version number can be incorporated in the metadata of the project database.
- Post new versions on the internet and forward copies to all individuals with a previous version of the protocol narrative or SOPs.

Abstract

The Mediterranean Coast Network (MEDN) parks protect and conserve important elements of the unique and highly threatened flora of southern California. The shrub-dominated vegetation of these parks is defined by and in turn defines ecosystem processes that support a large number of rare and endemic plant and animal species. Vegetation diversity within the MEDN is threatened by past and present activities associated with intensive human development, including land loss to housing, land conversion to agriculture, changing fire regimes, introduction of exotic species, and intensive recreational use. We expect that climate change will exacerbate these threats. A vegetation monitoring program is a necessary element in protecting against multiple, interacting, and potentially unknown drivers of vegetation change. We will monitor compositional and structural elements of vegetation that can be used to identify and document change and to study the processes by which change occurs. These elements include species cover, shrub and tree species density, species richness, and soil cover type. The target population is all terrestrial vegetation occurring in the MEDN parks. Permanent plots will be selected using a random, spatially balanced design that represents plant communities and environmental covariates in proportion to their areal occurrence. Channel Islands National Park will, in addition to employing new randomly selected plots, also continue monitoring existing index sites within major plant communities that were established under their monitoring program begun in 1984. Sites will be monitored using a serially alternating panel revisit design where plots are rested for 3-4 years between monitoring events. Annual status reports and periodic trend reports will be published.

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In developing this protocol we drew on draft and approved vegetation monitoring protocols produced by the NPS and other agencies. We are particularly indebted to the authors of the Sonoran Desert Network terrestrial vegetation, Upper Columbia Basin Network sagebrush steppe, North Coast and Cascades Network forest vegetation and Channel Islands National Park (prototype) terrestrial vegetation monitoring protocols and to Douglas H. Deutschman, Janet Franklin, and colleagues for their published work on the San Diego County Multiple Species Conservation Plan.

We thank Penny Latham, Lisa Garrett, Jon Bakker and two anonymous reviewers for their comments on previous versions of this protocol. We also thank Sonya Daw for formatting and editing this document.

List of Standard Operating Procedures (SOPs)

This report is linked to the following Standard Operating Procedures (SOPs), which are available from:

Tiszler, J., D. Rodriguez, K. Lombardo, T. Sagar, L. Aguilar, L. Lee, T. Handley, K. McEachern, L. Starcevich, M. Witter, T. Philippi, and S. Ostermann-Kelm. 2016. Terrestrial vegetation monitoring protocol for the Mediterranean Coast Network—Cabrillo National Monument, Channel Islands National Park, and Santa Monica Mountains National Recreation Area: Standard Operating Procedures, Version 1.0. Natural Resource Report NPS/MEDN/NRR—2016/1296.1. National Park Service, Fort Collins, Colorado.

SOPs 1a, 5a, and 7a correspond to the supplemental Post-Fire monitoring methods in Appendix D.

SOP 1: Preparations for the Field Season

SOP 1a: Preparations for Post-Fire Field Season

SOP 2: Recruitment and Observer Training

SOP 3: Safety

SOP 4: Field Navigation and GPS Procedures

SOP 5: Establishing Monitoring Plots

SOP 5a: Establishing Post-Fire Monitoring Plots

SOP 6: Revisiting Monitoring Plots

SOP 7: Vegetation Plot Monitoring

SOP 7a: Post-Fire Vegetation Monitoring

SOP 8: Collecting and Identifying Unknown Plants

SOP 9: Data Entry, QA/QC, and Processing

SOP 10: Photograph Processing

SOP 11: Field Season Closing Activities

SOP 12: Database Structure

SOP 13: Data Management, Storage, and Archiving

SOP 14: Data Analysis

SOP 15: Obtaining Permits (SAMO)

SOP 16: Revising the Protocol

List of Acronyms

ANI:	Anacapa Island
CA-1:	federal employee's notice of traumatic injury form
CABR:	Cabrillo National Monument
CHIS:	Channel Islands National Park
CPR:	cardiopulmonary resuscitation
DBH:	diameter breast height (140 cm, 4.5 ft)
FGDC:	Federal Geographic Data Committee
GIS:	geographic information system
GPS:	geographic positioning system
GRTS:	generalized random tessellation stratified (sampling design)
GSA:	United States General Services Administration
I&M:	NPS Inventory and Monitoring Program
MEDN:	Mediterranean Coast Network of the NPS Inventory and Monitoring Program
NPS:	National Park Service
OPM	Office of Personnel Management
QA/QC:	quality assurance / quality control
SAMO:	Santa Monica Mountains National Recreation Area
SBI:	Santa Barbara Island
SCI:	Santa Cruz Island (specifically, the eastern 25% owned by NPS)
SMI:	San Miguel Island
SOP:	standard operating procedure
SRI:	Santa Rosa Island
TNC:	The Nature Conservancy
USGS:	U.S. Geological Survey

1 Introduction

The purpose of the National Park Service (NPS) Inventory & Monitoring (I&M) Program is to develop and provide scientifically credible information on the current status and long-term trends of the composition, structure, and function of park ecosystems, and to determine how well current management practices are sustaining those ecosystems (NPS 2014a). As part of the NPS's effort to improve park management through greater utilization of scientific knowledge, the primary role of the I&M Program is to collect, organize, and make available natural resource data and to contribute to NPS institutional knowledge by transforming data into information through analysis, synthesis, and modeling of key vital signs. The I&M Program defines vital signs as a subset of physical, chemical, and biological elements and processes of park ecosystems that is selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values (Fancy et al. 2008).

The five goals of the I&M Program are to

1. Inventory the natural resources and park ecosystems under NPS stewardship to determine their nature and status
2. Monitor park ecosystems to better understand their dynamic nature and condition and to provide reference points for comparisons with other, altered environments
3. Establish natural resource inventory and monitoring as a standard practice throughout the NPS system that transcends traditional program, activity, and funding boundaries
4. Integrate natural resource inventory and monitoring information into NPS planning, management, and decision making
5. Share NPS accomplishments and information with other natural resource organizations and form partnerships for attaining common goals and objectives

These goals are accomplished through parkwide inventories and long-term monitoring programs. In establishing a servicewide natural resources I&M Program, the NPS created networks of parks that are linked by geography and shared natural resource characteristics. Working within and across networks improves the efficiency of inventory and monitoring because parks are able to share budgets, staffing, and other resources to plan and implement an integrated program.

The Mediterranean Coast Network (MEDN) is one of 32 monitoring networks across the NPS. The MEDN comprises three NPS units (Figure 1): Cabrillo National Monument (CABR), Channel Islands National Park (CHIS), and Santa Monica Mountains National Recreation Area (SAMO).

The MEDN vital signs monitoring plan (Cameron et al. 2005) provides the foundations for the long-term ecological monitoring programs of the network and describes the rationale and basis for the programs.

The protocol described in this document is for terrestrial vegetation (plant community) monitoring. The objective of the MEDN Terrestrial Vegetation monitoring program is to determine the status and long-term trends in species composition, richness, and abundance in the vegetation of the three

MEDN park units, for use in developing and evaluating management actions. Other MEDN vital signs monitoring protocols that address plants and vegetation are the Invasive Plant (Irvine et al. 2016), Landscape Dynamics (Willis et al., in review) and Water Quality and Riverine Integrity (Federico et al., in preparation) protocols. Both CHIS and SAMO have programs to monitor rare plant species, but these are not part of the I&M program.

This protocol describes new programs at CABR and SAMO, and a modification of an existing program at CHIS. For over 25 years, CHIS has conducted a long-term vegetation monitoring program as one of the four I&M Program prototype parks. Annual sampling began on Anacapa (ANI), Santa Barbara (SBI), and San Miguel (SMI) Islands in 1984, Santa Rosa Island (SRI) in 1989, and Santa Cruz Island (SCI) in 1998 (Halvorson et al. 1988, Johnson and Rodriguez 2001, Rodriguez 2006). A 2001 technical program review (McEachern 2001) resulted in some additions and changes to the methodology used at each sample site, as well as recommendations for future expansion and improvement of the program. This protocol presents a strategy for revising and updating the CHIS program to take advantage of advancements in experimental design and statistical analysis while preserving continuity with the data already collected.

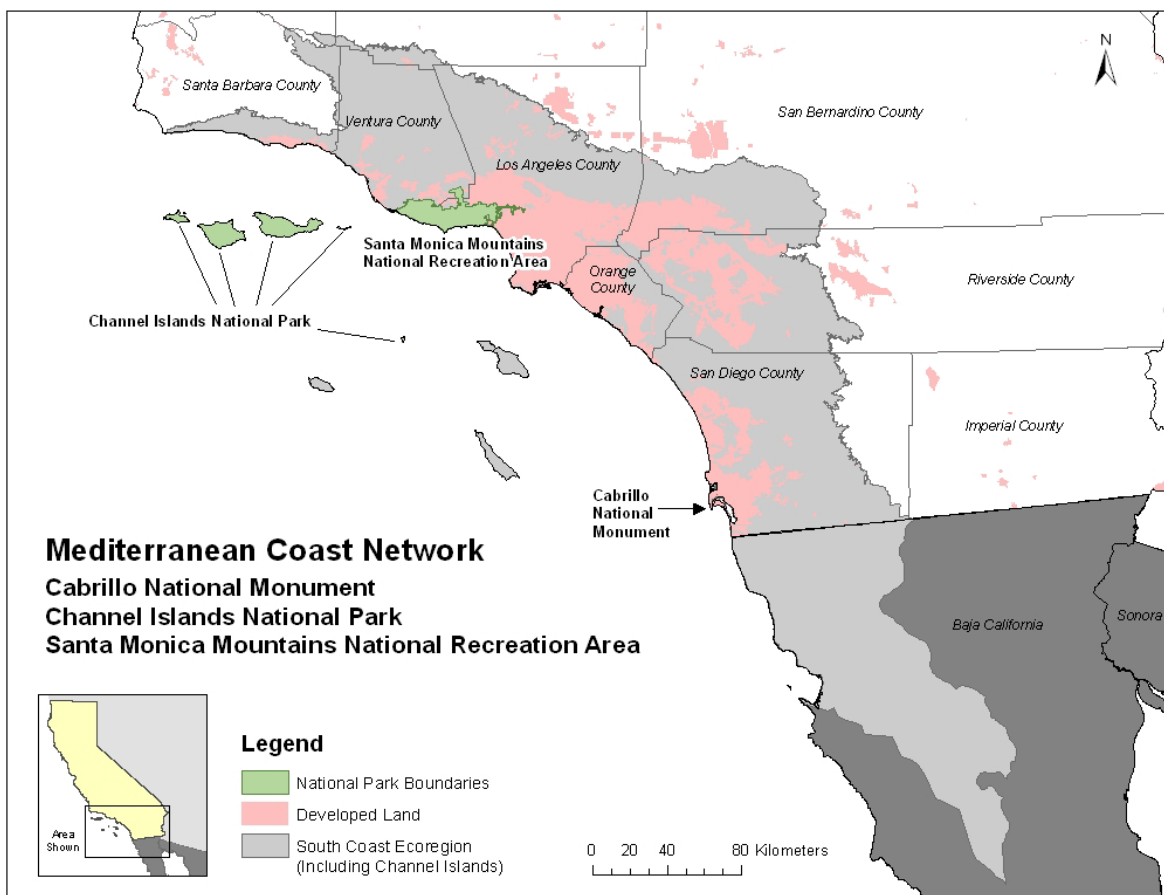


Figure 1. Location of the three parks of the Mediterranean Coast Network within the South Coast Ecoregion. The ecoregion encompasses approximately 8% of California (3.4 million ha) and extends over 300 km into Baja California Norte.

2 Background and Objectives

2.1 Monitoring Need

Preserving biodiversity is a key responsibility of the MEDN parks. The variety of past vegetation change and the complexity and unknown nature of future ecological threats create uncertainty for land managers. Experience has shown that threats are best managed through informed, early and coordinated actions. Detecting and understanding the complexity of vegetation change is therefore critical for developing effective management strategies. A long-term monitoring program that provides for routine evaluation of the status and trends in vegetation communities is essential to meeting this need. The monitoring program described in this document will meet these critical information needs and enable staff to make more effective management choices at all three parks in the MEDN.

2.2 Rationale for Monitoring Vegetation in the Mediterranean Coast Network

2.2.1 High Biodiversity and Unique Vegetation of MEDN Parks

California's South Coast Ecoregion, here defined to include the Channel Islands (Hickman 1993; Bailey et al. 1994), has high biological diversity. The region supports more than 30% of California's native plant species while comprising less than 10% of the state's land area (California Department of Fish and Game 2008). More endemic plant and animal species occur in this ecoregion than any other ecoregion in the country (Stein et al. 2000). This species richness and high endemism is contained within and supported by a comparable diversity of vegetation assemblages. Native vegetation communities are mostly shrublands typical of Mediterranean-climate regions, composed primarily of evergreen chaparral and summer-deciduous sage scrub occurring in association with woodland, grassland, riparian and coastal bluff communities (Rundel and Tiszler 2007). These broad community types are acted upon by a spatially complex set of environmental factors including geology, topography, soils, gradients in moisture and temperature regimes, fire history, and land use history, which create a panoply of vegetation alliances and associations unique to the region (Conservation Biology Institute 2001; Barbour et al. 2007; Keeler-Wolf et al. 2007; Sproul et al. 2011).

The vegetation within the three MEDN parks is representative of the breadth of floristic and vegetation diversity in the South Coast Ecoregion. The Point Loma peninsula of San Diego (CABR) is located at the transition between the coastal sage scrub of southwestern California and the maritime succulent scrub characteristic of northwestern Baja California (Stein et al. 2000; Rundel 2007). The four northern Channel Islands have floristic affinities with coastal central and northern California (Junak et al. 2007). Santa Barbara Island and the Santa Monica Mountains are representative of the central portion of the ecoregion, with a range of vegetation types reflecting a gradient from wet maritime conditions to dry inland valleys (Junak et al. 2007; Keeley and Davis 2007; Rundel 2007). Together, the MEDN parks contain 1,031 native plant taxa—about 25% of the native taxa found in the California Floristic Province (Hickman 1993). Only 10% of these species occur in all three parks (NPS 2014b). The Santa Monica Mountains contain 15 endemic plant taxa, while the Channel Islands contain a remarkable 75 endemic plant taxa. This species richness occurs in a complex mosaic of over 110 vegetation alliances and 250 vegetation associations (Keeler-Wolf

and Evens 2006; Junak et al. 2007; Keeler-Wolf and Klein 2010). Shrubland alliances occurring in the MEDN parks represent 40% of those defined for the California Floristic Zone in the Manual of California Vegetation (Sawyer et al. 2009).

2.2.2 Threats to Vegetation

Urbanization and historical land use

Along with exceptional richness in flora and fauna, the South Coast Ecoregion is distinguished by the tremendous population growth and urban expansion that has occurred since the 1940s (Bunn et al. 2007). While the South Coast Ecoregion constitutes 10% of California's land area, it contains nearly 50% of the state's population (20 million people). A defining characteristic of this population growth is the juxtaposition of urban landscapes with parklands and other natural areas (Bunn et al. 2007). The resulting combination of habitat loss and fragmentation threaten the long-term sustainability of ecosystems and organisms protected in parklands. There are also significant immediate and ongoing effects of population growth on protected areas. These include polluted air, changed hydrological and nutrient cycles, biological invasions, altered fire regimes, and impacts from heavy recreational use (Flather et al. 1998; Minnich and Dezzani 1998; Paul and Meyer 2001; Rundel and King 2001; Groffman et al. 2002; Allen et al. 2005; Keeley 2005; CDFG 2008).

Urban development, in conjunction with earlier land conversion for ranching and crop production, has transformed the landscape and had a profound impact on biodiversity. The entire California Floristic Province is recognized as a global biodiversity "hotspot" because of its exceptionally high levels of plant endemism and biodiversity coupled with ongoing history of natural habitat degradation and destruction (Myers et al. 2000). Southern California is a "hotspot within a hotspot" of threatened and endangered species, with over 200 plant species listed as protected or considered sensitive (Wilcove et al. 1998; Stein et al. 2000; McEachern et al. 2007; Hunter 1999). Coastal sage scrub, a unique and defining component of South Coast vegetation, is estimated to be reduced to between 10% and 44% of its extent at the beginning of European settlement (Taylor 2005). The majority of oak savannas and woodlands in the region have been cut down, and most coastal habitats have been highly altered (Ricketts et al. 1999). The MEDN parks protect some of the best remaining examples of these vegetation types, harboring 25 federally listed threatened or endangered plant taxa.

Just as the MEDN parks represent the breath of floristic and vegetation diversity in coastal southern California, they also represent the range of past and present environmental disturbances in the type, degree, and trajectories they experience. The last two centuries of social and ecological history of southern California can be traced through these parks.

SAMO is the most urban of the three MEDN parks and is affected by all of the stressors associated with population growth and urbanization. The effects of biological invasions and altered fire regimes are particularly evident here. Non-native species have become established in almost all native plant communities (Rundel 2000; Keeler-Wolf et al. 2007), and increasing anthropogenic fire frequency has resulted in localized type conversion from native vegetation to non-native annual grasslands (Keeler-Wolf 1995; Keeley 2005; Keeley et al. 1999; Witter et al. 2007). Population growth is projected to continue at a rapid pace (California Department of Finance 2013), and despite efforts to

mitigate adverse impacts, the direct and indirect effects of growth are expected to increase in the Santa Monica Mountains (Syphard et al. 2008, 2009). It is difficult to anticipate how these multiple, interacting stressors will affect native vegetation communities.

At CABR, urban development and land use is also a substantial threat to the integrity of the native plant communities. However, unlike at SAMO, the threat to CABR does not come from urban encroachment, but from the effects of isolation. Surrounded by urban development, military infrastructure and water, CABR is an isolated island of natural habitat at the southern tip of the Point Loma peninsula. The surrounding residential and military development serves as a source of non-native species introductions while at the same time limiting the ability of native species to disperse, restricting the flow of genetic material into and out of the park. Fire, never frequent at CABR, has been effectively excluded by military development. The absence of fire is a potential long-term threat to at least one unique community dominant, *Ceanothus verrucosus*, which requires fire to germinate. At the same time, many other unique elements of the flora, especially succulents, are fire intolerant and may have developed to their current extent because of fire exclusion (Zedler et al. 1995).

CHIS stands in sharp contrast to SAMO and CABR, both in the nature of impacts and the trajectory of disturbance. The islands have not been subject to urban development and are buffered by the Pacific Ocean from the direct effects of increasing population growth, urban development, and habitat conversion that are occurring on the mainland. Regional population growth, however, has and will continue to result in increased recreational use of the islands, increasing the likelihood of accidental introduction of non-native invasive plants or other organisms to the islands.

Ranching and farming were important activities on all of the islands from the mid-1800s through the 1900s. Just as urbanization has acted on the mainland, ranching and farming have destroyed and fragmented island habitats (Hobbs 1980; Junak et al. 1995) and have created cascading effects on many aspects of ecosystem function (McEachern 2004). Up to 75% or more of the native land cover on each island was altered either from plowing and planting of crops or overgrazing that occurred as introduced animals became feral and their population numbers soared into the tens of thousands (Clark et al. 1990; Junak et al. 1995). The result was topsoil erosion (Cole and Liu 1994), conversion of native scrub to non-native annual grassland (Halvorson et al. 1997), and the reduction of native vegetation and endemic plant species habitats to remnant, fragmented stands (Clark et al. 1990; Halvorson et al. 1992; McEachern et al. 1997; Christian 2009; McEachern et al. 2009).

In recent years, the NPS has made a strong systematic effort to remove introduced herbivores from CHIS. Successful removal of most of the introduced herbivores has led to large changes in plant community composition and increases in the range of many native species (Junak et al. 2007; Dirk Rodriguez, CHIS botanist, unpublished data). While invasive plants have also spread dramatically, the islands are in many ways a recovering ecosystem. In all of California, these islands are one of the few places in which disturbance is decreasing rather than increasing, and in which native vegetation and threatened endemic species are expanding rather than contracting.

Invasive Species

The introduction and spread of non-native plant species is perhaps the most significant threat to native diversity in the MEDN parks, as it is in natural areas throughout California and the nation (Wilcove et al. 1998; Pimentel et al. 1999; Powell et al. 2011). Presently, non-native plants comprise 27% of the Channel Islands flora, 31% of the Santa Monica Mountains flora, and 37% of the Point Loma (CABR) flora (NPS 2014b). The introduction of non-natives is generally associated with urban, agricultural or ranching activities. Introductions may be purposeful or accidental, and are often associated with stresses to the landscape created by human activities. Once introduced, non-natives may spread beyond the bounds of the disturbance that enabled their introduction (Dowell and Krass 1992; Morse et al. 1995). Thus, as the scope of human activities is only expected to increase, the numbers and abundance of non-native species are also expected to increase.

While many non-natives simply become a minor element in the landscape, others are invasive. Invasive species have the capacity to out-compete native plants, to alter habitats, and to reduce native wildlife habitat quality (Pimentel et al. 1999; Bossard et al. 2000). In the worst case, invasive species alter ecosystem function in a way that promotes their further spread (Richardson et al. 2000). Aggressive invasive plant species are common or threaten to become common at each of the MEDN parks. We have found that invasive species can only be controlled through active, coordinated, long-term management efforts predicated on an understanding of how they spread within and alter the composition and function of native communities.

Fire

Fire is a dominant evolutionary and ecological force shaping California plant communities, and changes in fire regime can result in significant changes in vegetation composition and structure. (Sugihara et al. 2006; Keeley et al. 2012). Natural fire events at CHIS and CABR are rare because of their maritime climates and low natural ignition rates. The relative isolation of both of these parks (and at CABR, effective fire prevention and control by the military) insulates them from the anthropogenic fires that sweep many other vegetated areas in southern California.

In contrast, large wind-driven fire events occur several times each decade at SAMO. Natural, lightning-ignited fires are uncommon in the low-elevation coastal Santa Monica Mountains, while anthropogenic fires are frequent due to human activities within and surrounding the recreation area (Keeley et al. 1999; Taylor 2004; Keeley 2005). These fires are important episodic events, which are unpredictable in time and extent, and which can result in rapid and dramatic vegetation change. Fires fully consume existing stands of shrubland vegetation and create the possibility for dramatic shifts in vegetation composition and species abundances. The exact nature of these changes depends on the interacting influences of pre-fire vegetation, site fire history, fire conditions, post-fire weather events, and the presence of invasive species (Zedler et al. 1983; Frazer and Davis 1988; Thomas and Davis 1989; Borchert 1995; Keeler-Wolf 1995; Keeley 1998; Jacobsen et al. 2004; Keeley, Baer-Keeley, Fotheringham 2005; Keeley, Fotheringham, and Baer-Keeley 2005; Witter et al. 2007; Pratt et al. 2010).

In the immediate post-fire years there is a flush of short-lived herbaceous and suffrutescent (somewhat shrubby) fire-followers that flourish and then die (Keeley and Davis 2007). These post-

fire species are a substantial and unique component of the Santa Monica Mountains flora and contribute significantly to our overall plant diversity (Keeley et al. 1981; Raven et al. 1986). Long-term threats to this post-fire flora, particularly from increasingly ubiquitous non-native annual grasses, are poorly understood and not well studied.

Climate Change

Global and regional climate models indicate that coastal southern California is a “hotspot” for climate change (Cayan et al. 2006). Multiple models predict that temperatures in southwestern California in most months will increase by approximately two degrees centigrade over the next 100 years. Model predictions for precipitation vary from no change to a decrease of more than 35% (PRBO 2011). The anticipated result of these changes will be a general latitudinal shift of climate zones northward, with projected losses of up to 40% of existing shrublands and a concomitant increase in non-native grasslands of over 350% (Moser et al. 2009, PRBO Conservation Science 2011). If climate changes in the manner predicted, it will exacerbate the negative effects of past land use and continued human population growth (Stephenson and Calcarone 1999; Keeley et al. 2000; Kus and Beyers 2005; Underwood et al. 2009).

2.3 Brief History of Monitoring at MEDN Parks

2.3.1 Monitoring at CABR

The U.S. Geological Survey (USGS) monitored vegetation at CABR from 1994 through 2008, employing 50 m line-point intercept transects to quantitatively describe species composition and vegetation structure in the major plant communities. The park was stratified along the Point Loma peninsula crest into two subunits with roughly east (bay side) and west (ocean side) facing aspects. An approximately equal number of sample locations were randomly selected in each of the two strata. The inference area is the entire park, with the exception of developed areas, roads, trails, and tidepool areas. Transects were monitored in 1994, 1998, 2003, and 2008, with new locations selected for each monitoring event. The number of transects monitored was set by the availability of staff and volunteers. Transects increased from 19 in 1994 to 29 in 2008. These transects employed the same basic field procedure as described in this protocol. The USGS monitoring protocol will be replaced by the new protocol described in this document.

2.3.2 Monitoring at CHIS

The original Channel Islands terrestrial vegetation monitoring program was designed and implemented in 1984 (Halvorson et al. 1988). At that time, the park consisted of only SBI, ANI, and SMI. CHIS acquired SRI in 1987 and began monitoring on that island in 1990. CHIS acquired the east end of SCI in 1997 and began monitoring that area in 1998. In 2001, The Nature Conservancy (TNC) donated the isthmus portion of SCI to the NPS, and CHIS began monitoring in 2006–2007. CHIS staff have conducted annual monitoring of all islands since the inception of the monitoring program on each island (Halvorson et al. 1988; Rodriguez 2006).

Most of the monitoring sites were selected based on subjective judgment of the representativeness of vegetation types. Some of the more recent sites, however, were selected using stratified random sampling. The monitoring response design uses 30 m line-point transects, but also includes some earlier established transects on SBI and ANI that are of longer length (Halvorson et al. 1988;

Rodriguez 2006). In the late 1990s, it was decided that estimates of shrub density would be helpful in understanding the recovering ecosystems of CHIS, and shrub and tree monitoring protocols based on belt transects were added to the program (McEachern 2000). A fuller description of the CHIS monitoring history, including site selection methods and allocation of monitoring plots among plant communities on each island, is provided in Appendix A.

2.3.3 Monitoring at SAMO

SAMO does not have an existing long-term vegetation monitoring program. The park has had a fire effects monitoring program since 1990. A detailed association-level vegetation map was completed in 2007. Vegetation maps were also created for the area in the 1930s (Wieslander 1935) and accurate fire occurrence maps go back to the early 1900s. In addition, numerous vegetation surveys and studies have been implemented by university researchers over the years. While this information has guided development of the MEDN monitoring protocol and will inform interpretation of data resulting from its implementation, no historical monitoring data exists at SAMO that could be incorporated into the protocol.

2.4 Monitoring Objectives

The three parks within MEDN seek to maintain and restore native ecosystems and ecological processes with the goal of preserving native vegetation and species diversity. Plant invasion, anthropogenic and climatically driven changes in community composition and species abundances, and loss of species diversity are all cited as concerns in the resource management plans for the MEDN parks. These principal concerns for park managers are addressed by our monitoring objective:

Determine the status (current condition) and trends in species composition, richness, and abundance within the terrestrial vegetation of MEDN parks, including post-fire changes in vegetation.

To achieve this objective we will quantitatively monitor the following plant parameters:

- Foliar cover – all plant species.
- Density of shrubs and trees (also basal area of trees) – seedling, sapling/juvenile, mature, dead.
- Species richness – all species occurring in a monitoring plot.
- Species frequency – number of times a species is present in a group of monitoring plots.
- Soil cover type – biological crust, litter, rock, soil.

All of these parameters provide information on composition and structure only; changes in these parameters over time and space will provide information for understanding process. Parameters will be monitored with permanent transects placed in a random, spatially balanced design that results in communities and environmental covariates being sampled in proportion to their areal occurrence. CHIS will also monitor a set of index sites that were selectively placed to target major plant communities and continue long-term data collection at selected sites established under their prototype monitoring program. Post-fire monitoring sites will include any permanent transects that

were burned plus an additional set of temporary sites selected with the same random, spatially balanced sampling protocol used for selecting long-term monitoring plots.

The information gathered through this monitoring program will be complemented by vegetation community change analyses completed as part of the MEDN landscape dynamics monitoring program (Willis et al., in review). These landscape analyses will allow us to document boundary shifts and vegetation type conversions among communities. SAMO and CHIS (but not CABR) will also have an early detection protocol for monitoring new occurrences of invasive plants at points of entry (e.g., trailheads, ports) to the park (Irvine et al. 2016), and SAMO (but not CHIS or CABR) will have a program for monitoring the spread of selected invasive species along roads and trails.

Results from this monitoring program will be of both scientific interest and practical utility. These data will provide insight into the patterns and processes that govern Mediterranean ecosystems in southern California. The information provided by this monitoring program on vegetation change will guide us in defining studies that determine the drivers of these changes and in formulating management responses. Similarly, the data obtained will provide managers with the information necessary to evaluate progress in their efforts to maintain the unique diversity of native plant communities within MEDN parks.

3 Sampling Design

In this section we describe the rationale for our sampling design, the target populations and sampling frames, the site selection procedures, and the revisit design for the three parks. The three parks are similar in vegetation physiognomy, but differ in their geographic size, mix and complexity of vegetation, configuration of parklands, travel logistics, access limitations, and monitoring history. The parks thus have common monitoring objectives, target populations, and site selection procedures, but differ in their sampling frames and revisit designs.

3.1 Rationale for Sampling Design

3.1.1 Need for Flexibility and Broad Utility in Long-term Monitoring

Long-term environmental monitoring programs should be designed to accommodate multiple uses of data, including the incorporation of new objectives arising from unanticipated environmental changes. Such programs should also be amenable to the application of analyses not foreseen at the time the program was designed (Manly 2009). We anticipate that the MEDN parks will experience potentially rapid and unpredictable vegetation changes as regional stressors interacting with climate change assert ever-stronger influences. Consequently, our sampling design must provide for flexibility in data analysis as novel patterns and trends emerge and new management questions arise.

Broad utility is best achieved by use of an equal probability random sampling design that imposes minimum structure on the data collected, provides inference to the entire population of interest, and requires only common data analyses to interpret (Overton and Stehman 1996). Broad utility, however, typically sacrifices precision in estimation of population state variables that otherwise would be gained by applying specialized designs or by stratifying the population into aggregations of similar units (Thompson 2002; Stevens and Olsen 2004).

To obtain broad utility while preserving as much precision (power) of estimation as possible, we will use a Generalized Random Tessellation Stratified (GRTS) sampling design that produces sets of randomly selected, spatially balanced monitoring locations (Stevens and Olsen 2003, 2004). Spatially balanced, equal probability site selection improves representation of a feature or covariate of interest according to the area occupied by that feature or covariate, but imposes minimal design structure and avoids the common problem of stratifying based on incomplete information or by vegetation types, which may change over time. This design provides an opportunity for parkwide inference without requiring the *a priori* assumptions that would be necessary for conventional sample stratification.

3.1.2 Continued Monitoring of Existing CHIS Sites

This vegetation monitoring protocol is a new program for SAMO and CABR, but a change in the existing monitoring program at CHIS, which began in 1984. The monitoring program on ANI, SBI, SMI, and SRI was designed using a set of subjectively selected “index” (of change) sites within major plant communities using relevé data and vegetation maps for the purpose of examining recovery after nearly a century of grazing. Sites on SCI were selected using stratified random sampling, with stratification based on watersheds (Halvorson et al. 1988; McEachern 2001; Appendix A).

These index sites are important for monitoring and understanding vegetation dynamics on SBI, ANI, SRI, and SMI. However, because the index sites were subjectively located, data from the original monitoring design do not allow for statistical inference to all of the vegetation on these islands. In addition, although the SCI sites were randomly selected and provide inference to the larger study area, the selection process differed from the probabilistic design that will be employed in this protocol and the SCI sites will therefore be treated as index sites.

Under this new protocol we will continue monitoring the 181 established index sites, although on a less frequent basis, and add 184 new probabilistically selected monitoring sites that will provide statistical inference to all of the vegetation at CHIS. The two datasets will be analyzed separately but interpreted with respect to each other. We will maintain continuity with the existing CHIS dataset (McEachern 2001).

The CHIS index sites are important to our understanding of vegetation dynamics and valuable in guiding and evaluating efforts to restore native plant communities. The vegetation on all of the islands has been adversely affected by human activities, most significantly from the introduction of non-native herbivores. After nearly four decades of effort, at great expense, and with sometimes considerable public controversy, all non-native herbivores have been removed from CHIS, and all islands are now in the process of recovery. The more than 30 years of data from the index sites have been and continue to be indispensable in documenting and assessing native plant species recovery following these herbivore removals. The data provide the highest quality and most detailed record that we have of pre-removal vegetation and of the sometimes dramatic post-removal changes that are occurring in that vegetation.

The value of the index sites extends beyond their ability to illuminate herbivore-related questions. The existing CHIS vegetation monitoring data are one of a very few long-term vegetation datasets, and the only such dataset in the region. These data have the ability to provide knowledge of a kind that shorter-term datasets cannot. For example, the CHIS data provide a detailed 30-year record of vegetation response to interannual variation in weather regimes.

As data from the probabilistically selected sites accumulate, we will explore the feasibility of replacing index sites with additional probabilistically selected sampling sites. We will also examine the possibility of integrating the two types of sites. It may be possible to combine information from subjectively selected sites and probabilistically selected sites in such a way as to have valid inference at a broad scope with greater sensitivity than would be possible from just using the probabilistic sites (e.g., Overton et al. 1993; Stoddard et al. 1998; Schreuder et al. 2001; Brus and De Gruijter 2003; Paul et al. 2008). Additional information on the possibility of using index sites to help with estimation of status and trend is provided in SOP 14.

3.2 Target Population and Sampling Frames

The target population for the MEDN vegetation monitoring program is all terrestrial vegetation occurring on park-owned lands and on other protected lands within or adjacent to the administrative boundaries of each park, as described below. This includes native and non-native vegetation, areas of disturbed vegetation that are otherwise unmaintained, and restored native plant communities. It

excludes vegetation associated with development and areas that are perpetually disturbed or maintained. Vegetation within 5 m of roads, trails, and other development is also excluded from the target population, as we consider these areas perpetually disturbed.

Vegetation occurring on slopes greater than 40 degrees meets the definition of our target population, but must be excluded, as this vegetation cannot be safely monitored (but see discussion of CHIS West ANI below). Working on these steep slopes is dangerous to field crews and damaging to the monitoring sites. At SAMO we will also reject any plots that on visitation are determined to be unmeasurable or inaccessible due to dense stands of poison oak (*Toxicodendron diversilobum*) and any plots that require more than 7.5 hours to access, measure, and return from to park headquarters. This time limit was set for safety; it prevents the crew from becoming overly tired and allows for sufficient extra time should difficulties arise. Field work to date has shown that time to and from a site is only roughly related to distance; travel time is also a strong function of terrain and vegetation density (i.e., how difficult it is to crawl beneath chaparral).

For CHIS there are five sampling frames, one each for ANI, SBI, SMI, and SRI; and one for the NPS-owned portion of SCI. SAMO has a single noncontiguous sampling frame that includes federal, state, and local parklands within and adjacent to the recreation area. CABR has a single contiguous frame that includes all NPS land and some adjoining US Navy land managed by the park.

Additional areas may be added to the sampling frames in the future if additional lands are acquired, interest in participation by other land management agencies within and adjacent to park boundaries increases (e.g., TNC on SCI, US Navy on Point Loma), or additional funding to expand the program becomes available.

3.2.1 CHIS

The target population for the CHIS monitoring program is all vegetation on undeveloped lands managed by the NPS within the administrative boundary of the park. This includes the entirety of ANI, SBI, SMI (owned by the US Navy), and SRI, and the eastern quarter of SCI. The combined area of these lands is about 32,000 ha (Figure 2). The western three-quarters of SCI are within the administrative boundary of the park, but are owned and managed by The Nature Conservancy (TNC). At current funding levels, monitoring of TNC lands on SCI by NPS personnel is not possible.

Each island is considered a separate stratum, with monitoring site density differing among islands. This is justified by differences in ecology and land use history among the islands, as well as by travel, logistical, and budget constraints that affect the allocation of monitoring effort to each island (Appendix A).

For all islands other than West ANI, areas with slopes greater than 40 degrees were excluded from the sampling frame. Exclusion of these steep locations results in loss of inference to about 3% of SMI, 8% of SRI, 9% of SBI, 20% of the NPS-owned lands on SCI, 16% of East ANI, and 23% of Middle ANI. On West ANI, 37% of the land has a slope greater than 40 degrees and complete exclusion of these slopes would result in loss of inference to an unacceptably large portion of the islet. Therefore, for this islet, we are not *a priori* excluding any locations based on slope, and will

instead make individual judgments about the safety and accessibility of each GRTS-selected sample site based on topographic maps and field visits. All decisions regarding West ANI sites will be documented so that the scope of inference for probabilistic sites on the islet is well-described.

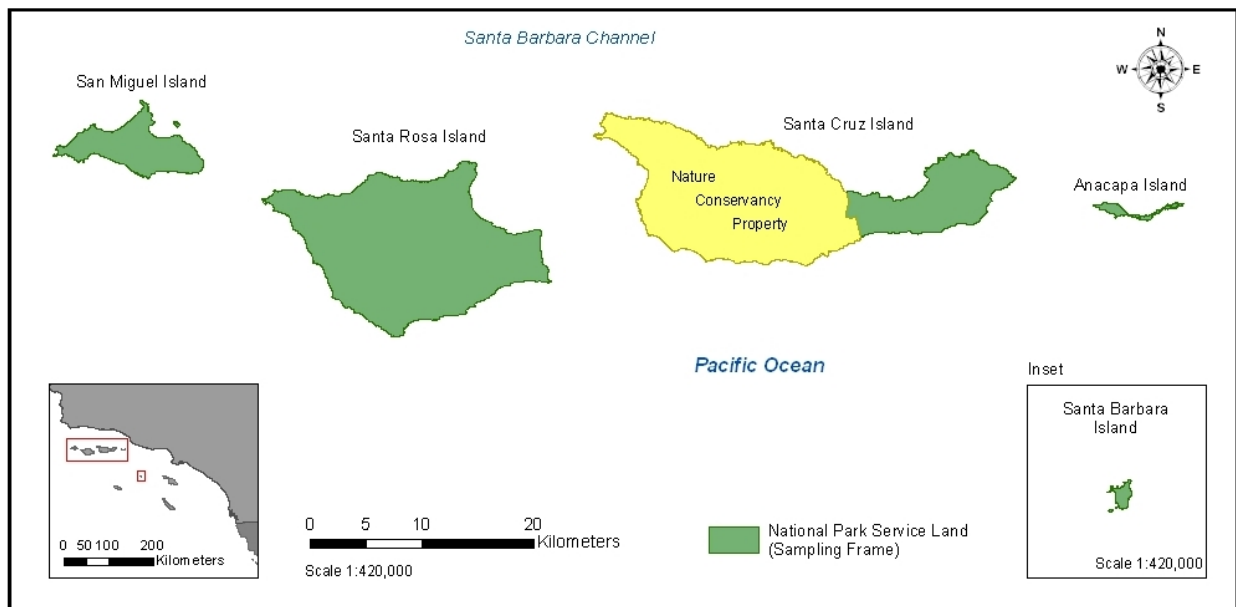


Figure 2. The CHIS sampling frame consists of all National Park Service land in Channel Islands National Park. The Nature Conservancy property is not part of the sampling frame, but may be added in the future.

3.2.2 SAMO

The target population for SAMO is all vegetation occurring on undeveloped park and other public lands within and adjacent to the administrative boundary of the national recreation area, an area encompassing approximately 41,000 ha (Figure 3). These public lands are generally representative of the Santa Monica Mountains region, although they tend to have a higher relative abundance of mixed-chaparral vegetation types and a somewhat lower abundance of coastal sage scrub vegetation types. Vegetation community changes on private and closed public lands will be monitored through the landscape dynamics monitoring protocol (Willis et al., in review). Some private lands within the recreation area are designated for future acquisition as parklands (NPS 1998) and certain public lands now closed to NPS access may be opened in the future. When these lands become available for access, the vegetation within them will be added to the target population and additional sampling sites will be established as staffing capacity allows (see discussion below of master sample at SAMO). Appendix B lists ownership of public lands included and excluded from sample site selection.

SAMO employs a single but spatially noncontiguous sample frame composed of most areas of public parklands supporting native or otherwise unmaintained vegetation within and adjacent to the national recreation area (Figure 3). We excluded parklands in the eastern end of the Santa Monica Mountains (east of Interstate 405) that are not federal or state owned; undeveloped lands owned by the Los Angeles County Sanitation Districts; reservoirs; beaches, bluffs, and coastal marshes; isolated park

units less than 2 ha; and privately owned parklands, with the exception of those owned by the Mountains Restoration Trust. These exclusions were made based on an assessment of the degree of sustained disturbance from landowner and public use and on the feasibility of obtaining long-term access to monitoring sites. Approximately 4% of the vegetation is on lands with slopes mapped at greater than 40 degrees and were therefore excluded from the sampling frame. In addition to areas excluded *a priori* from the sample, initial work at SAMO shows a greater than 30% rejection rate of selected sample sites due to the presence of poison oak, excessively long time to access, or overly steep slopes. Rejections were also caused by conditions that blocked access to the site.

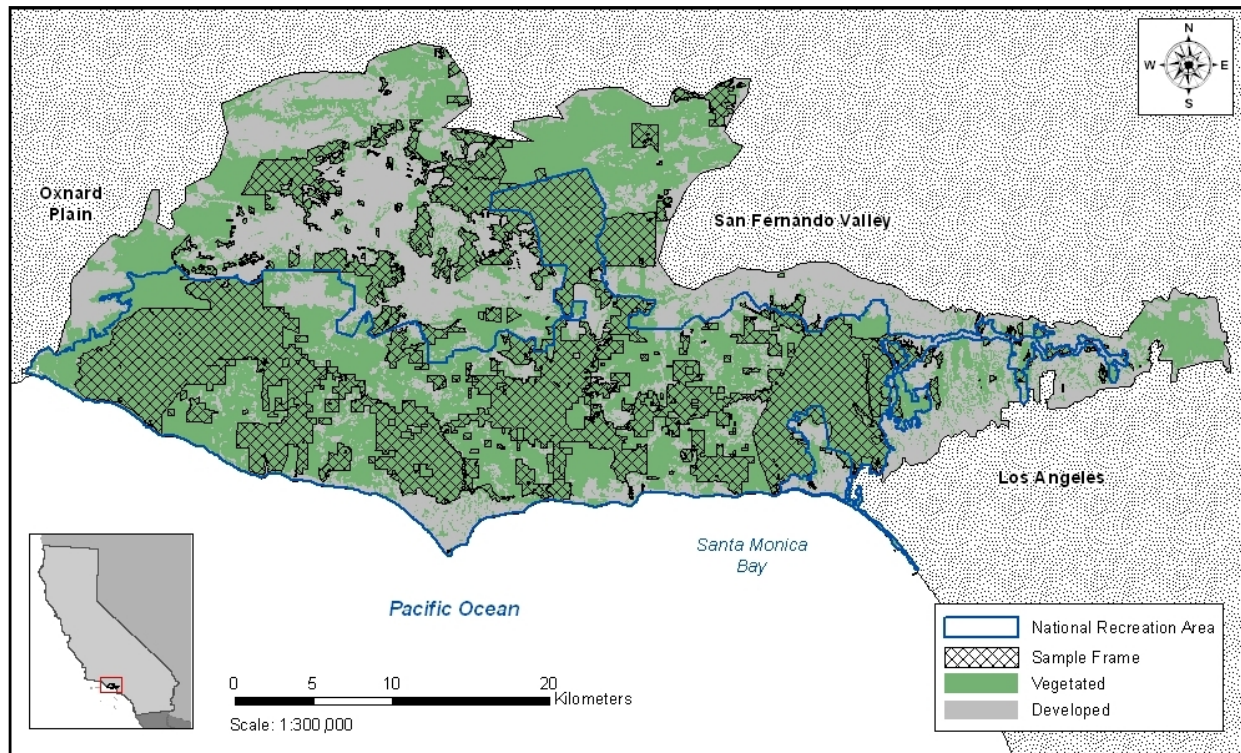


Figure 3. The SAMO sampling frame includes federal, state, and local parklands within and adjacent to the national recreation area. As additional public lands are acquired, they will be added to the sampling frame.

3.2.3 CABR

The target population for CABR is all vegetation on undeveloped areas within the park (65 ha) and within an adjoining parcel of US Navy property (15 ha). Natural resources on the Navy property are managed by CABR under a cooperative agreement with the Navy. The population may in the future be expanded to include vegetation on Navy lands within the Point Loma Ecological Conservation Area (an additional 180 ha) if the US Navy can provide funds to assist with the development and implementation of the protocol on its lands.

The sampling frame for CABR is a single, spatially contiguous unit (broken by developed areas and roads) excluding beaches and coastal bluffs (Figure 4). Only 0.5% of the target population is on lands with slopes greater than 40 degrees and excluded from the sample frame.

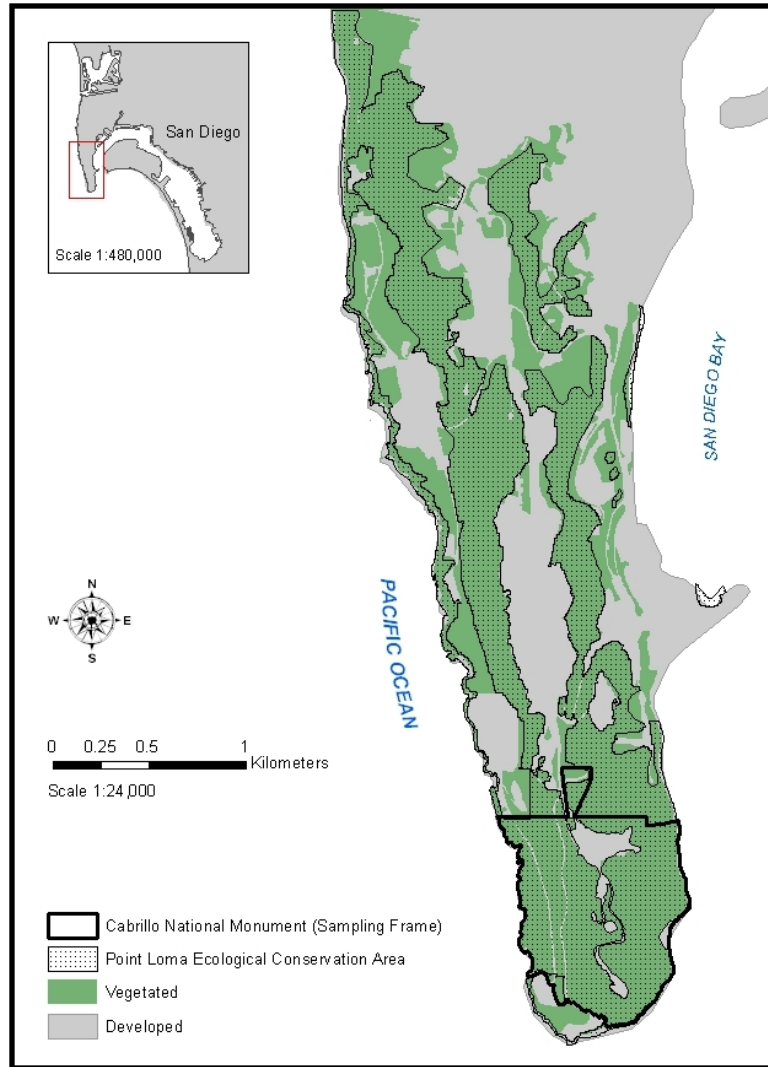


Figure 4. The CABR sampling frame includes the park (65 ha) and a portion of adjoining US Navy land managed by NPS (15 ha south of the park). The Point Loma Ecological Conservation Area (260 ha) includes CABR. The Navy-owned portion of the Conservation Area may be included in future monitoring efforts.

3.3 Site Selection

3.3.1 Probabilistically Selected Sites

The new monitoring sites at CHIS and all of the monitoring sites at SAMO and CABR were selected using Generalized Random Tessellation Stratified (GRTS) sampling with equal probability weighting (Stevens and Olsen 2003, 2004). The spatially balanced set of randomly distributed monitoring sites produced by the GRTS algorithm has advantages over both simple random site selection and stratified random site selection. It minimizes the problems related to aggregation of sites that can occur under a simple random selection, and maximizes spatial independence, which in turn minimizes problems related to spatial autocorrelation. At the same time, the random element of the GRTS selection ensures that sites are not regularly spaced, so that there is no systematic problem in observing processes that occur at the same spatial scale as the inter-site distance.

Spatially balanced site selection provides many of the advantages of traditional stratification procedures but imposes minimal design structure. For example, a common problem of stratification is defining strata with incomplete information or using strata that change over time, as commonly occurs in MEDN vegetation communities after fire or when released from disturbance such as grazing. Under a spatially balanced design, estimates for subpopulations of interest can be obtained using post-stratification (stratification at the time of analysis), providing flexibility for addressing future research questions and management needs (Manly 2009).

The use of design-based estimation from GRTS sampling can reduce error variance and thus increase power to detect change. Confidence intervals and hypothesis testing can incorporate the neighborhood variance estimator for spatially balanced samples (Stevens and Olsen 2003). The spatial stratification of the sample improves on the variance estimate of the Horvitz-Thompson estimator that assumes independent random sampling by giving less weight to the variance contribution of pairs of points that are farther away from each other. By defining neighborhoods of points that are assumed to be spatially correlated, pairs of points in different neighborhoods can be considered independent and do not contribute jointly to the variance of the estimator. This assumption results in variance estimates that are 22% to 58% smaller than the variance assuming independent random sampling (Stevens and Olsen 2003).

The GRTS algorithm also provides important practical advantages in the implementation of a long-term monitoring program. When the order of the GRTS sample is preserved, monitoring points selected using GRTS can be added or removed from the monitoring set without impacting the overall spatial balance of the design (Stevens and Olsen 2003, 2004). Thus, sites may be added if new lands are acquired or cooperative monitoring efforts increased (e.g., TNC on SRI), or to support temporary studies (e.g., post-fire monitoring). Similarly, sites can be eliminated and replaced if a site becomes inaccessible. (However, nonresponse bias may not be mitigated by substituting an accessible site, so nonresponse adjustment may still be required.) Lastly, sites may be rested if environmental constraints (e.g., pelican nesting at CHIS) prevent access, or staffing or funding to perform monitoring become temporarily unavailable.

3.3.2 Use of a Master Sample for SAMO

New lands continue to be brought under public protection within and adjacent to SAMO. To be able to add lands acquired in the future to the existing monitoring inference area, a master sample (Larsen et al. 2008) of the entire study area—including both private and public lands—was created. The sampling frame for existing parklands was then delimited as described earlier and a subsample of sites falling within that frame selected in sequential order to obtain the 300 monitoring locations.

When lands are acquired and added to the sampling frame, a subsample covering the new expanded frame (existing plus newly acquired public lands) can be drawn from the master sample in sequential order. If there are sites that fall within the newly added lands, they will be included in the set of monitoring stations. If no sequentially selected sites fall within the newly added lands, those lands will nevertheless be included within the inference area.

Since it is unlikely that additional monitoring resources will be provided with the acquisition of new public lands, the total number of sites monitored will therefore remain fixed and the addition of a monitoring site on newly acquired lands may require dropping an existing monitoring site that falls at the end of the selection sequence. That is, if the newly acquired land contains a site that falls earlier in the selection sequence than any of currently monitored sites, the final currently monitored site in the sequence will need to be dropped. To avoid the complication of having to shift sites to new monitoring panels (see revisit design below) when a new site is added, the site that will be dropped will be the last site in sequence for the panel to which the new site is added. Newly acquired lands will only be added at the beginning of a new monitoring cycle.

The master sample was created by a GRTS draw from an area including all land within the Santa Monica Mountains and Simi Hills vegetation map (Aerial Information Systems 2007) boundary, except for developed areas and continually disturbed areas. The sampling density for the master sample is one site per 20.2 hectares (50 acres), approximately nine times the density of the subsample of 300 sites selected for long-term vegetation monitoring. This density was chosen after discussion with park natural resources staff as being adequate for the smallest study region for which we might utilize the master sample in future vegetation or wildlife studies. Post-fire vegetation monitoring sites will be chosen from the master sample. Details of the selection of the master sample and subsample are described in Appendix B.

3.3.3 Sample Size and Site Density

We will sample 184 probabilistically selected sites at CHIS (in addition to 181 existing index sites), 300 sites at SAMO, and 72 sites at CABR. This will produce sampling densities of one probabilistically selected monitoring site per 173 ha at CHIS, one site per 137 ha at SAMO, and one site per 1.1 ha at CABR. At CHIS, where each island is treated as a separate sampling frame, sampling density varies among islands between one probabilistically chosen site per 12 ha on SBI and one site per 256 ha on SRI (Appendix A, Table A3). The total number of monitoring sites at CHIS and SAMO is based on the maximum number of sites that can be visited at current staffing levels in one field season across a spatially balanced representation of vegetation communities and major environmental gradients at each park: 146 sites at CHIS and 100 sites at SAMO. (The difference between CHIS and SAMO in number of sites sampled partly reflects the revisit design, but in large part is determined by differences in difficulty of traversing the landscape.) At CABR the number of monitoring sites is that found to be sufficient to obtain adequate sampling density to detect trends under the mix of vegetation communities and major environmental gradients at the park.

Appendix C provides an analysis of the power to detect change based on existing CHIS monitoring data. The estimated power to detect a 3% annual increase over 12 years is generally low, but power increases dramatically after 20 years of monitoring. The five revisit designs that were considered in this analysis (Appendix C; section 3.4 below) had little impact on statistical power after the first 10 years of monitoring.

Existing and proposed sampling locations are depicted on the following maps of CHIS (Figures 5–9), SAMO (Figure 10) and CABR (Figure 11). At CHIS, index sites shown have already been established under the existing CHIS monitoring program and will continue to be monitored under the

new program. The probabilistically selected sites depicted are proposed for establishment under this protocol. However, the final selection of sites will depend on accessibility and safety and can only be assessed by field visits. At SAMO, establishment of sites not on NPS land will depend on permission of other land management agencies in the national recreation area.

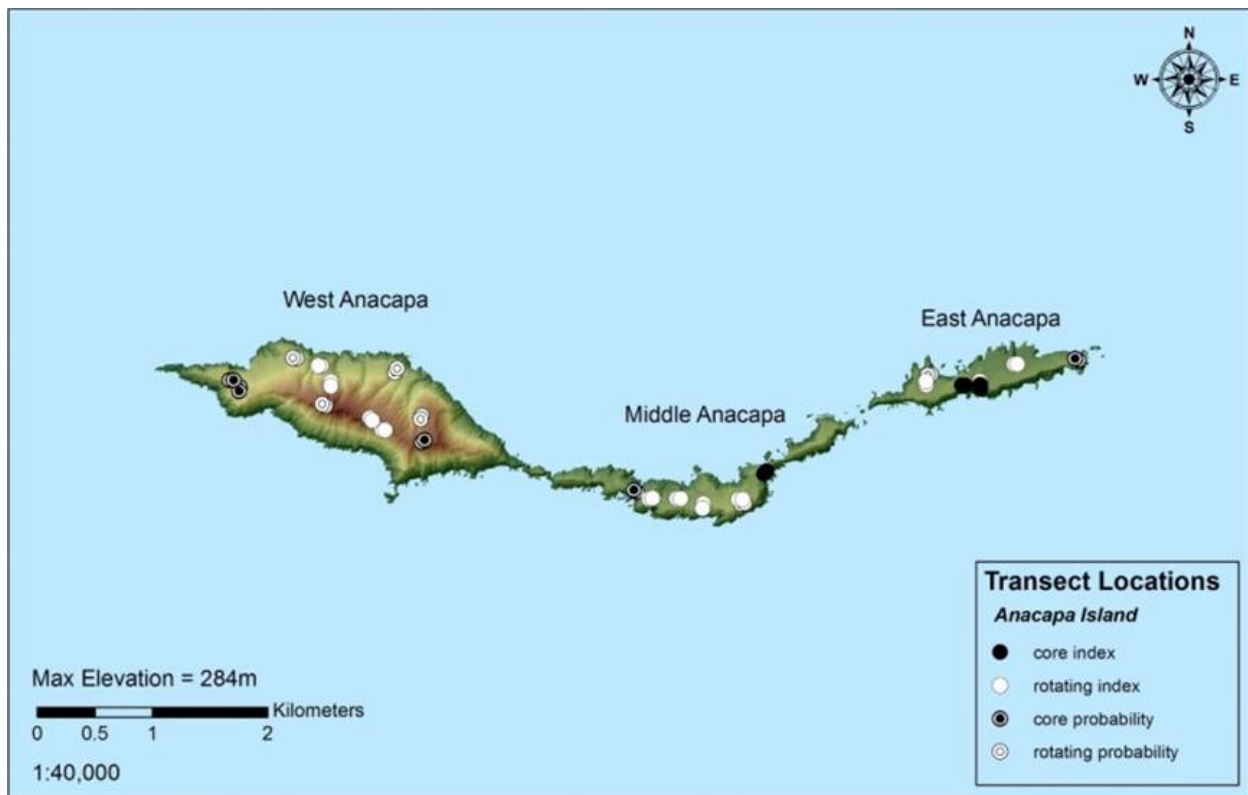


Figure 5. Anacapa Island monitoring locations. Index sites are subjectively chosen locations monitored under the existing CHIS program. Probabilistic sites are new, randomly chosen sites established under this protocol. Core sites are monitored every year. Rotating sites are divided into four panels, each monitored on a 4-year cycle.

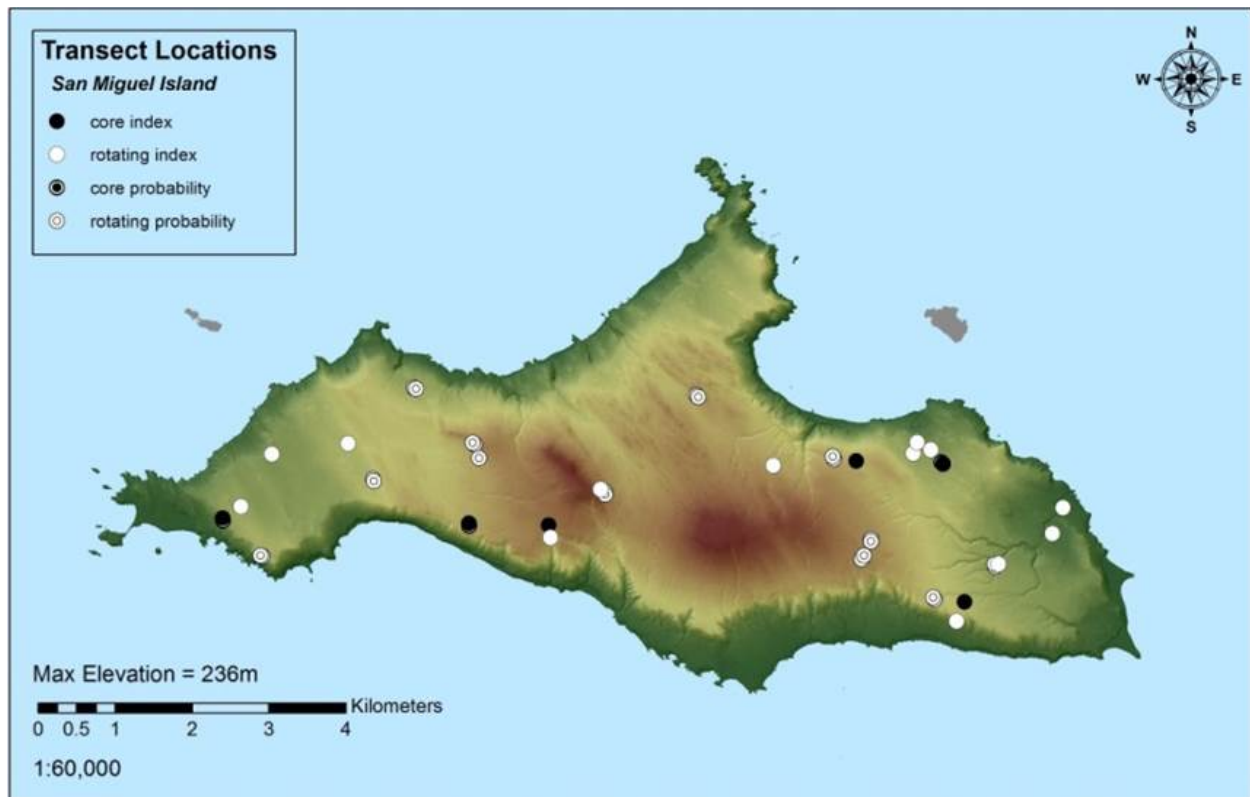


Figure 6. San Miguel Island monitoring locations. Index sites are those monitored under the existing CHIS monitoring program. Probabilistic sites are new, randomly chosen sites established under this protocol. Core sites are monitored every year. Rotating sites are divided into four panels, each monitored on a 4-year cycle.

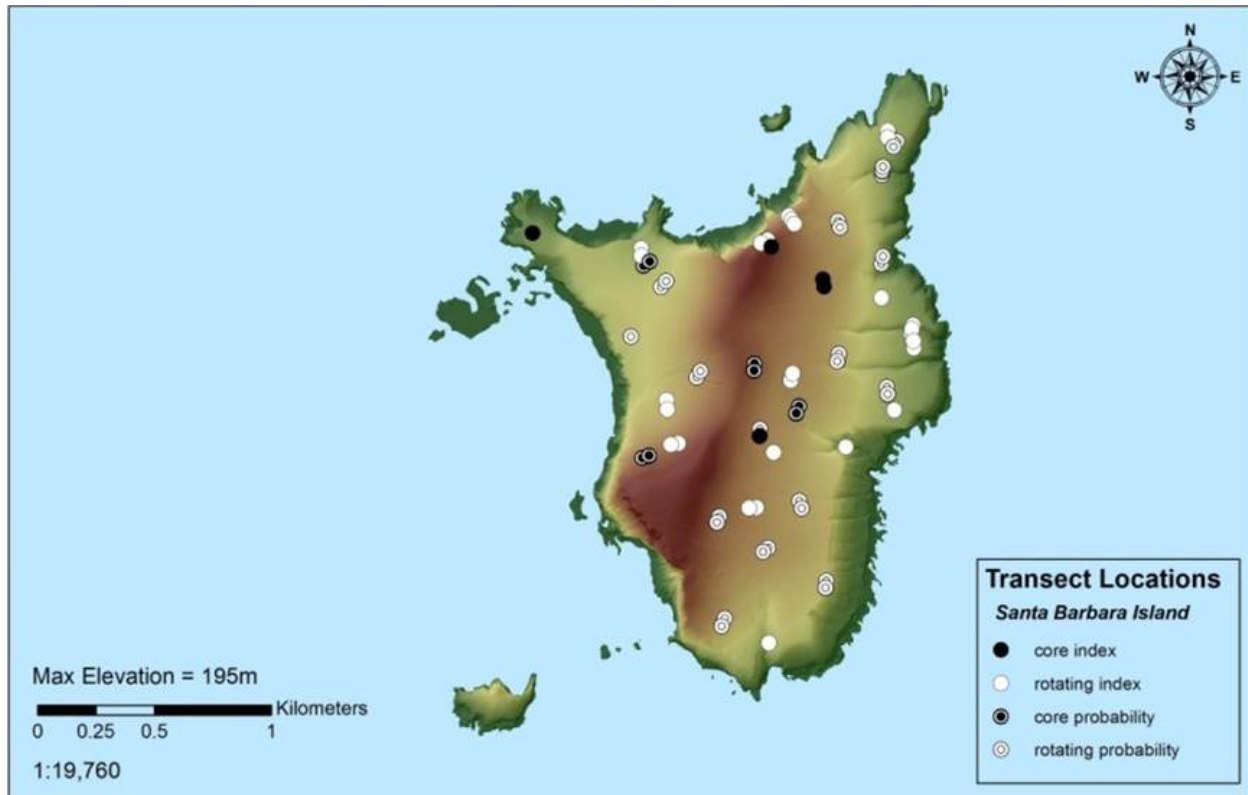


Figure 7. Santa Barbara Island monitoring locations. Index sites are those monitored under the existing CHIS monitoring program. Probabilistic sites are new, randomly chosen sites established under this protocol. Core sites are monitored every year. Rotating sites are divided into four panels, each monitored on a 4-year cycle.

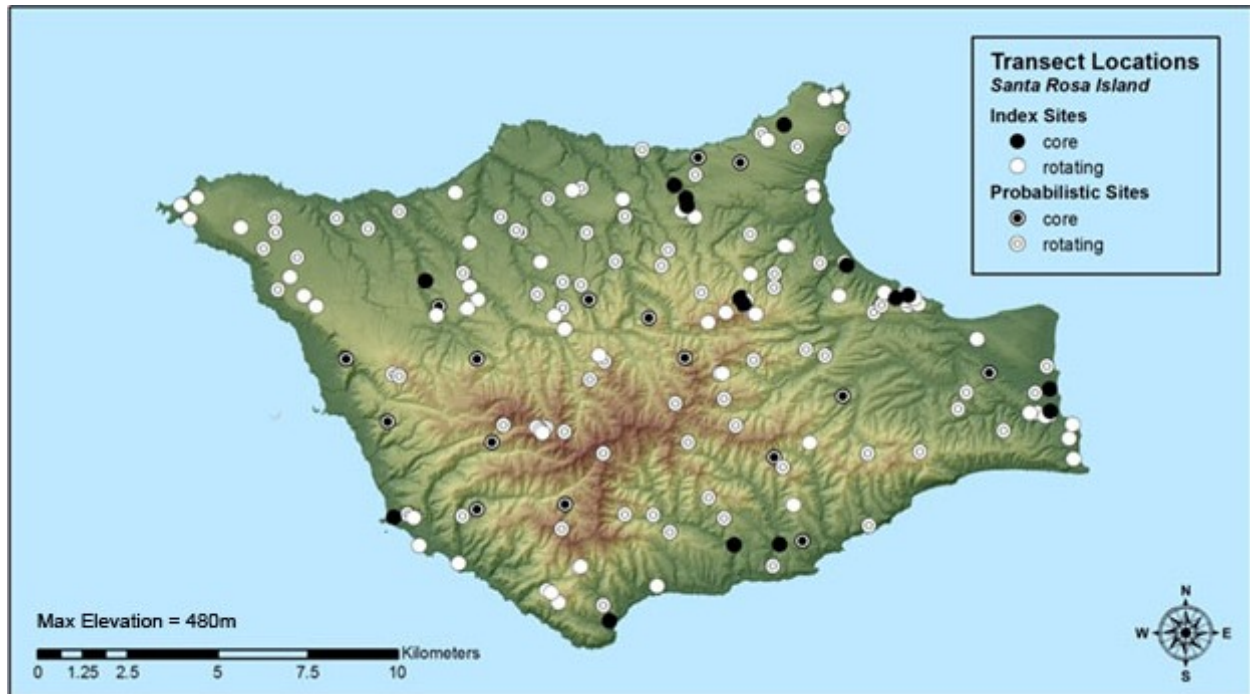


Figure 8. Santa Rosa Island monitoring locations. Index sites are those monitored under the existing CHIS monitoring program. Probabilistic sites are new, randomly chosen sites established under this protocol. Core sites are monitored every year. Rotating sites are divided into four panels, each monitored on a 4-year cycle.

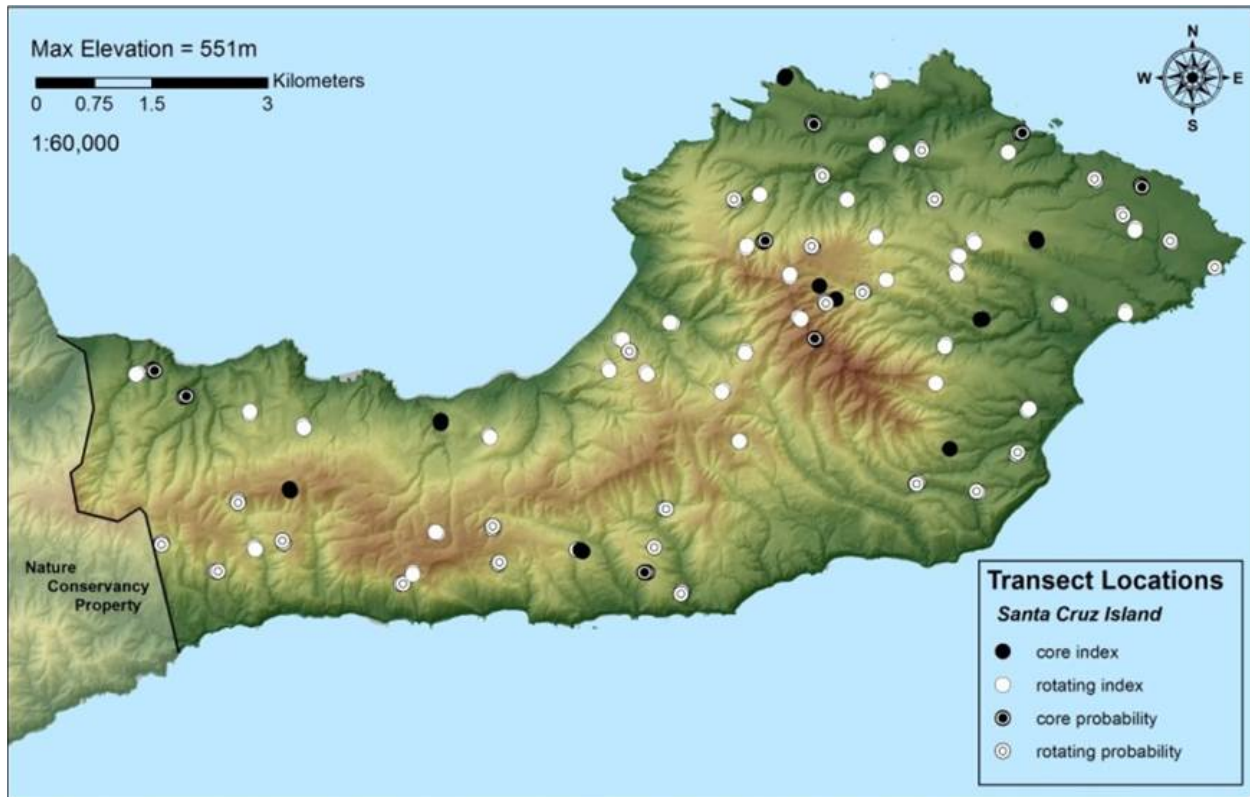


Figure 9. East Santa Cruz Island monitoring locations. Index sites are those monitored under the existing CHIS monitoring program. Probabilistic sites are new, randomly selected sites established under this protocol. Core sites are monitored every year. Rotating sites are divided into four panels, each monitored on a 4-year cycle.

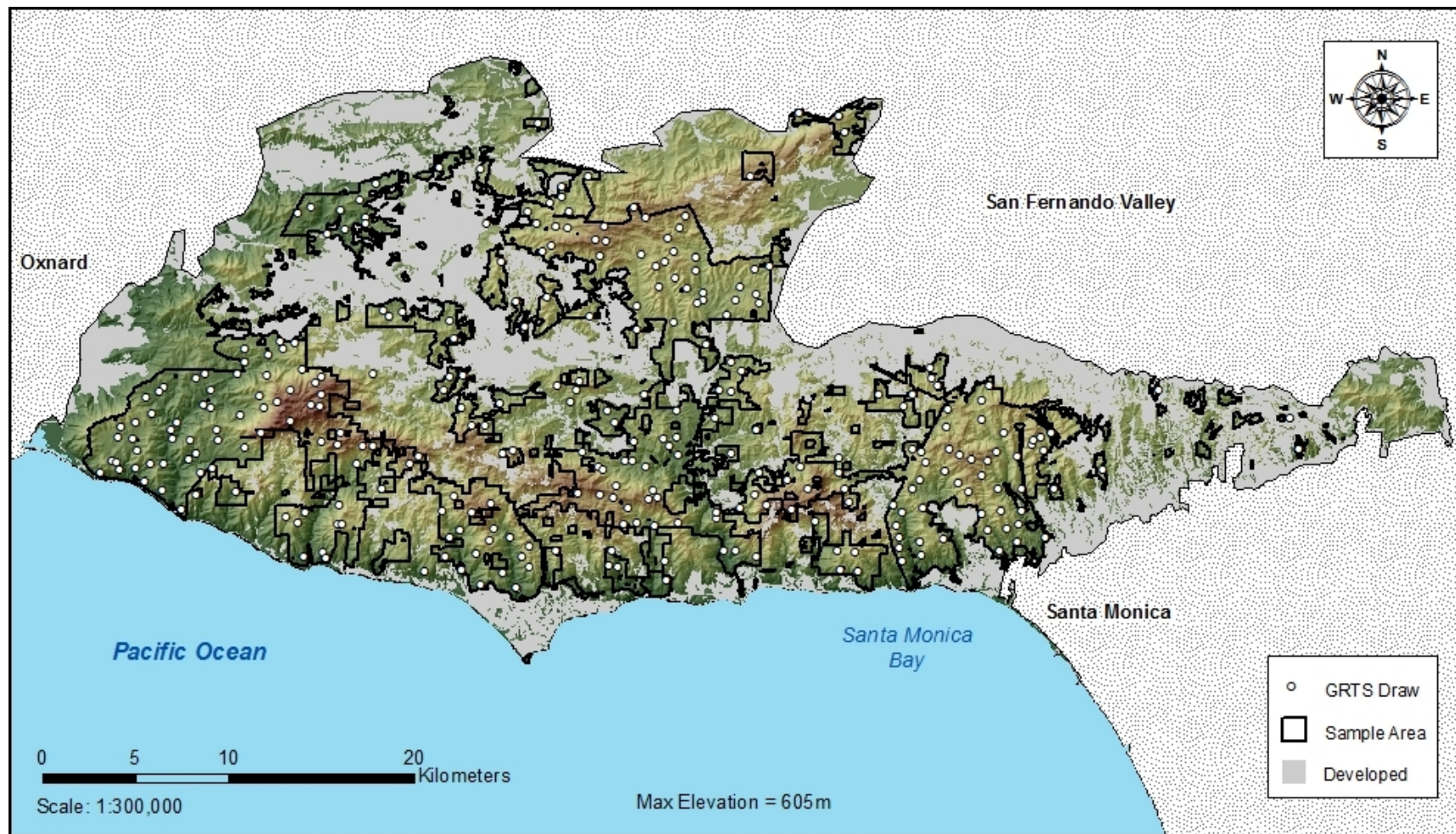


Figure 10. Santa Monica Mountains National Recreation Area, showing monitoring locations on public lands within and adjacent to the national recreation area. Monitoring sites are a subset of a master sample of all lands in the study area that was randomly selected by GRTS draw. Sites are monitored as six panels of 50 locations each. Each panel is visited for two years and then rested for four years; panels are rotated over a 6-year cycle.



Figure 11. Cabrillo National Monument, showing monitoring locations on NPS lands and US Navy lands administered by NPS. All sites were randomly selected by GRTS draw and are monitored as subsets of six panels on a rotating 6-year cycle.

3.4 Sampling Frequency and Revisit Design

We will use two different revisit designs: a serially alternating panel revisit design for SAMO and CABR, and an augmented serially alternating panel design at CHIS (Urquhart and Kincaid 1999). The advantage of multiple-panel revisit designs is that they permit monitoring of more sites than can be visited in a single field season, thus increasing our ability to assess status and to understand spatial patterns while maintaining our capability to monitor long-term trends (Deutschman et al. 2007). Use of a panel design also has the benefit of allowing vegetation at each monitoring location to rest and recover for several years before being revisited, reducing the impacts of trampling and opening of the shrub canopy that are unavoidable when working a site.

The CHIS panel design revisits monitoring sites more frequently (every four years) than the SAMO and CABR panel designs (every five years) and includes a subset of plots that are revisited every year. The CHIS revisit design was chosen to provide more frequent site information in order to examine post-herbivore vegetation change and its interaction with interannual weather patterns. At SAMO and CABR, where, outside of potentially rapid changes after fire occurrence, undisturbed vegetation communities are expected to change more slowly, a 6-year monitoring cycle (4-year

interval before returning to a specific site) is believed sufficient and will allow for an overall greater number of unique sample sites for a given yearly effort. At SAMO and CABR, no plots are visited annually (after the phase-in cycle described below), but each plot will be visited for two years in a row before being rested for four years in order to provide information on interannual weather influences on vegetation response. Power analysis indicates that the revisit designs used at CHIS and SAMO/CABR will differ little in their ability to detect long-term trends (Appendix C).

3.4.1 CHIS Revisit Design

The CHIS revisit design will use a [1-0, 1-3] augmented serially alternating panel design. (Notation is from McDonald (2003): the first number indicates the number of years a site is monitored before resting and the second number indicates the number of years a site is rested before resuming monitoring.) Sites in the core [1-0] panel will be monitored every year, while sites in the remaining four [1-3] panels will be monitored on a rotating schedule, with three rest years between each monitoring year. Each panel will include existing index sites and new probabilistically selected sites in approximately equal numbers (Tables 1–9).

Table 1. CHIS augmented serially alternating panel design for all islands, showing the number of sites monitored and the number of new transects installed each year: 365 sites, 146 monitored each year. Within each cell, numbers to the left of the slash are index sites; numbers to the right of the slash are probabilistically chosen sites (index site / probabilistic site). Probabilistically selected sites will be installed in the first year they are read.

Panel	Year 1	Year 2	Year 3	Year 4	Year 5
Core	39/34	39/34	39/34	39/34	39/34
A	37/36	—	—	—	37/36
B	—	36/37	—	—	—
C	—	—	35/38	—	—
D	—	—	—	34/39	—
Totals	76/70	75/71	74/72	73/73	76/70

The addition of the new probabilistically chosen sites without increasing staff effort is accomplished by sampling the 181 index sites, which are currently sampled yearly, less frequently. The new probabilistically chosen sites will include locations more difficult to access than the index sites and will require more travel time than the index sites. We anticipate that under the new design, the number of sites which may be monitored each year will decrease by approximately 20% to around 146 sites. However, use of the serially alternating design will double the total number of sites monitored to 365 sites (181 index sites and 184 probabilistically selected sites). Allocation of randomly selected sites to each island is approximately equal to the number of index sites on each island (Appendix A).

Table 2. CHIS augmented serially alternating panel design for Santa Barbara Island, showing the number of sites monitored and the number of new transects installed each year: 44 sites, 17 monitored each year. Within each cell, numbers to the left of the slash are index sites; numbers to the right of the slash are probabilistically chosen sites (index site / probabilistic site). Probabilistically selected sites will be installed in the first year they are read.

Panel	Year 1	Year 2	Year 3	Year 4	Year 5
Core	4/4	4/4	4/4	4/4	4/4
A	5/4	—	—	—	5/4
B	—	5/4	—	—	—
C	—	—	4/5	—	—
D	—	—	—	4/5	—
Totals	9/8	9/8	8/9	8/9	9/8

Table 3. CHIS augmented serially alternating panel design for Santa Cruz Island, showing the number of sites monitored and the number of new transects installed each year: 85 sites, 34 monitored each year. Within each cell, numbers to the left of the slash are index sites; numbers to the right of the slash are probabilistically chosen sites (index site / probabilistic site). Probabilistically selected sites will be installed in the first year they are read.

Panel	Year 1	Year 2	Year 3	Year 4	Year 5
Core	9/8	9/8	9/8	9/8	9/8
A	8/9	—	—	—	8/9
B	—	9/8	—	—	—
C	—	—	9/8	—	—
D	—	—	—	8/9	—
Totals	17/17	18/16	18/16	17/17	17/17

Table 4. CHIS augmented serially alternating panel design for Santa Rosa Island, showing the number of sites monitored and the number of new transects installed each year: 170 sites, 68 monitored each year. Within each cell, numbers to the left of the slash are index sites; numbers to the right of the slash are probabilistically chosen sites (index site / probabilistic site). Probabilistically selected sites will be installed in the first year they are read.

Panel	Year 1	Year 2	Year 3	Year 4	Year 5
Core	18/16	18/16	18/16	18/16	18/16
A	17/17	—	—	—	17/17
B	—	17/17	—	—	—
C	—	—	17/17	—	—
D	—	—	—	17/17	—
Totals	35/33	35/33	35/33	35/33	35/33

Table 5. CHIS augmented serially alternating panel design for San Miguel Island, showing the number of sites monitored and the number of new transects installed each year: 34 sites, 13 monitored each year. Within each cell, numbers to the left of the slash are index sites; numbers to the right of the slash are probabilistically chosen sites (index site / probabilistic site). Probabilistically selected sites will be installed in the first year they are read.

Panel	Year 1	Year 2	Year 3	Year 4	Year 5
Core	3/3	3/3	3/3	3/3	3/3
A	4/3	—	—	—	4/3
B	—	3/4	—	—	—
C	—	—	3/4	—	—
D	—	—	—	3/4	—
Totals	7/6	6/7	6/7	6/7	7/6

Table 6. CHIS augmented serially alternating panel design for Anacapa Island (all islets), showing the number of sites monitored and the number of new transects installed each year: 32 sites, 14 monitored each year. Within each cell, numbers to the left of the slash are index sites; numbers to the right of the slash are probabilistically chosen sites (index site / probabilistic site). Probabilistically selected sites will be installed in the first year they are read.

Panel	Year 1	Year 2	Year 3	Year 4	Year 5
Core	5/3	5/3	5/3	5/3	5/3
A	3/3	—	—	—	3/3
B	—	2/4	—	—	—
C	—	—	2/4	—	—
D	—	—	—	2/4	—
Totals	8/6	7/7	7/7	7/7	8/6

Table 7. CHIS augmented serially alternating panel design for East Anacapa Island, showing the number of sites monitored and the number of new transects installed each year: 11 sites, 5 monitored each year. Within each cell, numbers to the left of the slash are index sites; numbers to the right of the slash are probabilistically chosen sites (index site / probabilistic site). Probabilistically selected sites will be installed in the first year they are read.

Panel	Year 1	Year 2	Year 3	Year 4	Year 5
Core	2/1	2/1	2/1	2/1	2/1
A	1/1	—	—	—	1/1
B	—	0/2	—	—	—
C	—	—	0/2	—	—
D	—	—	—	0/2	—
Totals	3/2	2/3	2/3	2/3	3/2

Table 8. CHIS augmented serially alternating panel design for Middle Anacapa Island, showing the number of sites monitored and the number of new transects installed each year: 10 sites, 4 monitored each year. Within each cell, numbers to the left of the slash are index sites; numbers to the right of the slash are probabilistically chosen sites (index site / probabilistic site). Probabilistically selected sites will be installed in the first year they are read.

Panel	Year 1	Year 2	Year 3	Year 4	Year 5
Core	1/1	1/1	1/1	1/1	1/1
A	1/1	—	—	—	1/1
B	—	1/1	—	—	—
C	—	—	1/1	—	—
D	—	—	—	1/1	—
Totals	2/2	2/2	2/2	2/2	2/2

Table 9. CHIS augmented serially alternating panel design for West Anacapa Island, showing the number of sites monitored and the number of new transects installed each year: 11 sites, 5 monitored each year. Within each cell, numbers to the left of the slash are index sites; numbers to the right of the slash are probabilistically chosen sites (index site / probabilistic site). Probabilistically selected sites will be installed in the first year they are read.

Panel	Year 1	Year 2	Year 3	Year 4	Year 5
Core	2/1	2/1	2/1	2/1	2/1
A	1/1	—	—	—	1/1
B	—	1/1	—	—	—
C	—	—	1/1	—	—
D	—	—	—	1/1	—
Totals	3/2	3/2	3/2	3/2	3/2

The probabilistically selected sites will be allocated to one core and four serially alternating panels using the GRTS generated sample sequence to maintain spatial balance within each panel. The index sites will be apportioned to the five panels using the method described in Appendix A. Additional oversample sites will be selected to accommodate the possibility of eliminating locations because of unexpected conditions that prevent access or the possibility of adding sites as future needs might require.

3.4.2 SAMO and CABR Revisit Designs

The SAMO and CABR revisit designs are summarized in Tables 10 and 11, respectively. Monitoring sites are visited following a [2-4] serially alternating panel design. Each of six panels is monitored on a 6-year cycle in which all sites in the panel are visited for two consecutive years and then rested for four years. The cycles are staggered such that successive panels overlap by one year. This design provides temporal connectivity across panels, which allows for more precise and accurate estimation

of year-to-year variation caused by variation in environmental factors such as annual precipitation (Urquhart and Kincaid 1999; Deutschman et al. 2007).

Table 10. SAMO serially alternating panel design showing the number of sites monitored and number of new transects installed each year. During the first 6-year cycle only, sites in panels A and B will be revisited yearly (shown in bold, red italics; phased implementation is described in following text). “Install” is the number of new plots installed and “Monitor” is the number of plots read in a given field season.

Panel	Year												
	1	2	3	4	5	6	7	8	9	10	11	12	13
A	25	25	25	25	25	50	50	—	—	—	—	50	50
B	25	25	25	25	25	25	50	50	—	—	—	—	50
C	—	25	25	—	—	—	—	50	50	—	—	—	—
D	—	—	25	25	—	—	—	—	50	50	—	—	—
E	—	—	—	25	25	—	—	—	—	50	50	—	—
F	—	—	—	—	25	25	—	—	—	—	50	50	—
Install	50	25	25	25	25	25	25	25	25	25	25	0	0
Monitor	50	75	100	100	100	100	100	100	100	100	100	100	100

Table 11. CABR serially alternating panel design showing the number of sites monitored and number of new transects installed each year. During the first 6-year cycle only, half of the sites in panels A and B will be revisited yearly (shown in bold, red italics; phased implementation in following text). “Install” is the number of new plots installed and “Monitor” is the number of plots read in a given field season.

Panel	Year												
	1	2	3	4	5	6	7	8	9	10	11	12	13
A	12	6	6	6	6	12	12	—	—	—	—	12	12
B	12	12	6	6	6	6	12	12	—	—	—	—	12
C	—	12	12	—	—	—	—	12	12	—	—	—	—
D	—	—	12	12	—	—	—	—	12	12	—	—	—
E	—	—	—	12	12	—	—	—	—	12	12	—	—
F	—	—	—	—	12	12	—	—	—	—	12	12	—
Install	24	12	12	12	12	0	0	0	0	0	0	0	0
Monitor	24	30	36	36	36	30	24	24	24	24	24	24	24

At SAMO, we estimate that we can complete 100 sites (two panels of 50 each) during each field season and can therefore monitor 300 plots in a 6-year cycle (6 panels). At CABR we will monitor 24 sites (two panels of 12 each) each year for a total of 72 sites. At SAMO the 300 monitoring sites will

be allocated to 6 panels of 50 sites each using the GRTS generated sample sequence to maintain spatial balance within each panel. These sites and any required replacement sites will be selected from the SAMO master draw described earlier. At CABR, monitoring sites are allocated to 6 panels of 12 sites each. An additional 144 oversample sites will be selected to provide replacements for potentially inaccessible sites.

3.5 Phased Implementation and Evaluation of the Protocol

Sampling and response designs are best evaluated during the early years of monitoring program implementation (Elzinga et al. 1998). Optimum sampling designs, optimum response designs, and necessary sample sizes can only be approximately estimated during pilot studies. This is particularly true at SAMO and CABR, where there is little legacy data with which to estimate spatial and temporal variability and establish adequate sampling sizes for trend testing. Similarly, logistic effort and time requirements for SAMO and CABR are not fully known. A phased implementation, where there is a trial period in which less than the intended full set of locations are sampled and some sites are sampled more frequently than design requires, provides an opportunity to assess both sampling needs and logistic constraints before making a full commitment of resources to a particular design.

At SAMO only half of the planned plots in each panel (25 of 50 plots per panel) will be installed and monitored during the first 6-year sampling cycle. During this period we will conduct yearly monitoring of plots in the first two panels to develop an estimate of interannual variance for a power analysis. At CABR the full set of monitoring plots (12 plots per panel) will be installed and monitored over the course of the first sampling cycle. In addition, half of the plots in the first two panels at CABR will be monitored yearly for the first cycle to estimate interannual variance. During the initial 6-year monitoring cycle, we will evaluate the field protocol based on suitability for the vegetation measured and logistic constraints, and evaluate field activities for practicality and efficiency. Detailed information will be collected on the time and logistic requirements necessary to implement each element of the sampling and response designs for evaluation at completion of the first cycle. Changes will only be made after discussion and agreement among the park program leaders and the MEDN I&M program manager and following the guidelines described in SOP 16.

In contrast to SAMO and CABR, the extensive monitoring history at CHIS provides an existing basis to assess sampling and response designs and logistic constraints. CHIS will install the full complement of probabilistically selected sites on SBI, ANI, SCI, and SMI as the sites are visited during the first monitoring cycle. On SRI, randomly selected sites will not be established until the second monitoring cycle. The reason for this delay in the implementation of the new monitoring protocol on SRI is to facilitate the analysis of vegetation at index sites before and after ungulate removal. The 1998 removal of cattle resulted in fairly rapid vegetation change at some index sites. This change is expected to continue and perhaps even accelerate with the 2011/2012 elimination of deer and elk on the island. The addition of probabilistically selected sites will require changing the existing yearly sampling of all index plots to a design where 80% of the index plots on SRI are visited only every fourth year. Delaying implementation will avoid interrupting the continuity of monitoring during this critical post-ungulate period.

At the end of the first full monitoring cycle, after all panels have been visited once, we will conduct a full evaluation of the protocol, including a power analysis to assess change detection capabilities. We will also perform an accounting of time and staffing requirements against the monitoring data acquired and evaluate effectiveness and sustainability with the existing level of program support. Based on the findings of this review, we may increase or decrease the number of monitoring locations, and change the sample frame and/or the monitoring interval to maximize our ability to meet our monitoring goals with the resources available.

3.6 Seasonal Timing of Monitoring

Monitoring is scheduled during the spring growth season in order to best capture information about herbaceous species. At SAMO and CABR, the monitoring window is March through June (approximately 14 weeks). SAMO will require all three months for monitoring while CABR will implement its monitoring during the month of April, the time of greatest herbaceous flower expression.

At CHIS the peak of the growing season varies among islands, progressing sequentially from the more southern SBI to ANI and then west through SCI, SRI, and finally SMI. The CHIS monitoring period runs from mid-February through June (approximately 20 weeks) and can extend into July, beginning earlier and ending later than is considered optimum. This extended and varying monitoring season is necessitated by logistic issues and staffing limitations. Similarly, annual weather fluctuations, scheduling conflicts, and transportation issues can result in changes to the typical monitoring order across the islands.

Issues that can arise from an extended monitoring schedule, such as lower plant cover during the early growing season and senescence of annual species later in the monitoring period, are a definite concern, but are ameliorated somewhat by the cooler conditions on the islands, which can extend the growing season and make feasible “forensic” plant identification.

3.7 Post-Fire Monitoring

Fire is the most likely factor to cause rapid change in shrubland vegetation composition in all of the MEDN parks, even those with rare fire events. Mortality, survivorship, and recruitment of dominant shrub species are affected by fire intensity, fire return interval, and pre- and post-fire climate, all of which can change the post-fire community composition (Jacobsen et al. 2004; Keeley, Baer-Keeley, Fotheringham 2005; Keeley, Fotheringham, and Baer-Keeley 2005; Pratt et al. 2010, 2014).

Colonization of native plants from outside burned areas plays little role in post-fire vegetation succession in southern California shrublands, and the first two or three years of reestablishment and growth after a fire are the critical phase for determining shrub reestablishment (Keeley, Fotheringham, and Baer-Keeley 2005; Keeley et al. 2006; Witter et al. 2007; Keeley and Brennan 2012; Pratt et al. 2014).

The future pattern of plant community dominance can therefore be best detected by measuring the in-situ survivorship and seedling recruitment in the first two to three years post-fire. Peak species diversity also occurs between one to two years post-fire and many of the unique post-fire herbaceous wildflowers disappear after this period (Keeley, Baer-Keeley, Fotheringham 2005; Keeley,

Fotheringham, and Baer-Keeley 2005). At SAMO, this post-fire native herbaceous flora contains approximately 100 species or 30% of the native herbs (not all of these species are limited to the post-fire environment). At CHIS and CABR, fire rarely occurs and the post-fire flora is much less observed and therefore much less understood.

Although fires have been much less frequent and limited in scope at CABR and CHIS than at SAMO, fires can occur under the right combination of ignition and climate conditions (NPS 2006a, 2006b), and have the potential to cause vegetation change. At CABR the effect of fire on various unique elements of the flora is unknown, particularly the succulent species unique to that park. Prescribed fire on SRI (1997) and a small wildfire on SCI (2006) have been shown to inhibit recovering coastal sage scrub (NPS 2008; Marti Witter and Timothy Handley, unpublished data). However, wildfires on both SCI and Santa Catalina Island (one of the Channel Islands south of CHIS) have stimulated germination of rare species present in the seed bank. The 1994 China Harbor prescribed fire on SCI resulted in extensive germination of the endemic island rush-rose (*Helianthemum Greenei*) (Kathryn McEachern, pers. obs.). On Santa Catalina Island, recent fires have also been followed by an extraordinary germination of native plants, some of which are rare and endangered or uncommon (Knapp 2005). As these examples show, merging the long-term monitoring program with the post-fire monitoring program is essential to understanding vegetation dynamics and mechanisms of vegetation change, and to formulate useful management responses.

Monitoring in the first two years immediately post-fire is necessary to fully capture species diversity, to detect abrupt shifts in vegetation—especially those anticipated with climate change and extreme climate events, and to detect potential expansion of invasive species at this vulnerable period. We will respond to fire events at MEDN parks by temporarily increasing the frequency of monitoring within the fire perimeter and by adding supplemental, fire-specific monitoring protocols. If the number of Terrestrial Vegetation monitoring sites is not sufficient for post-fire monitoring, we will add additional probabilistically chosen monitoring sites from the master sample at SAMO and from a new GRTS draw at CHIS and CABR. Plots will be visited each spring for the first two years post-fire, unless an extreme climatic event occurs that warrants an additional year of data collection. Terrestrial Vegetation monitoring sites will then return to their normal rotation within the long-term monitoring cycle and sites added specifically for post-fire monitoring will be dropped from the regular monitoring cycle.

Post-fire plots will be monitored by vegetation and fire ecology staff under the cooperative supervision of the MEDN Fire Ecologist and the Botanist/Plant Ecologist at each of the parks. Appendix D provides a full description of the supplemental Post-Fire monitoring protocol. This protocol employs all of the Terrestrial Vegetation monitoring SOPs, plus three supplemental SOPs (1a, 5a, and 7a) that modify and add to the procedures for installing and monitoring plots. The Post-Fire SOPs are included with the Terrestrial Vegetation monitoring SOPs.

4 Response Design

The MEDN will adopt the response design currently used by CHIS (Halvorson et al. 1988; Johnson and Rodriguez 2001; McEachern 1998, 2000, 2001; Rodriguez 2006). It has been tested and refined over nearly 30 years and found to be efficient and effective in our vegetation types. The response design follows the same approach as the sampling design, emphasizing breadth and generality: attributes of all species occurring at all monitoring sites will be recorded using a suite of complementary measurements (Table 12).

Our response variables are vegetation foliar cover, density, species richness and frequency, and soil surface cover. No single vegetation measure is adequate for characterizing all aspects of all species in a stand of vegetation (Bonham 1989). The set of measures used here address different facets of species abundance and community composition. They are of proven utility and in common use (Bonham 1989; Elzinga et al. 1998).

Table 12. Summary of response measures for MEDN parks showing measurements taken at each monitoring location.

Measure	Population of interest	Technique employed
Cover (foliar)	All vascular and nonvascular plant species Soil surface features	Line-point intercept transect • 30 m transect, 100 points
Density	Shrub & tree species	Counts of seedling, sapling/juveniles and mature live and plants, plus basal area for tree species. • Shrubs – 1 × 30 m belt plot > read as 6 contiguous 1 × 5 m plots • Trees – 10 × 30 m plot > read as 2 adjacent 5 × 30 m plots • Trunk diameter at 1.37 m (4.5 ft) height
Species Richness & Frequency	All vascular plant species	Species list • 1 × 30 m belt plot > read as 6 contiguous 1 × 5 m plots subdivided into pairs of 1 × 1 m and 1 × 4 m plots

4.1 Response Variables

4.1.1 Vegetation Cover

Vegetation cover is the projection of the aerial parts of a plant onto the ground: the amount of stems and leaves (or thallus) of a species or group of species obscuring the ground surface when viewed from directly above (Bonham 1989). Vegetation cover provides a quantitative measure by which

different species and different growth forms may be compared, equalizing the contribution of small but abundant species with that of larger species that are less abundant (Elzinga et al. 1998). Because plants are sessile, cover is often interpreted as an integrated estimate of the influence or importance of a species within the plant community (Barbour et al. 1980). Two types of vegetation cover can be measured. “Canopy cover” is used in some treatments to specifically refer to the area contained by a vertical projection onto the ground of the outermost perimeter of the foliage of a plant, while “foliar cover” refers to the area defined by vertical projection onto the ground of the aerial portions of a plant, excluding small openings in the canopy and overlapping branches of the same species (Coulloudon et al. 1999). We use the latter definition in this protocol.

4.1.2 Soil Surface Cover

Soil surface cover describes the biotic and abiotic materials on the soil surface. We will measure the cover of biological crusts (algal crusts, mosses, lichens), litter/thatch, wood, pebbles, rock, soil, and sand. This information provides a dynamic structural indicator of nutrient cycling processes, the potential for soil erosion, and the physical barriers faced by germinating seedlings (National Research Council 1994). Soil surface cover is simple to estimate and data are collected concurrently with plant cover data.

4.1.3 Density of Shrubs and Trees

Density is the number of individuals or ramets of a species occurring in a given area. Monitoring density provides information on the number of individuals in a plot and a direct accounting of changes in species population structure over time. Density of perennial species is not affected by seasonal variations in productivity that may affect cover estimates. Similarly, measurements of density can reveal population changes otherwise obscured by compensatory growth that maintains constancy of cover even as numbers of individuals decline (Bonham 1989). On the other hand, the utility of density as a measure of trends in population for annual species is limited by their high seasonal variation in population numbers resulting from year-to-year environmental variability (Elzinga et al. 1998). For this reason, and the difficulty in collecting density data on annuals and herbaceous perennials, we will only monitor density of shrub and tree species. These are the growth forms that create the overstory in most native communities and for which changes in population numbers may result in significant community changes.

4.1.4 Plant Species Richness

Species richness is the number of species occurring in a particular location. It is a simple and robust measure of diversity and is generally viewed as an integrative indicator of community well-being (Magurran 2004). Richness is affected by the size and shape of the sample plot employed, making it difficult to compare results from studies employing different methodologies (Keeley and Fotheringham 2005). However, richness can be an important metric in long-term studies that employ consistent methodology. Information on richness can be combined with information on abundance to develop additional, complementary diversity measures.

4.1.5 Frequency

Frequency differs from cover and density in that it provides an estimate of the way in which individuals or populations of a species are distributed across the landscape. It is estimated as the

proportion of all monitoring sites on which a species occurs. Frequency estimates are influenced by the size and shape of sample plots relative to the size and distribution patterns of each species measured. This means that, as for richness, comparisons of frequency metrics among studies are difficult to interpret unless those studies employ the same type of sampling plot (Bonham 1989). Frequency monitoring is an effective tool for monitoring and interpreting the establishment and spread of non-native species in the landscape. Frequency data are easily obtained from the data collected in density, cover, and richness monitoring and no unique data acquisition effort is required.

4.2 Measurement Techniques

As for the different vegetation measures, no single field technique is completely adequate for characterizing all of the species that comprise a stand of vegetation (Bonham 1989; Elzinga et al. 1998). Based on the existing CHIS vegetation monitoring response design that we are adopting, our primary response measure is foliar cover as determined by the line-point intercept method. This technique is simple to implement, robust to changes in observers, and able to accurately describe vegetation composition in southern California's shrubland-dominated plant communities (Keeley and Fotheringham 2005, Deutschman et al. 2008). The full suite of response measurement techniques we employ are summarized below and fully described in SOPs 5 and 7.

4.2.1 Plant Foliar Cover and Soil Cover: Line-Point Intercept

The line-point intercept is a common and efficient technique for measuring vegetation cover. In this method, a small-diameter rod is positioned vertically through the canopy at fixed-interval points along a line and each species touching the rod at each point is recorded. The number of “hits” of a given species out of the total number of points measured is its cover. This method provides a measure of foliar cover where small openings in the canopy and overlapping branches of the same species (measured at each point) are *excluded* from the vertical projection of the plant canopy onto the ground (Coulloudon et al. 1999). In our protocol, soil surface features (bare soil, sand, litter/thatch, wood, biological crust type, pebbles, rock) and height of the tallest vegetation layer will also be recorded at each point.

We employ a single 30 m straight-line transect with 100 sample points spaced at 30 cm intervals (Figure 12). Each transect is oriented in the field according to the following rules:

- On slopes above 5 degrees the transect is placed perpendicular to the primary slope, running along the primary contour.
- On slopes below 5 degrees (that is, where no slope can be detected) the transect is randomly oriented.

Orientation of transects along contour on steeper slopes is to minimize damage to the soil and vegetation during monitoring activities (transects are always read from the downslope side) and to provide more stable footing for workers. While this rule results in nonrandom orientation of transects, orientation is not based on vegetation attributes and is not directly biased by vegetation. In addition, the transects are short with respect to vegetation gradients in the landscape; during pilot data collection we observed no consistent difference in vegetation variability or pattern along 30 m transects running up or across slope.

At each sampling event vegetation transects will be photographed from both ends. In addition, supplemental photographs may be taken of plants and conditions or features of interest. The purpose of these photographs is to provide visual documentation—a visual sense—to support the transect data.

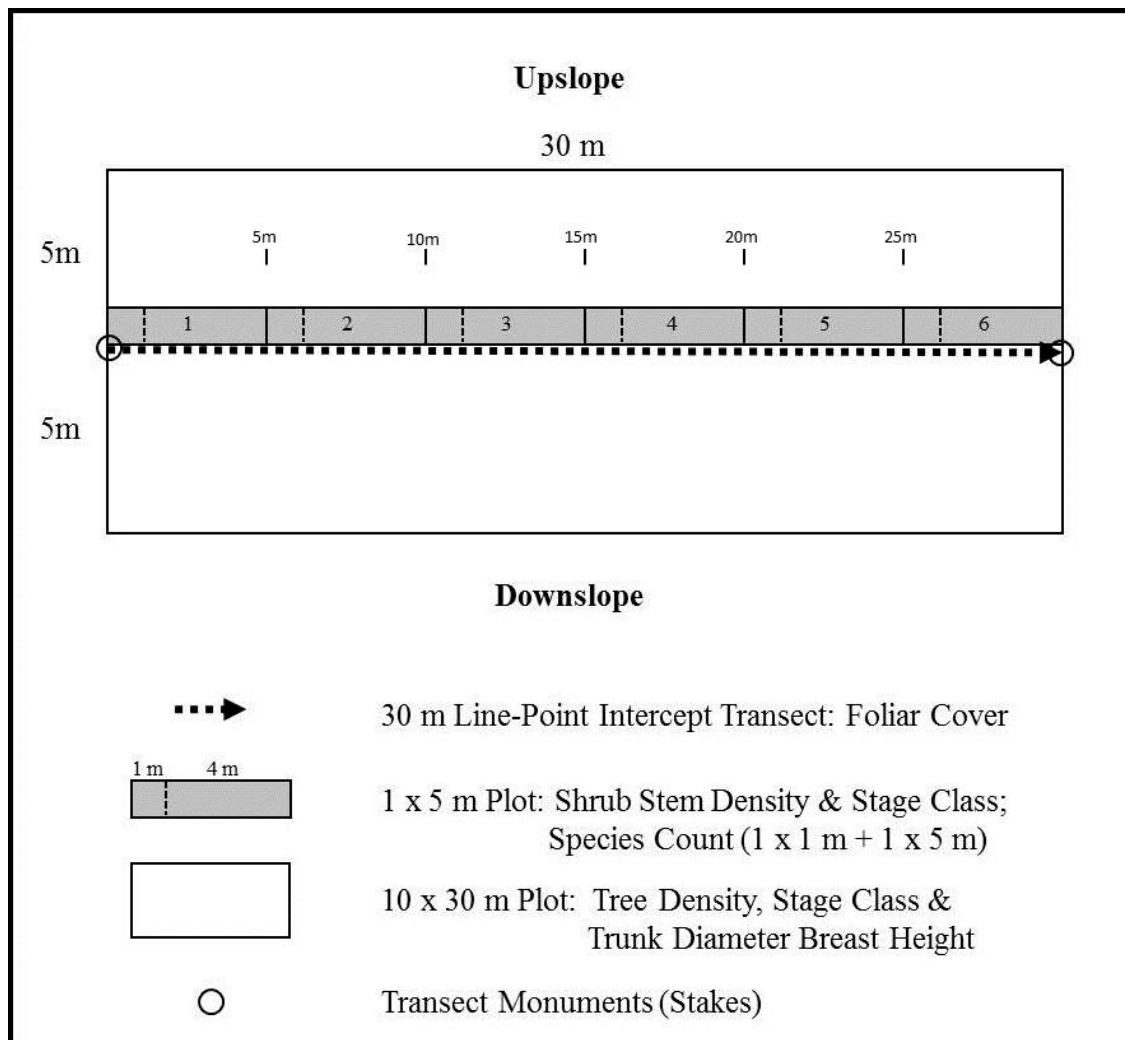


Figure 12. Schematic representation of the sampling plot.

The monitoring rod used at CHIS and adopted by the MEDN is fashioned from a straight aluminum ski pole (approximately 10 mm wide at base and 16 mm wide at handle) graduated to 115 cm height (1 cm increments for the first 10 cm, 5 cm increments thereafter). A 2 mm wide vertical line is etched into the pole and each plant species touching the line at a given monitoring point is recorded at the highest height of contact (Figure 13, see SOP 7 for diagram of rod). Canopy above the monitoring rod is recorded using a GRSTM periscope single-point densitometer placed at the top of the monitoring pole.

In some vegetation stands at SAMO and CABR, measurements can be more effectively made using a 3-m avalanche probe. We use poles of similar diameter to the ski pole, graduated in 1 cm increments, and as for the ski pole, marked with a 2 mm wide vertical line.

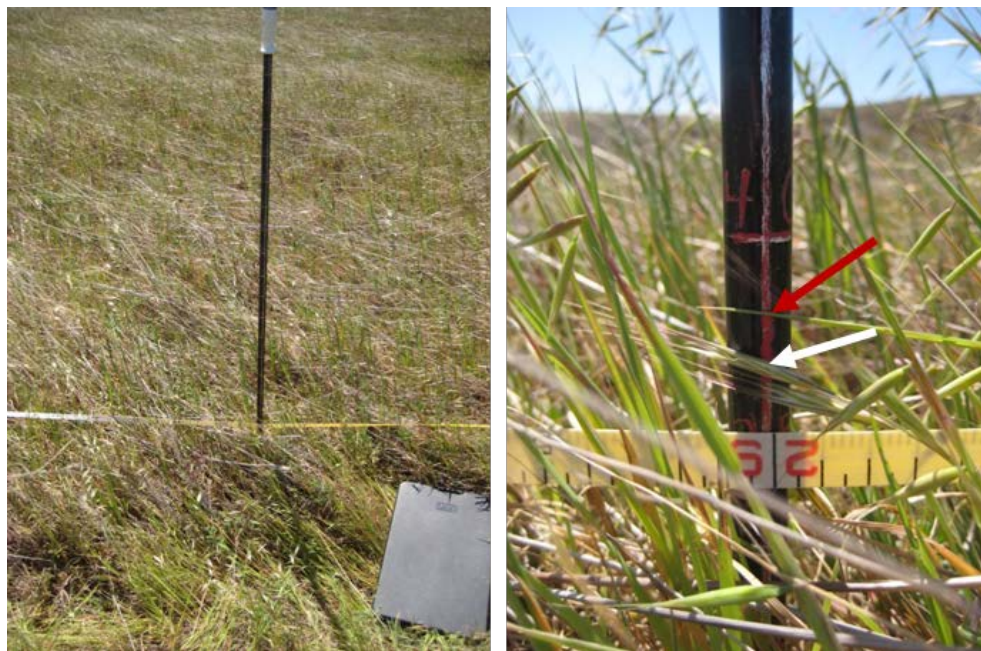


Figure 13. Monitoring rod fashioned from a ski pole employed along a transect in non-native grassland. Species are recorded from the ground up, with each taxon recorded at the lowest point it intersects the 2-mm wide vertical line etched on the rod. In the photograph at right, *Bromus diandrus* (white arrow) is recorded before *Avena fatua* (red arrow). Since the latter species is the highest contacted by the line along the rod, its height at contact is also recorded as canopy height, even though surrounding grasses are taller.

4.2.2 Density of Shrub and Tree Species; Trunk Diameter and Basal Area

Estimating density can be a laborious and time-consuming task, often made difficult by the inability to determine what constitutes an individual in clonal species. We limit our density estimation to shrub and tree species, the growth forms that make up the overstory of most of our native communities and for which changes in population numbers may result in significant community changes.

Shrub density will be monitored by counting all shrubs and subshrubs rooted within a 1 × 30 m belt plot adjacent to the line-point transect. For tabulation convenience the belt plot is divided into six contiguous 1 × 5 m plots (Figure 12). Individuals are recorded by taxa and classified into five stage classes: seedling, juvenile, mature (adult), dead, and resprout (see SOP 7 for descriptions of stage classes).

CHIS and SAMO/CABR will monitor shrub density in different ways. At CHIS all stems are counted grouped by individual shrubs, whereas at SAMO/CABR, only whole shrubs will be counted. This reflects a different monitoring focus at CHIS than at SAMO/CABR and a difference in the difficulty of collecting density data at the parks. CHIS is interested in documenting detailed patterns of shrub

increase in the post-grazing environment (see discussion under 3.1, Rationale for Sampling Design). At the same time, the relative sparseness of shrubs at CHIS makes individual stem counts feasible. At SAMO/CABR, shrub stands are mostly mature and the high density of shrub stems in the understory makes stems difficult to count without negatively impacting the vegetation. Furthermore, counting of individual stems is so time-consuming as to unreasonably extend the time needed for data collection. (After fire, when vegetation is sparse, the pattern of shrub recovery is documented by the post-fire monitoring protocol.)

Tree density and basal area are monitored by counting all trees and measuring trunk diameters at 1.4 m above the ground (4.5 ft, the “diameter at breast height” or DBH) in a 10 × 30 m plot centered on the line-point transect (Figure 12). Trees are recorded by individual taxa and assigned to one of six stage classes: seedling, resprout, root sprout, sapling, mature, and dead (see SOP 7 for descriptions of classes). On multiple-trunked trees, diameter is recorded for all individual trunks at breast height. Basal area is calculated from diameter at breast height.

Shrub and tree data are not collected during every monitoring event. At SAMO and CABR, these data are collected only in the second consecutive year of monitoring at a particular site. At CHIS, data are collected for every monitoring event in the rotating panels, but at the core sites, which are monitored yearly, shrub data are collected every second year and tree data are collected every fourth year (Table 13). Experience at CHIS and observations at SAMO/CABR indicate that shrub community dynamics are such that consecutive-year monitoring of shrubs, including seedlings, will not provide additional information that improves interpretation of density changes over time over a monitoring design that allows a 4-year interval between monitoring events, as at SAMO/CABR.

Table 13. Cycle of cover and density monitoring at CHIS, SAMO, and CABR. C is foliar cover, S is density of shrubs, T is density of trees. Species richness is recorded during every monitoring event.

Park	Panel	Year												
		1	2	3	4	5	6	7	8	9	10	11	12	13
CHIS	Core	CST	C	CS	C	CST	C	CS	C	CST	C	CS	C	CST
	A	CST	—	—	—	CST	—	—	—	CST	—	—	—	CST
	B	—	CST	—	—	—	CST	—	—	—	CST	—	—	—
	C	—	—	CST	—	—	—	CST	—	—	—	CST	—	—
	D	—	—	—	CST	—	—	—	CST	—	—	—	CST	—
SAMO & CABR	A	C	—	—	—	—	C	CST	—	—	—	—	C	CST
	B	C	CST	—	—	—	—	C	CST	—	—	—	—	C
	C	—	C	CST	—	—	—	—	C	CST	—	—	—	—
	D	—	—	C	CST	—	—	—	—	C	CST	—	—	—
	E	—	—	—	C	CST	—	—	—	—	C	CST	—	—
	F	—	—	—	—	C	CST	—	—	—	—	C	CST	—

4.2.3 Species Richness

Species richness will be assessed as the total number of taxa recorded along the 30 m line-point intercept transect and in the adjacent 1 × 30 m belt plot. This procedure will document less common, low cover species that occur along the transect but may be missed by the line-point intercept technique (Dethier et al. 1993 cited in Elzinga et al. 1998). Species richness will be recorded at each plot monitored, each time the plot is visited.

A separate species list will be made for each of six pairs of alternating 1 × 1 m and 1 × 4 m plots. For each pair of plots, the 1 × 1 m plot will be read first, recording all species within the plot. The adjacent 1 × 4 m plot will then be read, adding only those species not already recorded in the 1 × 1 m plot. The reason for this somewhat complicated division is to provide richness data based on 1 m² plots that might be comparable to other studies. Plots of this size are often used in diversity studies in Mediterranean-type ecosystems (Cowling et al. 1996). The data from each plot pair may be combined into six 1 × 5 m contiguous plots to provide a schematic representation of species distribution within the plot.

4.2.4 Frequency of Species Occurrence

Assessment of frequency of species occurrence can be used to monitor changes in species distribution across the landscape or to provide an estimate of population change at the local scale (Elzinga et al. 1998). Frequency of species occurrence across the landscape (among sites) will be derived from the species recorded in the 30 m line-point intercept transect and adjacent 1 × 30 m belt plot (10 × 30 m belt for trees).

Frequency of herbaceous and shrub species within sampling sites will be calculated from the six 1 × 5 m contiguous plots within the 1 × 30 m belt transect used for collecting shrub density and species richness data. The purpose of this calculation is to monitor changes over time in the distribution of species within the belt transect.

5 Field Methods

5.1 Field Season Preparation and Field Schedule

Field season preparation begins in January (SOP 1). At SAMO, maps of proposed new sites and permit requests/renewals must be provided in December before the field season to California State Parks, Mountains Recreation and Conservation Authority, and other partner land management agencies in order to allow time for the agencies to evaluate the requests (SOP 15). All geo-location equipment and cameras will be checked for serviceability. Intern (or seasonal employee) recruitment will be completed by the end of January at all three parks. Intern training, including safety training and certification, will be completed within two weeks of hiring (SOPs 1, 2, 3 and 4). Site reference packets will be reviewed at this time and preparation for establishment of new monitoring plots will be made (SOP 5). Field monitoring will be conducted over the course of the spring growth period. This usually runs from February through June at CHIS, and from March through June at SAMO and CABR.

5.2 Locating, Establishing, and Revisiting Plots

At CHIS, probabilistic plots will be installed on SCI, SMI, SBI, and ANI during the first monitoring cycle. Installation of probabilistic plots on SRI will be delayed until the second monitoring cycle in order to maintain yearly monitoring of the full number of index sites during the first cycle necessary to complete an assessment of vegetation response to the recent removal of deer and elk. We will install 37 probabilistic plots in the first monitoring season and 20–22 plots each year for the following 3 years as we rotate through panels. Beginning in the second cycle (5th season), a total of 84 probabilistic plots will be installed at SRI over the next 4 years. At SAMO we will install 50 plots in the first year and 25 plots each year for the following 10 years. At CABR we will install 24 plots in the first year and 12 plots each year for the following 4 years.

Locating and establishing probabilistically selected plots will be time consuming and uncertain; optimum road, trail, and cross-country routes to each site need to be established and it is only on attempting a first visit to a new sampling location that a site definitively can be determined accessible or inaccessible. At SAMO plot locations will require evaluation and prior approval by the agencies that own the land where plots are proposed for placement. Depending on logistic concerns and field season time constraints, new monitoring plots may be installed either before or during the monitoring season.

Once a team has determined a site is accessible and otherwise suitable for monitoring, they will lay out the monitoring transect. Permanent monuments will be installed, and each site will be fully documented with written descriptions and photographs. Plot establishment and photo documentation are described in SOP 5.

After a monitoring plot is installed, a site reference packet will be created (SOP 1). The packet will include maps and photographs, directions, location and waypoint information, and any other information necessary for relocating the site for future monitoring. A list of plants observed at the site will also be included. Packets will be updated after each monitoring visit.

Revisiting established sites for assessment requires considerable preparation (SOP 6). Team members will read and discuss the directions, site descriptions, and photographs contained in the reference packet for each site to be visited. The crew will also check GPS units to ensure that site locations, waypoints, datum, and all GIS layers necessary for navigation to and locating sites are properly loaded (SOP 4). Field survey equipment and materials must be inventoried and checked for serviceability prior to departure for the field. If the crew observes changes in conditions or access routes from those recorded in the site reference packet, they should carefully document those changes and report them to the field supervisor or program leader.

Prior to visiting the field for any purpose, each crew member must ensure that they have proper clothing and all equipment necessary for field comfort and safety. The weather forecast should be checked. Radios, GPS units and emergency beacons should be checked to assure they are fully charged and working. Emergency response protocols and contact information must be carried by each crew member. Crew members must report their location to park dispatch or other cognizant staff prior to entering the field and confirm their departure from the field (SOP 3).

In the Santa Monica Mountains, marijuana cultivation is an increasing problem. Sites to be visited each season must be submitted and approved by law enforcement staff prior to beginning field work. If any signs of cultivation are found when in the field, the crew should leave the area immediately and report the information to law enforcement.

5.3 Training, Calibration and Consistency

At the start of the field season, staff will be provided with a 5-day training program followed by field training as work begins (SOP 2, SOP 7). The most important field requirements for monitoring are accurate plant identification and consistent application of sampling procedures. Each field team will be composed of a staff member with experience and skill in applying the monitoring protocol and in local plant identification, and an intern or seasonal employee with background in botany. The presence of one experienced member on each team will help to assure consistent application of techniques across field seasons and accurate plant identification.

Prior to beginning field work, regional and site-specific plant lists will be reviewed and difficult-to-identify species or groups will be discussed. Procedures for collecting and documenting unknown plants also will be reviewed (SOP 8). When multiple crews are involved in monitoring, the training and calibration of workers in estimation of cover and density will be done in the field. Prior to beginning surveys as individual teams, at least one plot in each major vegetation type will be assessed by the full group and at least two plots double-assessed by the individual teams to ensure that everyone follows the protocol in the same way and is consistent in cover and density determinations. If necessary, additional plots will be read as a group until the team members agree that consistency has been obtained.

5.4 Field Data Review and Entry

At the time of development of this protocol there is no electronic data entry system adequate for field data collection at the MEDN parks. All data will be collected on paper datasheets. We anticipate that

in the future, an electronic field data system will become available and data review procedures will be modified to the specific requirements of that system.

Datasheets will be checked for completeness and accuracy before leaving the sampling site. On returning from the field, datasheets will be reviewed for legibility and correct use of plant codes (SOP 9). Unknown species will be noted on the field form and vouchers coded to the specific form and placed in a refrigerator or pressed (SOP 8). Unknowns should be identified as soon as possible after collection. GPS points must be downloaded, checked, and annotated at the end of each day. Photographs must also be downloaded and annotated at the end of each day.

Data on field forms should be entered as soon as feasible after collection and preferably by the person(s) who collected them. To minimize transcription errors, data entry should follow the procedures for team and individual entry described in SOP 9. Processing of plot photographs is described in SOP 10.

5.5 After the Field Season

All field data not entered during the field season will be entered into the database as soon as possible (within 30 days) after field surveys conclude. Equipment will be checked for serviceability and supplies will be inventoried. Datasheets and reference materials will be filed (SOP 11).

An informal logistics report will be prepared, documenting

- Difficulties that occurred in the field.
- Changes in the sampling sites from what is described in the site reference packets.
- Changes in how the sampling plots were accessed and read.

Using the logistics report, the survey team will update the site reference packets and modify the field SOPs as necessary. Salient information will be included in the annual status report. Data will be reviewed and verified under the direction of the Data Manager following SOPs 9, 10, 12 and 13.

6 Data Management

The following section outlines general procedures for data handling, analysis, and report development. **This section is required reading for anyone involved in the collection or processing of data for this program, including field crews.** Proper data management ensures that data will be reliable, relatively free of errors, and ready for analysis.

Specific data management procedures are described in the MEDN data management plan (Lee 2005) and SOPs 12, 13 and 14. The MEDN vital signs monitoring plan (Cameron et al. 2005) provides an overview of the network's information management and reporting plan. All project personnel must know and understand their responsibilities in data management.

6.1 Data Management Overview

The stages of the data management life cycle are summarized below. Quality assurance and documentation are not limited to any particular stage but rather occur throughout the life cycle.

- *Preparation* – Training, logistics planning, printing forms and maps.
- *Data acquisition* – Field data collection.
- *Data entry and processing* – Data entry on a daily basis, database uploads, GPS processing, etc.
- *Quality review* – Program Lead(s) oversee data verification (paper datasheet checked against electronic record) and validation (reviewed for completeness and logical consistency using queries within the database). Data verification and validation constitute the quality review.
- *Metadata* – Documentation of the year's data collection (e.g., version of protocol followed) and results of the quality review. Example metadata are provided in SOP 9.
- *Data certification* – Program Lead(s) in consultation with the MEDN Data Manager certifies the data in the database after it has been verified and validated. The data are certified as complete for the period of record. See description in SOP 9.
- *Data delivery* – Certified data and metadata are delivered to the MEDN Data Manager for archiving.
- *Data analysis* – Data are summarized and analyzed.
- *Product development* – Reports, maps, and other products are developed.
- *Product delivery* – Deliver reports and other products for posting and archiving.
- *Posting and distribution* – Distribute products as planned and/or post to NPS websites.
- *Archiving and records management* – Review analog and digital files for retention (or destruction) according to NPS Director's Order 19. Retained files are renamed and stored as needed.
- *Season closeout* – Review and document needed improvements to project database, procedures or infrastructure; complete administrative reports; and develop work plans for the coming season.

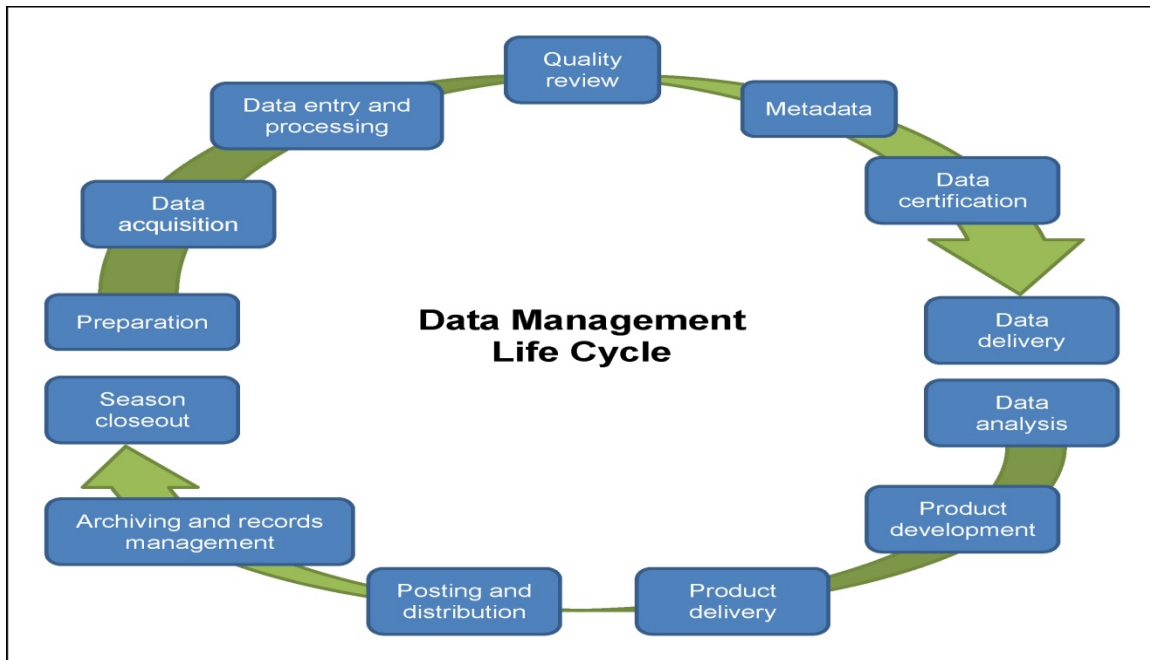


Figure 14. Recommended flow diagram of data management, from pre-season preparation to season closeout. Quality review includes data verification (checking paper datasheets against the electronic data) and validation (queries for logical consistency and completeness) that require input from the Program Leads. Adapted from Acker et al. (2010).

6.2 Overview of Database Design

The MEDN Terrestrial Vegetation database is a customized relational database developed in MS Access 2010. It is used to store and manipulate the data associated with this project. The MEDN Data Manager is responsible for the development and maintenance of the database. The design of this database follows the Natural Resource Database Template (NRDT) and is consistent with NPS Inventory and Monitoring Program guidance for the management of natural resource data (Lee 2005).

The database consists of a "back-end" database, where data resides in a series of related tables, and a "front-end" database, where users can enter, view, edit, error-check, summarize, and export data through an interactive interface. By splitting the database into front- and back-end components, multiple users can interact with the data simultaneously.

The back-end database schema (tables, fields, and relationships) is provided in SOP 12. The front-end database contains the forms, queries, and reports customized with Visual Basics for Applications (VBA) programming code. Data entry forms are designed to meet the requirements of Project Managers and are based on existing field forms used to record data. The database is structured to minimize data entry errors by guiding the data entry technician through a simple two-form digital data entry process. Details of the database, including a description of the structure and relationship links among data tables, are presented in SOP 12.

The Program Lead(s) participate in and oversee data collection and entry at each park. After verification, validation, and certification procedures have been followed, the database is used to create summaries for annual reports and data are uploaded to the master database for long-term storage.

The master database will house all the data collected using this protocol. Network parks will have read-only access to this database and can use it to conduct multiyear data summaries and analyses for reports and publications.

6.3 Data Entry, Verification, Editing, and Validation

The Program Lead is responsible for ensuring that all data collected are accurate and complete and that data are entered properly into the database on a daily basis. Data should be uploaded or entered as soon as possible after each survey in order to keep current with data entry tasks, and to identify any errors or problems as close to the time of data collection as possible. The database has a user-friendly interface to facilitate data entry and checking. Each data entry form is patterned after the corresponding field form and has built-in pick-lists and validation rules to test for missing data or illogical combinations.

As soon as possible after data are entered, records should be visually checked against the paper datasheet. This should be done for each record prior to moving to the next field datasheet. As a result, by the end of the field season, entered data will have been checked against each field datasheet. Data verification is the process of ensuring the electronic data match what was recorded on the hardcopy field forms. Once the data have been entered and saved, the Program Leader (with assistance from the MEDN Data Manager) will run validation queries (built by the Data Manager in consultation with the Program Lead) and evaluate the data for completeness and logical consistency. The creation of data validation queries requires a reviewer to have extensive knowledge of what the data mean and how they were collected. Queries and reports have been built in the database to look for apparent outliers, inconsistencies in entry, null values, or any other anomalous data points. Anomalies are reported to the Program Lead for resolution. Unresolved anomalies will be documented and included in the metadata and certification report. Any questions about the data, data entry procedures, or difficulties with the database are to be resolved by the Program Lead(s) in consultation with the MEDN Data Manager.

Once the data have been certified, the working database will be transferred to the MEDN Data Manager, who will upload the data to the master database. While uploading the data to the database, the data will be subjected to an automated data quality process that will flag potential missing sites and invalid or improperly formatted data.

6.4 Metadata Procedures

Data documentation or the creation of metadata is a critical step toward ensuring that datasets are usable for their intended purposes well into the future. Metadata is defined as structured information about the content, quality, and condition of data. Additionally, metadata provide the means to catalog datasets within intranet and internet systems, making data more accessible to a broad range of potential users. Metadata for all MEDN monitoring data will conform to Federal Geographic Data

Committee (FGDC 1998) and NPS guidelines (NPS 2014c) and will contain all components of supporting information such that the data may be confidently manipulated, analyzed, and synthesized. For long-term projects such as this one, metadata creation is most time consuming the first time developed—after which most information remains static from one year to the next (see SOP 9 for sample metadata). Metadata records in subsequent years then only need to be updated to reflect current publications, references, taxonomic conventions, contact information, data disposition and quality, and to describe any changes in collection methods, analysis approaches, or quality assurance for the project.

Specific procedures for metadata development and posting are outlined in the MEDN data management plan (Lee 2005). In general, the Program Leader and MEDN Data Manager will work together to create and update an FGDC- and NPS-compliant metadata record in XML format. The Program Lead(s) should update the metadata content as changes to the protocol are made, and each year as additional data are accumulated. Edits within the document should be tracked so that any changes are obvious to those who will use it to update the XML metadata file. The MEDN Data Manager will post edited metadata records to the NPS IRMA (Integrated Resource Management Applications) data system, where they will be made available to the public.

6.5 Sensitive Information

Part of metadata development includes determining whether or not the data include any sensitive information. For example, the locations of rare, threatened, or endangered species could be considered sensitive data. Prior to completing metadata, the Program Lead and park resource manager should work together to identify any sensitive information in the data. Their findings should be documented and communicated to the MEDN Data Manager. At this time, we do not anticipate that sensitive information will be present in the Terrestrial Vegetation monitoring program.

6.6 Data Certification and Delivery

Data certification is a benchmark in the project information management process that indicates that 1) the data are complete for the period of record; 2) they have undergone and passed the quality assurance checks; and 3) they are appropriately documented and in a condition for archiving, posting, and distribution. Certification is not intended to imply that the data are completely free of errors or inconsistencies that may not have been detected during quality assurance reviews.

To ensure that only data of the highest possible quality are included in reports and other project deliverables, the data certification step is an annual requirement for all tabular and spatial data. The Program Lead for each park is primarily responsible for completing certification, in consultation with the MEDN Data Manager. The certified data and updated metadata should be delivered to the MEDN Data Manager according to the Table 17 timeline in Chapter 9, Operational Requirements. Additional details of the certification and delivery processes, including a season close-out form, are included in SOP 13. Data certification will be completed by 1 November, each year.

6.7 Data Archiving

File structure, version control, and regular backups are carefully controlled to preserve the integrity of MEDN datasets. Field datasets will be stored in designated file cabinets at each network park.

After field datasheets have been entered into the database, these datasheets will be scanned into PDF documents and stored in the project directory on the server. After all data for a field season have been entered, verified, validated, and certified by the Program Lead(s), the database will be sent to the MEDN Data Manager for archiving and distribution. The archived database will be stored on a secure server with regularly scheduled backups and will be read-only accessible to the network parks. A complete copy of the database also will be archived prior to any database version changes.

Once the data have been archived, any changes made to data values must be documented in the edit log database table. Paper field datasheets will not be altered; field data will be reconciled to the database through the use of the edit log. Any editing of archived datasets will be accomplished jointly by the Program Lead(s) and MEDN Data Manager.

Certified and archived nonsensitive data, along with any associated metadata, will be made available through the NPS IRMA data system at <http://irma.nps.gov>. The MEDN Data Manager will post certified datasets to IRMA, where they may be downloaded for research and management applications. Other datasets, including those containing sensitive data, may be requested in writing from the Program Lead. Sensitive data will be released only with a signed confidentiality agreement.

7 Data Analysis and Reporting

At the end of each calendar year, an annual report will be compiled that summarizes data collected in all three parks. The report will describe the status of vegetation at each park through simple summary statistics, descriptions of interesting or unusual observations, and basic interpretation of that year's findings. Although each park will be summarized separately, the report will include a brief integrated assessment of observations in all three parks. A single report will be prepared for all three parks in the MEDN and published in the Natural Resources Data Series or the Natural Resources Report Series. A draft template of the annual report is provided in Appendix E.

Park-specific trend reports will be prepared at the completion of each monitoring cycle: every four years for CHIS and every six years for SAMO/CABR. Trend reports will summarize all vegetation monitoring efforts up to the date of publishing, describe status of and changes in vegetation, interpret those changes, and provide a critical review of the monitoring effort. This review will allow for adaptation of protocols to fit changing programmatic goals, or changing environmental conditions. Trend reports will be published as Natural Resource Reports or in a peer-reviewed journal. Although trend reports are produced in different years for CHIS and SAMO/CABR, each report will include an integrated network-level assessment of observations by drawing on the most recent report available from the other park(s). Every 12 years we will produce a single integrated report for the three parks.

In both status and trend reports, we will analyze and report on the status of and changes in the abundance of plant functional types (e.g., non-native species), the abundance of selected species from each park, and community diversity. In combination, these provide sensitive indicators for vegetation status and change at the MEDN parks and provide for regional evaluation of patterns and trends that reflect management concerns.

7.1 Response Metrics

7.1.1 *Plant Functional Types*

In complex vegetation assemblages, it is often difficult to identify keystone or indicator species, or even a few dominant species representative of all communities. In addition, without stratified or targeted sampling, it may be difficult to obtain sufficient samples of any one species to allow for trend detection, even for relatively common species. For example, the shrublands that cover 85% of vegetated uplands in SAMO are composed of 48 alliances that include 94 associations defined by combinations of 46 dominant species. The three network parks, although in close proximity, share less than 20% of their species. This complexity makes regional assessments and comparisons based on individual species difficult. A commonly employed solution to this problem is to group species into “functional types” of similar growth form, life history, and origin. We will group plants into the following categories for status and trend analysis and reporting:

- Growth form: tree, shrub, forb, grass.
- Life history: annual (and biennial), perennial.
- Origin (nativity): native, non-native.

Aggregation of species into groupings with similar characteristics will allow broader comparisons than may be possible among individual species. Analysis by functional types also provides an important indirect assessment of ecosystem processes, as plant morphology and life history characteristics are generally related to how a species acquires resources and responds to environmental stresses.

Non-native Plant Species

Non-native plant species are a major resource management concern for the MEDN. Non-native plants comprise 26% of the Channel Islands flora, 29% of the Santa Monica Mountains flora, and 38% of the flora on Point Loma (The Point Loma Ecological Conservation Area, including CABR). New introductions are reported each year. A number of these species are considered ecosystem transformers (Richardson et al. 2000) and are of high management concern.

Each park, however, contains a different suite of non-native and invasive plant species. Further, individual non-native and/or invasive species, ubiquitous as a group, are often localized or sporadic in distribution, and while present in large numbers locally, may occur in low numbers relative to the total vegetation monitored. For these reasons, to facilitate assessment of status and trend, we will report on non-native species only as plant functional types (e.g., non-native annual grasses). Although all non-native species will be monitored as individual species, we will not routinely report on individual species.

Changes in the distribution and abundance of individual invasive, ecologically damaging species will be directly addressed by the Invasive Plant monitoring protocol for CHIS and SAMO (Irvine et al. 2016), which will monitor invasive species along roads and trails and attempt to provide early warning of new introductions at park entry sites. The Terrestrial Vegetation protocol will complement the Invasive Plant protocol by monitoring and reporting on the occurrence and abundance of non-native species as components of plant communities.

7.1.2 Individual Species

Monitoring of individual species represents a floristic approach to assessing community change. All species observed using our response methodology will be monitored. It is, however, infeasible to provide reports on each individual species observed. We will only report on the status and trend of the selected native species shown in Table 14, in addition to plant functional types. These species have been chosen based on their importance in defining community structure or for what we believe is their ability to provide inference to community function. They represent varying ranges of environmental adaptation and their co-occurrence is a response to the unique conditions in each park. Comparing changes in broadly and narrowly distributed species may provide insight into the nature of community changes that occur. As our understanding increases and management interests change over time, we may change the species we report. Non-native species have not been chosen as target species to be reported (see discussion in previous section). However, important changes in any particular species observed will be reported, and non-native species may be added to the yearly report.

Table 14. Target native species to be monitored at MEDN parks, showing the geographic distribution of each species and the distribution of the vegetation alliances which they characterize. Park acronyms indicate which parks have identified a particular species for targeted monitoring. Broad, Medium, and Narrow refer to the relative breadth of distribution. CA is California and CI is Channel Islands.

Vegetation alliance	Species	Distribution of species	Distribution of alliance in California
Chaparral	<i>Adenostoma fasciculatum</i> CABR, SAMO, CHIS	Broad—Coastal CA, Sierra Nevada into Baja CA	Narrow—Coastal CA incl CI, foothills and lower elevation Sierra Nevada
	<i>Arctostaphylos confertiflora</i> CHIS	Narrow—Santa Rosa Island	Narrow—Santa Rosa Island
	<i>Ceanothus crassifolius</i> SAMO	Narrow—Southwestern CA into Baja CA, excl CI	Narrow—Southwestern CA
	<i>Ceanothus megacarpus</i> SAMO	Narrow—Transverse Ranges, CI, and extreme southwestern San Diego County	Narrow—Southwestern CA from s. Santa Barbara County to n. Orange County, incl CI
	<i>Ceanothus oliganthus</i> SAMO	Broad—Coastal central and southern CA	Broad—CA coast ranges, interior foothills and valleys
	<i>Ceanothus spinosus</i> SAMO	Medium—Southwestern CA and Transverse Ranges into Baja CA, excl CI	Narrow—Southwestern CA excl San Diego Co and CI
	<i>Ceanothus verrucosus</i> CABR	Narrow—Coastal San Diego County and northern Baja CA	Narrow—Coastal San Diego County and possibly northern Baja CA
	<i>Cercocarpus betuloides</i> SAMO	Broad—Throughout CA excl high elevation mountains, into Oregon and Baja Ca	(No Alliance). CA coast ranges, Sierra Nevada
	<i>Quercus pacifica</i> CHIS	Narrow—CI	Narrow—CI
	<i>Rhus ovata</i> SAMO	Medium—Coastal southern CA into AZ and Baja CA	Narrow—Southern California coast, mountains and valleys
Coastal Sage Scrub	<i>Xylococcus bicolor</i> CABR	Narrow—Coastal San Diego County into northern Baja CA, southern CI	Narrow— <i>Adenostoma fasciculatum</i> - <i>Xylococcus bicolor</i> co-dominant alliance: San Diego and western Riverside Counties
	<i>Artemisia californica</i> CABR, SAMO, CHIS	Medium—Coastal central and southwestern CA into Baja CA	Medium—Central and southwestern coast, interior foothills and valleys
	<i>Baccharis pilularis</i> CHIS	Broad—Throughout CA into Mex	Broad—Throughout CA
	<i>Encelia californica</i> CABR, SAMO	Medium—Coastal Southern CA into Baja CA	Narrow—Extreme coastal southwestern CA
	<i>Eriogonum cinereum</i> SAMO	Medium—Coastal southern CA incl Santa Rosa Island	Narrow—Extreme coastal southwestern CA down to Orange County, excl CI
	<i>Lycium californicum</i> CABR, CHIS	Narrow—Coastal Los Angeles and San Diego Counties into northern Baja CA, southern CI	Narrow—Coastal Los Angeles and San Diego Counties into northern Baja CA, southern CI
	<i>Nassella lepida</i> CABR, SAMO, CHIS	Broad—Coastal CA into Baja CA	Broad—Coastal CA, interior foothills and valleys

Table 14 (continued). Target native species to be monitored at MEDN parks, showing the geographic distribution of each species and the distribution of the vegetation alliances which they characterize. Park acronyms indicate which parks have identified a particular species for targeted monitoring. Broad, Medium, and Narrow refer to the relative breadth of distribution. CA is California and CI is Channel Islands.

Vegetation alliance	Species	Distribution of species	Distribution of alliance in California
Coastal Sage Scrub (continued)	<i>Nassella pulchra</i> CABR, SAMO, CHIS	Broad—Throughout CA into Baja CA	Broad—Coastal, southern and central CA, interior foothills and valleys
	<i>Salvia leucophylla</i> SAMO	Medium—Coastal central and southwestern CA east along Transverse Ranges	Medium—Central western and south coast, excl CI
Coastal Bluff Scrub	<i>Leptosyne gigantea</i> CHIS, SAMO	Narrow—Coastal south-central and southwestern CA incl CI	Narrow—Coastal south-central and southwestern CA incl CI
	<i>Isocoma menziesii</i> CHIS	Medium—Coastal central and southwestern CA into Baja CA	Narrow—Coastal southern CA incl interior foothills and valleys and CI
	<i>Suaeda taxifolia</i> CHIS	Narrow—Coastal southern CA incl CI, into Baja CA	(No Alliance)
Transitional / Ubiquitous	<i>Eriogonum fasciculatum</i> CABR, SAMO	Broad—Central and southern CA into UT, AZ, northern Mexico	Broad—Central and southwestern CA, southern CA deserts
	<i>Malosma laurina</i> CABR, SAMO	Narrow—Coastal southern CA, into Baja CA	Narrow—Coastal Transverse Ranges, including CI, Southern CA mountains and valleys
	<i>Rhus integrigolia</i> CABR, CHIS	Narrow—Coastal southern CA into Baja CA	Narrow—Coastal southern CA, possibly into Baja CA
	<i>Salvia mellifera</i> CABR, SAMO	Medium—Coastal central and southern CA into Baja CA.	Medium—Western central and southern CA, excl CI, incl interior foothills and valleys

7.2 Status and Trend Analysis

Detailed guidance for data analysis is provided in SOP 14. The MEDN vegetation monitoring program is structured to allow estimation of both status and of trend. Status measures provide indices of the condition of a resource of interest for a given point in time. Trend measures characterize the change in a resource over time. Outcomes that provide information on the function, composition, and structure of park ecosystems are chosen for long-term monitoring and include species cover, density, and frequency and richness.

Trend, the overall change in a population of interest, will be estimated with parametric regression models. These will provide the basis for our trend testing. Nonparametric trend tests, such as the Regional Kendall test (Helsel and Frans 2006), will also be examined as a second assessment tool or when monitoring data do not meet the assumptions of parametric models.

7.3 Annual Status Reports

An annual data summary report will be submitted to the MEDN Program Manager in November following each season of data collection. The purpose of the report is to quantitatively describe the

current conditions (status) of vegetation, provide brief interpretation of findings relevant to management concerns, and create metadata describing the monitoring year. The description of status will include standard univariate descriptive statistics as well as graphical representations. Table 15 shows data and summary statistics that we plan to include in the report and the table and figure types recommended for presenting these data and statistics. Appendix E provides a draft template for the report.

Table 15. Data and summary statistics for annual report.

Timeframe	Format	Metric	Species aggregation	Site aggregation ¹	Descriptors
For current year only	Table	Species Richness (# species)	All species combined Growth form ² Nativity Nativity × growth form	All sites Major veg. types ³	Mean SD ⁴ Range
	Table	Absolute Cover (%)	All species combined, Growth form Nativity Growth form × nativity Soil surface features Each target species	All sites Major veg. types	Mean SD Range
	Table	Shrub & Tree Density (# / ha)	All species combined Life stage ⁵ Nativity Each target species	All sites Major veg. types	Mean SD Range
	Bar chart	Absolute Cover (%)	All species combined, Growth form Nativity Growth form × nativity	All sites Major veg. types	Mean SD
	Stacked bar chart	Relative Cover (%)	Growth form Nativity Growth form × nativity	All sites Major veg. types	Relative Cover of each group
For current year and previous 5 years	X-Y plot	Absolute Cover (%)	All species combined Growth form Nativity Growth form × nativity	All sites Major veg. types	Mean SD
	X-Y plot	Shrub & Tree Density (# / ha)	Growth form Nativity	All sites Major veg. types	Mean SD

¹For CHIS, each of these site groupings will be further stratified by island and selection method (probabilistically or subjectively selected).

²Growth form is tree, shrub, forb, and grass. It is combined with life history, such that species may be classified as annual forb, perennial forb, etc.

³Major vegetation type groupings are chaparral, coastal sage scrub, woodland, and grassland.

⁴Standard Deviation.

⁵Life stage is seedling, sapling, or mature.

In addition to presenting data, summary statistics, and a brief interpretation of findings, the annual report will include the following information:

- A brief summary of the year's progress in establishing monitoring plots. This summary will include difficulties encountered and a listing of locations rejected, along with the reasons for rejection.
- A brief narrative of the year's monitoring methodology, effort, basic results, noteworthy observations, and any changes in the sampling or analysis procedures.
- The names of personnel that conducted surveys in that year.
- A brief description of field procedures, quality control and data handling, and data analysis methods, with identification of any data quality concerns and/or deviations from protocols that affect data quality and interpretation.
- A table and accompanying map with the location, date, and type of survey for each monitoring plot visited in that year.
- Graphs showing temperature and precipitation conditions for the sampling season and two years prior to the sampling season.
- Suggested or required changes to the protocol.

7.4 Periodic Trend Reports

After the initial pilot study phase, an in-depth synthesis report on status and trends will be produced at the end of every monitoring cycle. The vegetation Program Leader(s) will coordinate the production of this report, which will involve network and park staff as well as external subject matter experts. The purpose of this report is to (1) describe trends in vegetation, (2) evaluate the effects of potential explanatory variables and covariates, and (3) synthesize this information to explore patterns and better understand processes of vegetation dynamics and potential drivers of change.

In addition, the report will evaluate operational aspects of the monitoring protocol. Specific issues to be evaluated include whether sample allocations need to be adjusted; whether the sampling period remains appropriate; and whether new management concerns exist that might dictate some reallocation of effort, changes in target species, or additions to the indicator metrics that are assessed annually. The report will also present an accounting of staff and funding resources that were needed to collect and analyze the data and to complete the written periodic report.

7.5 Data Archival Procedures

Paper datasheets will be scanned immediately after review, and the resulting files will be placed on a local network server to preserve information in case of loss of originals. All local network servers are backed up nightly onto an off-site tape drive. Paper copies will be retained at park headquarters until after QA/QC and certification of digital data are complete. They will then be submitted to the park archives and stored in the park collections building. Scanned datasheets will remain on the designated local network drive.

After certification, digital copies of data and reports will be archived on the MEDN network drive, posted to the MEDN website, and posted to the Integrated Resource Management Application (IRMA), a web-based "one-stop" for data and information related to National Park Service natural and cultural resources. IRMA is managed by the NPS Washington Areas Support Office (WASO) National I&M program.

8 Personnel Requirements and Training

8.1 Roles and Responsibilities

The Terrestrial Vegetation monitoring program will be managed and implemented primarily by I&M and park-funded park resource management staff. At CHIS the Program Leader is the Monitoring Botanist. At SAMO the program is jointly led by the MEDN/SAMO Botanist and SAMO Plant Ecologist. At CABR the Program Leader is the Plant Biologist. The MEDN Data Manager will provide support for the development and maintenance of databases, analysis of data, and report development. Program oversight and support is provided by the MEDN I&M Program Manager (Table 16).

The Program Leaders at each park, in collaboration with the I&M Program Manager, are responsible for logistical planning, field implementation, data handling and data entry, project administration, completing analyses, and preparing status and synthesis (trend) reports. The Program Leaders and I&M Program Manager are jointly responsible for assessing the efficacy of work performed and modifying the SOPs as necessary to improve field capabilities and ensure that collected data are adequate to meet monitoring program goals. The MEDN Data Manager, in collaboration with the Program Leads, will develop data entry and QA/QC procedures, maintain databases, and create database queries to support summary, analysis, and reporting of findings.

Field data collection will be performed by the Program Leaders with assistance from other resource management staff, interns, and volunteers. The MEDN/SAMO Botanist will provide support and assistance to all MEDN parks, but with primary responsibility to SAMO. Data analysis, summary, interpretation, and synthesis will be conducted in consultation with park resource managers and academic advisors. Elements of the MEDN Invasive Plant monitoring program will be implemented simultaneously with Terrestrial Vegetation monitoring field activities. At SAMO, the Restoration Ecologist will assist in coordinating field Terrestrial Vegetation data collection with Invasive Species data collection and with hiring and supervising interns that will support both monitoring programs.

Post-fire plot monitoring will be led by the MEDN Fire Ecologist and performed by both Fire Effects and Terrestrial Vegetation monitoring staff, with the mix depending on funding availability. Based on a typical range of fire sizes in the Santa Monica Mountains, we anticipate anywhere between 20 and 50 plots will require monitoring after a given fire at SAMO. Fires at CHIS and CABR have been historically small and very infrequent, so it is not possible to predict monitoring requirements for these parks.

Table 16. Roles and responsibilities for implementing the MEDN Terrestrial Vegetation monitoring protocol.

Position / Role	Responsibilities
CHIS Monitoring Botanist (CHIS Program Leader)	<i>Planning, Coordination, Analysis, Reporting</i> Track project objectives, budget, requirements, and progress toward meeting objectives (in coordination with I&M Program Manager)
SAMO Plant Ecologist (SAMO Program Co-leader)	- Maintain and archive project records - Establish and document plot locations - Perform data summaries and analyses
MEDN/SAMO Botanist (SAMO Program Co-leader)	- Complete reports, metadata, and other products according to schedule - Coordinate and ratify changes to protocol (in coordination with MEDN I&M Program Manager and regional I&M Program Manager)
CABR Plant Biologist (CABR Program Leader)	<i>Field Activities, Data Collection</i> - Serve as lead for communications between NPS and other land management agencies - Lead intern recruitment - Acquire and maintain field equipment - Establish and document plot locations - Plan and execute field visits - Prepare guide materials for site visits - Direct training and assure safety of field teams - Assure calibration and consistency of team members - Serve as field crew leader for data collection - Oversee data collection and entry, verify accurate data transcription into database
MEDN Data Manager	- Serve as primary steward of MS Access database and GIS data and products - Develop data entry and QA/QC procedures - Certify each season's data for quality and completeness - Maintain and update database applications - Provide database training as needed - Consult on GPS use - Work with SAMO Plant Ecologist to analyze spatial data and develop metadata for spatial data products - Create database queries to support summary, analysis, and reporting of findings - Facilitate check-in, review, and posting of data, metadata, reports, and other products to national databases and clearinghouses
MEDN Program Manager	- Provide project oversight; track project objectives, budget, requirements, and progress toward meeting objectives (in coordination with park Program Leaders) - Perform program administration and budget - Consult on all phases of protocol review and implementation - Coordinate assistance with annual and trend reports as needed - Review reports and serve as peer-review coordinator for annual and synthesis reports

Table 16 (continued). Roles and responsibilities for implementing the MEDN Terrestrial Vegetation monitoring protocol.

Position / Role	Responsibilities
Field Assistants • Technicians • Interns, Volunteers	• Install plots • Collect, record, enter, and verify data
SAMO Restoration Ecologist	• Serve as co-lead w/Botanist for intern recruitment • Coordinate field data collection with data collection for Invasive Plant monitoring protocol
MEDN Fire Ecologist (Post-fire monitoring only)	• Monitor burned plots for 2 consecutive years post-fire • In consultation with I&M/park staff, plan and execute field visits • Prepare guide materials for site visits • Direct training and ensure safety of field teams • Ensure calibration and consistency of team members • Oversee data collection and entry, verify accurate data transcription into database • Oversee and/or perform data summary, analysis, and reporting

8.2 Crew Qualifications and Training (Staffing)

The installation and assessment of plots will be conducted by permanent staff (i.e., Program Leaders) assisted by interns, or if funding permits, term and seasonal staff, working in teams of two individuals. CHIS and CABR will each have a single team. At SAMO one full-time and one half-time team will work simultaneously to conduct surveys. If funding becomes available in the future, a second team will be added to CHIS.

Participation in field activities by Program Leaders provides several advantages over simply hiring seasonal staff. Permanent staff members are familiar with the native and non-native flora of the region, experienced in application of field assessment procedures, and knowledgeable about navigation within the topographically and jurisdictionally complex project areas. Greater flexibility is provided in adjusting to yearly vegetation phenology, and the time-consuming and uncertain work of establishing plots can be done in the off season if necessary. The result is that significant time is saved in recruitment and training, and, more importantly, field work is implemented more efficiently, with greater understanding of the data being collected and greater capability to respond to contingencies. Program Leaders also gain direct knowledge of field conditions that will greatly enhance interpretation of data. Finally, use of permanent staff allows implementation of the program largely from existing park base funds.

Field teams require two members for efficiency in data collection and for safety. Program Leaders will be assisted by undergraduate and graduate interns with botany or ecology backgrounds. Student Conservation Association and seasonal hires may be used as funding permits. Because permanent staff will be knowledgeable in procedures and plant identification, components of necessary training, particularly species identification, will be provided while performing field work. However, prior to field work, species lists will be reviewed and difficult-to-identify species will be discussed. Crews will calibrate cover and density estimates as described under Chapter 5, Field Methods.

At the beginning of each field season, and on recruitment of any new crew member, the job hazard abatement (safety) analysis (SOP 3) will be reviewed, and all elements necessary to ensure safety in the field will be discussed. This includes driving on and off-road, use of hand-held radios, wildfire safety procedures, and health concerns such as heat exposure, ticks, rattlesnakes, and poison oak. Brief safety meetings will be conducted each field day addressing issues and concerns related to that day's work. Permanent park staff will maintain Standard First Aid and CPR certification.

9 Operational Requirements

9.1 Field Schedule and Project Workflow

The annual work schedule is structured around the spring season when herbaceous and suffrutescent species can be best located and identified. This period generally runs from mid-February through June for CHIS and March through June for SAMO and CABR, but may vary from year to year depending on environmental conditions. Staffing shortages, logistical or resource issues, and inclement weather may also cause the survey period to extend outside of the typical survey period.

New plots will be installed as required for monitoring a given year's panel. In order to maximize the time allocated for ground surveys during the spring growth and flowering period, installation of new plots may be done either in the winter before the monitoring season (SAMO/CABR) or in the summer or fall preceding the following year's monitoring season (CHIS).

Organization and recruiting for the field season will be performed in January for SAMO/CABR and in October of the preceding year for CHIS. Data will, as much as possible, be entered during the field season. Data entry for data not entered during the field season, data quality assurance and control, analysis, and report preparation will be performed July through November (Table 17).

9.2 Facilities and Equipment Needs

All field activities, data entry, and data management will be based at each park's headquarters. No special facilities should be required, with the exception of housing for out-of-town interns at the SAMO dormitory.

Field equipment is required for three general purposes: site navigation and mapping, plot layout and measurement, and crew transport and safety. Paper forms will be used for field data collection; therefore, no specialized field data entry equipment will be required. We will, however, attempt to develop use of electronic field data entry (e.g., tablets or PDAs) for this monitoring protocol as opportunity and funding permits.

Site navigation and mapping equipment includes global positioning system (GPS) units for each crew and software for programming the units. Accessing many sites will require circuitous off-trail navigation where visibility will be limited by hills and vegetation. Transect markers will generally not be visible until an observer is within a few feet of them. It is therefore necessary to have accurate units with the capability of supporting various shape files that will assist in orienteering to and relocating sample sites (SOPs 4, 5 and 6).

Plot layout and measurement equipment includes measuring tapes, plot frames, compasses, clinometers, rangefinders, cameras, and binoculars. Equipment for crew transport and safety includes backpacks, lathe bags, communication devices (radio and/or cellular phone), snake chaps, tick removal kits, and first-aid kits. Additional details on field equipment can be found in SOP 1.

Table 17. Annual schedule of major tasks for MEDN Terrestrial Vegetation monitoring protocol. The SAMO Technician is required only for the first three years (plot installation phase) of the program.

Month	Activity	Responsible party			
		CHIS	SAMO	CABR	SOP
January–February	Prepare field equipment, datasheets, and site visit information packages	M	B	P, T	1
	Coordinate planned fieldwork with cooperating land mgmt. agencies	M	B	P	1 (15)
	Recruit Interns, complete training and safety documents	M	B, E, R, T	P	1,2,3,4
	Establish new plots	M	B, E, T	P, T	4,5
	Monitor vegetation plots	M	B, E, T, Interns	—	4,6,7,8
March–June (July)	Monitor vegetation plots	M Intern	B, E, T, Interns	P, T Vols.	4,6,7,8
July	Data entry and verification	M Intern	B, E, T, Interns	P, T Vols.	9,10
August	Prepare internal logistics report, plan staffing requirements and budget for new fiscal year, and revise SOPs as needed	M	B, E	P, T	11,16
September	Data certification and archiving, metadata production	D	B, D	P, D	12,13
October	Data analysis of current year's results	D	B, E, D	P, D	14
November	Prepare annual report	D	B, E, D	P, D	Protocol Appx. E
	Submit research permit requests	—	B, E	—	15

CHIS M = Monitoring Botanist

SAMO B = MEDN/SAMO Botanist, E = Plant Ecologist, R = Restoration Ecologist, T = Technician

CABRP = Plant Biologist, T = Technician(s), Vols. = volunteers

MEDN D = Database Manager

9.3 Startup costs and yearly budget

This monitoring protocol is a cooperative effort between the MEDN I&M program and the resource management programs at each of the three network parks. The total cost of equipment and materials required for implementation of this protocol is \$38,440 (2015 dollars; Table 18). All equipment is already owned by the park resource management programs. Only materials (e.g., stakes) need to be purchased.

The anticipated yearly operational cost for implementation of this protocol at the three parks is approximately \$265,500 (2015 dollars). Ninety-four percent of this cost is for staff. The CHIS program is supported with \$109,000 from the park's I&M Prototype base funds, supplemented with

funds from the park resource management program. The programs at SAMO and CABR are supported with \$41,000 from the MEDN I&M program and \$103,000 from the park resource management programs.

Although permanent NPS staff members are supported by base operating funds, seasonal staff and interns are not. Funding has been identified to support temporary staff for the next several years. Continuing funds may need to be obtained to maintain the scope of the program and/or the number of sites monitored each season may need to be reduced.

Table 18. Equipment needs for start of vegetation monitoring programs at SAMO/CABR and expansion of existing program at CHIS. Numbers in parentheses indicate number of items for each park when more than one item is required. Cost estimates are in 2015 dollars.

Function	Equipment	CHIS	SAMO	CABR
Site Navigation and Mapping	Trimble GeoExplorer XT3000 (1 , 2)	4,400	8,800	—
	Trimble TerreSync Pro Software (1 , 2)	1,760	3,520	—
	Garman GPSMAP 62S (3, 2)	—	410	270
Plot Layout and Measurement	Compasses and Clinometers (3 , 3 , 2)	600	600	400
	Digital Field Cameras w/GPS-geotagging (1 , 3)	440	1,100	—
	Tapes, Pins, Flags, etc.	—	500	330
Plot Monuments	Rebar / Angle Aluminum	5,280	560	170
	PVC pipe sheathing for rebar	—	320	—
	Rebar caps	—	—	70
	Miscellaneous	440	220	110
Transport and Safety	Packs, Chaps, First Aid, etc.	220	1,100	220
	Radios (1 , 3 , 2)	1,100	3,300	2,200
Total	—	\$14,240	\$20,430	\$3,770

9.3.1 CHIS

The cost of field equipment and supplies for establishing and relocating plots at CHIS is approximately \$14,200 (2015 dollars, Table 18). The necessary equipment is already owned by the park. Some of it is used almost exclusively by the Monitoring Botanist; however, the more expensive GPS equipment is shared within the resource management office. Eventually it will be necessary to provide funds for replacing the equipment.

Yearly operational costs for implementation of the Terrestrial Vegetation monitoring program are approximately \$111,100 (2015 dollars, Table 19), all but \$2,250 of which is supported by I&M Prototype park base funding. The field effort for this protocol relies on one permanent employee at a

cost of \$75,700. In some years the effort will be (has been) supported by volunteers or a Student Conservation Association intern. The yearly cost for the latter is approximately \$27,500.

Table 19. Estimated annual budget for Terrestrial Vegetation monitoring at CHIS. Staffing includes plot installation, monitoring, data analysis, and reporting. Cost estimates are in 2015 dollars and based on pay rates of staff currently implementing the protocol. Estimates do not include staff time spent locating and installing new transects, which are expected to require only small additional time and cost. See Table 17 for tasks performed in specified time periods.

Cost category	Month (Pay periods ¹)	Botanist (GS-11)		SCA Intern	
		FTE ²	Cost	Cost	Total cost
Staffing	Jan. – Feb. (4.5)	0.7	\$13,510		\$13,510
	Mar. (2)	1.0	8,580	2,300	10,880
	Apr.–Jun. (7)	1.0	30,030	13,700	43,730
	Jul. (2)	0.6	5,150	4,600	9,750
	Aug. (2.5)	0.6	6,440	4,600	11,040
	Sep. (2)	0.5	4,290	2,300	6,590
	Oct. (2)	0.5	4,290	—	4,290
	Nov. (2)	0.3	2,570	—	2,570
	Dec. (2)	0.1	890	—	890
	Total Yearly (Staffing)	0.7	\$75,750	\$27,500	\$103,250
Non-staffing					
Transportation					2,500
Housing					850
Per diem					1,800
GSA Vehicles					2,250
Supplies ³					400
Total Yearly (Non-Staffing)					7,800
Grand Total					\$111,050

¹Each pay period is 14 days as defined on the OPM payroll schedule

²Portion of full-time position

³Includes routine replacement of measuring tapes, monument posts, etc., but not major items such as GPS units

There are travel costs associated with working on the islands; the annual cost for transportation, housing, and per diem is approximately \$6,000. Travel to the islands is usually by park boat using the normal island travel schedule. The cost of operation and maintenance of park boats is covered under park accounts and is not incurred by the CHIS I&M or Resource Management budgets. However there are occasions when travel outside of the park's normal travel schedule is necessary and on

those occasions funding does come out of the CHIS I&M budget. These costs vary on an annual basis and occur due to emergencies, scheduling issues, and field conditions. Over the past twelve years the costs for alternative travel has varied from approximately \$200 to \$2,500 per year.

Yearly GSA vehicle costs at CHIS are not taken directly out of the CHIS I&M budget, however, they are deducted from the resource management budget and do have an indirect effect on the program in terms of available dollars. There are three vehicles (1 on SCI and 2 on SRI) rented from the General Services Administration (GSA) that are available for use by the Monitoring Botanist. The annual yearly lease cost for one vehicle is approximately \$15,500. In a typical year, the Monitoring Botanist has use of one of the vehicles for 7 weeks. The indirect cost to the monitoring program is around \$2,250. Mainland facilities and computer costs, as well as costs for CHIS administrative services such as purchasing, human resources, and IT support are not included in this budget projection.

9.3.2 SAMO

The cost of field equipment and supplies for establishing and relocating plots at SAMO is approximately \$20,400 (2015 cost, Table 18). Sixty-two percent of the equipment cost is for the GPS devices necessary for navigation and plot location. The necessary equipment is already owned by SAMO, is available for general use, and will be used for implementation of the Terrestrial Vegetation monitoring protocol. As this and other monitoring programs develop, however, it may become necessary to obtain dedicated equipment. Over time it will be necessary to provide funds for replacement equipment.

The yearly operational cost for implementation of the SAMO Terrestrial Vegetation monitoring program is approximately \$106,000 (2015 dollars, Table 20). The MEDN I&M program will provide \$28,000; the remainder of the support will be provided by SAMO resource management program funds. The field effort for this protocol utilizes permanent staff supported by interns. While permanent employees are more costly on an hourly basis, the knowledge and experience they bring to the work provide greater survey efficiency, increased capability to respond to unforeseen circumstances, and higher quality data. The cost of park staff is approximately \$92,500 and the cost of interns to support field work is approximately \$13,500.

Planning for and installing plots at SAMO is more difficult than at the other MEDN parks due to the recreation area's dense shrub vegetation, steep terrain, and complex land ownership. Additional staff support for installation of monitoring transects will be required during the first three years of the program. A cartographic technician will help plan access routes, field test viability of access, install new transects, and document access routes. The yearly estimated cost for this technician is approximately \$37,900, increasing the staffing cost during plot installation to approximately \$147,300 (Table 21).

Yearly GSA vehicle costs are estimated at \$7,500, and annual costs for replacement supplies and equipment replacement are estimated at \$300. Annual service fees for the inReach emergency beacon are estimated at \$840. Replacement costs of GPS units are not included in the estimated annual budget. Replacement of these units will incur an occasional but significant cost to the project.

Facilities and computer costs, as well as costs for SAMO administrative services such as purchasing, human resources, and IT support, are not included in this budget projection.

Table 20. Estimated annual budget for Terrestrial Vegetation monitoring at SAMO. Staffing includes plot installation, monitoring, data analysis, and reporting. Cost estimates are in 2015 dollars and based on pay rates of staff currently implementing the protocol. Estimates do not include staff time spent locating and installing new plots. See Table 17 for tasks performed in specified time periods.

Cost category	Month (Pay periods ¹)	Botanist (GS-9)		Plant Ecologist (GS-12)		Interns ³		Total cost
		FTE ²	Cost	FTE	Cost	FTE	Cost	
Staffing	Jan. – Feb. (4.5)	0.9	\$13,230	0.2	\$4,510	1	\$1,500	\$19,240
	Mar. (2)	0.9	5,880	0.4	4,010	2	3,000	12,890
	Apr.–Jun. (7)	0.9	20,580	0.4	14,020	2	9,000	43,600
	Jul. (2)	0.5	3,270	0.2	2,000	—	—	5,270
	Aug. (2.5)	0.4	3,270	0.1	1,250	—	—	4,520
	Sep. (2)	0.4	2,610	0.1	1,000	—	—	3,610
	Oct. (2)	0.5	3,270	0.3	3,000	—	—	6,270
	Nov. (2)	0.5	3,270	0.5	5,010	—	—	8,280
	Dec. (2)	0.2	1,310	0.1	1,000	—	—	2,310
	Total Yearly (Staffing)	0.7	\$56,690	0.3	\$35,800	1	\$13,500	\$105,990
Non-staffing								
GSA Vehicles (1.5)								7,500
inReach emergency beacons								840
Supplies ⁴								300
Total Yearly (Non-Staffing)								8,640
Grand Total								\$114,630

¹Each pay period is 14 days as defined by OPM payroll schedule

²Portion of full-time position

³Estimate is based on \$500 stipend and \$250 housing cost per intern each month

⁴Includes routine replacement of measuring tapes, monument posts, etc., but not major items such as GPS units

Table 21. Estimated annual budget for installation of transects and initial Terrestrial Vegetation monitoring at SAMO. Staffing includes plot installation, monitoring, data analysis, and reporting. Cost estimates are in 2015 dollars and based on pay rates of staff currently implementing the protocol. Estimates include staff time spent locating and installing new plots. The cartographic technician is only employed for the 3-year transect installation phase of the project. See Table 17 for tasks performed in specified time periods.

Cost category	Month (Pay periods ¹)	Botanist (GS-9)		Plant Ecologist (GS-12)		Cartographic Technician (GS-11)		Interns ³		Total cost
		FTE ²	Cost	FTE	Cost	FTE	Cost	FTE	Cost	
Staffing	Jan.– Feb. (4.5)	0.9	\$13,230	0.1	\$2,250	0.7	\$7,210	1	\$1,500	\$24,190
	Mar. (2)	0.9	5,880	0.2	2,000	0.5	2,290	2	3,000	13,170
	Apr.–Jun. (7)	0.9	20,580	0.3	10,520	0.7	11,210	2	9,000	51,310
	Jul. (2)	0.9	5,880	0.1	1,000	0.7	3,200	—	—	10,080
	Aug. (2.5)	0.5	4,080	0.1	1,250	0.6	3,430	—	—	8,760
	Sep. (2)	0.8	5,230	0.2	2,000	0.6	2,750	—	—	9,980
	Oct. (2)	0.8	5,230	0.3	3,000	0.6	2,750	—	—	10,980
	Nov. (2)	0.8	5,230	0.5	5,000	0.6	2,750	—	—	12,980
	Dec. (2)	0.4	2,610	0.1	1,000	0.5	2,280	—	—	5,890
	Total Yearly (Staffing)	0.8	\$67,950	0.2	\$28,020	—	—	1	\$13,500	\$147,340
Non-staffing										
GSA Vehicles (1.5)										7,500
inReach emergency beacon										840
Supplies ⁴										300
Total Yearly (Non-Staffing)										8,600
Grand Total										\$155,940

¹Each pay period is 14 days as defined by OPM payroll schedule

²Portion of full-time position

³Estimate is based on \$500 stipend and \$250 housing cost per intern each month

⁴Includes routine replacement of measuring tapes, monument posts, etc., but not major items such as GPS units

9.3.3 CABR

The cost of field equipment and supplies for establishing and relocating plots at CABR is approximately \$3,770 (2015 cost, Table 18). The necessary equipment is owned by CABR and will be used to begin implementation of the Terrestrial Vegetation monitoring protocol. However, over time it will be necessary to provide funds for replacement equipment—in particular GPS units, computer hardware, software and associated licenses.

Yearly operational costs for implementation of the Terrestrial Vegetation monitoring program are \$30,410 (2015 dollars, Table 22), of which \$13,000 will be funded by the MEDN I&M program and the rest will come from resource management program funds. Yearly GSA vehicle costs are estimated at \$150, and annual costs for replacing supplies and equipment are estimated at \$250. Replacement costs of GPS units are not included in the estimated annual budget. Replacement costs for these units will incur an occasional but significant cost to the project. Facilities and computer costs and costs for CABR administrative services such as purchasing, human resources, and IT support, are not included in this budget projection.

Table 22. Estimated annual budget for vegetation monitoring at CABR. Staffing includes plot installation, monitoring, data analysis, and reporting. Cost estimates are in 2015 dollars. Estimates do not include staff time spent locating and installing new transects, which are expected to require only small additional time and cost. See Table 17 for tasks performed in specified time periods.

Cost category	Month	Biologist (GS-11)		Biological Technician (GS-05)		Biological Technician (GS-05)		Biological Technician (GS-05)		Total cost
		FTE ¹	Cost	FTE	Cost	FTE	Cost	FTE	Cost	
Staffing	January	—	—	—	—	—	—	—	—	—
	February	0.1	\$890	—	—	—	—	—	—	\$890
	March	0.2	1,780	0.1	480	—	—	—	—	2,260
	April	0.4	3,560	0.6	2,880	0.5	2,400	0.5	2,400	11,240
	May	0.4	3,560	0.6	2,880	0.1	480	0.1	480	7,400
	June	0.2	1,780	0.3	1,440	—	—	—	—	3,220
	July	0.1	890	0.1	480	—	—	—	—	1,370
	August	—	—	—	—	—	—	—	—	—
	September	—	—	—	—	—	—	—	—	—
	October	—	—	—	—	—	—	—	—	—
	November	0.3	2,670	0.1	480	—	—	—	—	3,150
	December	—	—	0.1	480	—	—	—	—	480
	Total Yearly (Staffing)	0.2	\$15,130	0.2	\$9,120	0.1	\$2,880	0.1	\$2,880	\$30,010
Non-Staffing										
GSA Vehicles (1.5)										150
Supplies ²										250
Total Yearly (Non-Staffing)										400
Grand Total										\$30,410

¹Portion of full-time position

²Includes routine replacement of measuring tapes, monument posts, etc., but not major items such as GPS units

9.3.4 MEDN I&M Program Manager and Data Manager

The cost of MEDN network staff support is \$10,000 (2015 dollars). We anticipate the MEDN I&M Program Manager will spend approximately 1 week (0.02 FTE, GS-12) each year working on this project at a salary cost of approximately \$2,300. The MEDN I&M Data Manager will spend approximately 4 weeks (0.08 FTE, GS-11) at a salary cost of \$7,700.

Park-specific trend reports will be prepared at the completion of each monitoring cycle: every 4 years for CHIS and every 6 years for SAMO/CABR. The report will be prepared by a cooperator in collaboration with NPS staff. We estimate the contracting costs for the initial trend analyses will be \$15,000–\$20,000 for CHIS and \$10,000–\$15,000 for SAMO/CABR. Subsequent trend analyses are expected to cost considerably less.

9.4 Protocol Revision

Protocol implementation will undergo yearly evaluation, and an in-depth assessment will be performed at the end of each monitoring cycle. Over time, revisions to both the protocol narrative and specific SOPs are expected. Careful documentation of any changes to the protocol and a library of previous protocol versions are essential for maintaining consistency in data collection and for appropriate summary analyses. The database for each monitoring component will contain a field that identifies which version of the protocol and SOPs was used when the data were collected.

The protocol narrative is a general overview of the protocol that gives the history and justification for doing the work and an overview of monitoring methods, but does not provide methodological details. The protocol narrative will only be revised if major changes are made to the protocol.

The SOPs, in contrast, are specific, step-by-step instructions for performing tasks. They are expected to be revised more frequently. All versions of the protocol and SOPs will be archived in a MEDN Terrestrial Vegetation project digital library. Current versions will be available from the MEDN website and the national I&M protocol database.

The steps for changing the protocol (either the narrative or an SOP) are provided in SOP16. Each SOP contains a change log that should be filled out each time an SOP is revised to explain why the change was made and to assign a new version number to the revised SOP. The new version of the SOP or protocol narrative will be archived in the project library under the appropriate folder.

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Appendix A: History of Long-term Vegetation Monitoring at Channel Islands National Park

The original Channel Islands National Park (CHIS) terrestrial vegetation monitoring program was designed and implemented in 1984. At that time, the park consisted of just three islands—Santa Barbara (SBI), Anacapa (ANI), and San Miguel (SMI)—and the original protocol document addressed just those three islands. CHIS acquired Santa Rosa Island (SRI) in 1987, and began monitoring on the island in 1990. CHIS acquired the east end of Santa Cruz Island (SCI) in 1997, and monitoring on those lands began in 1998. In 2001, The Nature Conservancy (TNC) donated the isthmus portion of SCI to CHIS, and long-term transects were installed there in 2006–2007. The methods used for index site selection are documented in Halvorson et al. (1988), McEachern (1998), McEachern (2001), and Rodriguez (2006).

Monitoring Program Design

The monitoring program was to have two complementary parts: yearly transect sampling and periodically repeated vegetation mapping. Transect monitoring was designed to track and describe change within each of the island plant communities, while the repeated vegetation mapping was intended to document change in community distributions across the landscape. However, due to budget constraints, only the transect sampling part of the protocol has been implemented.

The program had three broad goals: 1) the program needed to monitor change in both native and non-native vegetation across the range of topographic settings on each island, 2) the methodology needed to be robust to frequent changes in monitoring staff, and 3) the program needed to be clear and easy to implement so that it could be sustained over the long term. Sample size was limited to the number of sites that one Monitoring Botanist could reasonably access in one growing season. Program expectations were that the full-time Monitoring Botanist would have sole responsibility for collecting, entering and summarizing the data for each island annually, assisted opportunistically by volunteers.

Monitoring Site Selection

On SBI and SMI, major plant communities were identified based on randomly located relevés (Lenihan 1983; Halvorson 1988). On ANI, communities were identified based on expert observations (McEachern 2001). Observations and relevé results indicated that the vegetation of each island consisted of a matrix of widespread non-native annual grassland with scattered small patches of remnant native vegetation. Vegetation composition and condition were thought to be the best indicators of response to changing environmental conditions. It was presumed that stands with native species would change differently than stands that had been converted to grassland (information provided by personal communications to Kathryn McEachern by individuals responsible for the design and early implementation of the program: Ralph Philbrick, botanist at Santa Barbara Botanic Garden, Sept. 1993; William Halvorson, NPS ecologist, James Lenihan, NPS biologist, and Stephen Veirs, Cooperative National Park Service Studies Unit Coordinator, University of California Davis, December 2000). Representative stands from each plant community were then subjectively selected for long-term monitoring, roughly stratified by topography, as it was thought that this would best

allow for future comparison of recovery trajectories (Halvorson et al. 1998). The program incorporated transects that had already been established on SBI and ANI in support of other research projects. These were also line-point intercept transects, but had lengths of 40 m rather than the 30 m lengths that the program designers opted to use.

When SRI was acquired in 1987, vegetation maps were drawn from aerial photographs. Relevé sampling was then used to check the accuracy of those maps and to describe community composition (McEachern 2001). Afterwards, monitoring sites were subjectively selected to be within representative vegetation stands, away from community boundaries, and roughly stratified by topography (Halvorson in McEachern 2001; McEachern 2001). Sites were installed in 1990.

The NPS acquired the eastern quarter of SCI in two stages, in 1997 and 2000. Staff created a sampling frame that consisted of all NPS-owned areas of the island with slopes less than 36 degrees. Areas with steeper slopes were excluded due to concerns about safety and negative site impacts. Sample sites were chosen from this frame using stratified random sampling. The island was stratified by watershed and monitoring sites were allocated in proportion to watershed area, but with a minimum of three sites in each watershed. The total number of monitoring sites was constrained by the field effort available for SCI. Monitoring of east-end sites began in 1998, while monitoring of isthmus sites began in 2006.

The number of index sites and monitoring effort on each island are shown in Table A.1. The distribution of monitoring sites among vegetation communities on each island is shown in Table A.2. The number of monitoring sites is the maximum that can be accomplished given funding levels and the logistics of transportation to/from and on the islands. The locations of index sites are shown in Figures 5 through 9 of the narrative.

Table A.1. Current (2014) distribution of vegetation monitoring effort among islands of Channel Islands National Park.

Island	Area monitored	Area (km ²)	Number of index sites	Sites / km ²	2-person team	
					Days required to monitor	Sites / day
Santa Barbara	All	2.6	22	8.5	7	3.1
Anacapa	<i>West</i>	—	6	—	2	—
	<i>Middle</i>	—	5	—	1	—
	<i>East</i>	—	5 ¹	—	1	—
	All	2.9	16	5.2	4	4.0
Santa Cruz	NPS-owned	60	43	0.4	7 – 8	5.5 – 6.1
Santa Rosa	All	215	86	0.4	21 – 35	2.5 – 4.1
San Miguel	All	38	16	0.4	5 – 6	2.7 – 3.2
All Islands		318	183	14.9	45 – 61	3.1 – 4.0

¹Two index sites monitored under the existing CHIS protocol are retired under this new protocol.

Table A.2. Vegetation communities and number of transects sampled on five islands in Channel Islands National Park.

Community	ANI	SBI	SMI	SRI	SCI	Total
Grassland	8	4	3	23	11	49
Coastal sage scrub	3	1	3	11	4	22
Coreopsis scrub	3	7	3	—	—	13
Sea cliff/coastal bluff scrub	—	3	1	3	2	9
Chaparral	—	—	4	6	11	21
Coastal dune scrub/coastal strand	—	—	1	2	—	3
Caliche scrub	—	—	2	2	—	4
Riparian	—	—	—	7	4	11
Perennial iceplant	2	—	—	—	—	2
Boxthorn scrub	—	2	—	—	—	2
Cactus scrub	—	3	—	—	—	3
Seablite scrub	—	4	—	—	—	4
Baccharis scrub	—	—	—	9	—	9
Lupine scrub	—	—	—	3	—	3
Coastal marsh	—	—	—	2	—	2
Fennel	—	—	—	—	4	4
Mixed woodland	—	—	—	7	—	7
Oak (<i>Q. tomentella</i>) woodland	—	—	—	4	—	4
Santa Cruz Island pine	—	—	—	2	—	2
Torrey pine	—	—	—	5	—	5
Oak (<i>Q. agrifolia</i>) woodland	—	—	—	—	2	2
<i>Lyonothamnus</i> groves	—	—	—	—	3	3
Disturbed scrub savanna	—	—	—	—	2	2
Totals	16	24	17	86	43	186

Program Review and Revision

In December 2000, a formal technical review (McEachern 2001) identified the need for modification of the field methods to better capture species diversity and woody plant change, and the need for updated vegetation mapping. In response, belt transect methodologies for woody shrubs and trees were added to the field protocol in 2001 (McEachern 2000). Vegetation was mapped on SCI in 2004 by TNC and on SBI in 2011 by NPS (in draft). Mapping of the remaining islands is underway and expected to be completed by 2016.

The review panel recognized the limitations inherent in the existing nonrandom design and recommended adding probabilistic sites to the program. The panel also noted the value of the dataset collected from the existing monitoring program, and emphasized the importance of retaining continuity in any revision of the program (McEachern 2000).

To achieve this goal of obtaining broader inference while maintaining continuity with the existing program, the new Terrestrial Vegetation monitoring protocol will add an approximately equal number of probabilistically selected plots to the index sites already established on each island (Table A.3). Since yearly sampling effort is fixed by existing staff resources, we will accomplish this by reducing the frequency of sampling at index plots, which under the existing protocol are sampled yearly. The new probabilistically chosen sites will include locations more difficult to access than the index sites, and will require more travel time than the index sites. Under the revised design, and assuming no change in funding or staff availability, we anticipate that the number of sites which may be monitored each year will decrease by approximately 20%, to 146 sites. However, the use of the serially alternating design described in the narrative of this document will double the total number of sites monitored, to 365 sites comprised of 181 index sites (Table A.1) and 184 probabilistically chosen sites (Table A.3) with approximately equal numbers of each type visited each year.

Table A.3. Distribution of vegetation monitoring effort among islands of Channel Islands National Park, incorporating probabilistically chosen sites.

Island	Area monitored	Number of index sites	Number of probabilistically chosen sites	Total sites	Hectares per probabilistically chosen site	Ratio of probabilistic to index sites
Santa Barbara	All	22	22	44	12	1.0
Anacapa	West	6	5	11		0.8
	Middle	5	5	10		1.0
	East	3 ¹	8	11		2.7
	All	14	18	32	16	1.3
Santa Cruz	NPS-owned	43	42	85	143	1.0
Santa Rosa	All	86	84	170	256	1.0
San Miguel	All	16	18	34	211	1.1
	All Islands	181	184	365	173	1.1

¹Two index sites monitored under the existing CHIS protocol are retired under the new protocol.

The specific disposition of each index site among monitoring panels was decided through a combination of expert judgment and random sampling. First, each index site was evaluated for its potential to contribute to the understanding of vegetation change on the islands and placed into one of three categories described below. The evaluation was carried out by Kathryn McEachern (Research Ecologist, USGS Western Ecological Research Center) and Dirk Rodriguez (Botanist,

CHIS). The evaluation was based on an inspection of the vegetation types present on each island, the degree of representation of each type in the current set of index sites, the consistency of sampling at each site, and ecological knowledge about the vegetation types. Based on the results of this evaluation, each index site was placed into one of three groups:

1. Sites to be retained in the core panel
2. Sites to be placed into a rotating panel
3. Sites that could be placed either in group 1 or 2

Index sites were placed into the core panel (monitored yearly) if any of the following were true:

- There had been a high rate of change in the vegetation on the site during the previous five years.
- Local conditions suggested that there was potential for rapid vegetation change in the near future.
- The site was located in an underrepresented community type.
- The site was in an area of high management concern (e.g., the coastal marsh on SRI).

Index sites were placed into a rotating panel (monitored every 4 years) if any of the following were true:

- The site was located in fragile habitat in which continued annual monitoring may be detrimental to the site.
- There had been little change in vegetation at the site during the course of the monitoring program.
- The site had been visited infrequently.
- The site had been deliberately installed so as to cross community boundaries.
- The site was located in an overrepresented community type.
- The site was in a community of limited biological interest.
- The site had been recently installed, and had no long-term monitoring history.
- The site was located close to another monitoring site in the same community type.

Sites that were not placed directly into a core or rotating panel based on the criteria described above (group 3) were assigned to panels using a two-step process. We randomly assigned half of the sites to the core panel and the other half of sites to the rotating panels. For the sites assigned to the rotating panels, we determined the number of sites to be placed in each rotating panel (total divided by four), and then randomly apportioned the sites among the four rotating panels. Two sites, both on East Anacapa Island, were retired because monitoring was no longer feasible due to brown pelican nesting at those sites.

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Appendix B: Selection of Master Sample and Vegetation Monitoring Subsample for the Santa Monica Mountains National Recreation Area Study Area

Master Sample

The master sample area included all land within the boundary of our vegetation map of the Santa Monica Mountains and environs (AIS and ESRI 2007) except for developed areas (urban or built up), continually disturbed areas (agriculture, road cuts), and water. The feature class was derived from Vegetation_AllPolys (SMMNRA_Vegetation.gdb, February 2014), with the following Final Map Classes excluded:

- Agriculture Mapping Unit
- Artificial cuts/Embankments Undifferentiated Vegetation Mapping Unit
- Urban/Disturbed or Built-up Undifferentiated Mapping Unit
- Water Mapping Unit

Algorithm for Selection of the Master Sample

The master sample was selected using R statistical software (version 2.13.0; see Kincaid and Olson (2015) for latest version). The sample area was 208,221 acres (84,265 ha) and the sampling density was set at 1 site per 50 acres (20 ha). This density was selected after consultation with several park staff members and was considered the maximum density that would be needed for future research or monitoring projects. The seed number used for the draw was 57956575. The total number of sample sites selected was 4164. The data input and selection code used for the draw are shown below.

```
=====
==
SAMO I&M Terrestrial Vegetation Monitoring
File "SAMO I&M Veg Monitoring GRTS R code - MasterDraw.c"
Anthony J. Valois, 02-05-14.
=====
==
```

Input calculations:

```
-----
Master Frame "20140130" attribute "tbl_Monito" = "1":
Area = 842645210.303 (m^2)
842645210.303 /10000 (m^2/ha) * 2.471044 (ac/ha)
[1] 208221.3
Chosen site density = 1 site / 50 acres
208221.3 (ac) / 50 (ac/site)
[1] 4164.426
Use 4164 sites.
```

```
=====
```

02-05-2014 11:00AM

=====

Run Rgui with no workspace files on Dell760, win7, 10GB RAM.

```
setwd("D:/___R_Work_I&M2013")
```

```
library(spsurvey)
```

```
sample(100000000,1)
```

```
[1] 57956575
```

```
set.seed(57956575)
```

```
samoIM_Master_design <- list("1"=list(panel=c(Master=4164),  
seltype="Equal"))
```

```
samoIM_Master_attframe <-
```

```
read.dbf("GIS_Layers/Master_Sample_Frame_20140130")
```

```
samoIM_Master_attframe // verify the input shp.
```

	OBJECTID	tbl_Monito	Shape_Leng	Shape_Area	area_mdm
1	1	0	3762406	383362612	383362612
2	2	1	3681914	842645210	842645210

```
samoIM_Master_GRTS_Draw <- grts (  
  design=samoIM_Master_design,  
  DesignID="MasterFrame",  
  type.frame="area",  
  src.frame="shapefile",  
  in.shape="GIS_Layers/Master_Sample_Frame_20140130",  
  att.frame=samoIM_Master_attframe,  
  stratum="tbl_Monito",  
  shapefile=TRUE,  
  prjfilename="GIS_Layers/Master_Sample_Frame_20140130",  
  out.shape="GRTS_Output/SAM0_IM_GRTS_Master_Frame"
```

Final number of levels: 8

=====

R version 2.13.0 (2011-04-13)

Copyright (C) 2011 The R Foundation for Statistical Computing

ISBN 3-900051-07-0

Platform: i386-pc-mingw32/i386 (32-bit)

```
> setwd("D:/___R_Work_I&M2013")
```

```
> library(spsurvey)
```

Loading required package: sp

Version 2.2 of the spsurvey package was loaded successfully.

```
> sample(100000000,1)
```

```

[1] 57956575
> set.seed(57956575)
> samoIM_Master_design <- list("1"=list(panel=c(Master=4164),
seltype="Equal"))
> samoIM_Master_attframe <-
read.dbf("GIS_Layers/Master_Sample_Frame_20140130")
> samoIM_Master_attframe
  OBJECTID tbl_Monito Shape_Leng Shape_Area  area_mdm
1          1          0    3762406    383362612 383362612
2          2          1    3681914    842645210 842645210
> samoIM_Master_GRTS_Draw <- grts (
+ design=samoIM_Master_design,
+ DesignID="MasterFrame",
+ type.frame="area",
+ src.frame="shapefile",
+ in.shape="GIS_Layers/Master_Sample_Frame_20140130",
+ att.frame=samoIM_Master_attframe,
+ stratum="tbl_Monito",
+ shapefile=TRUE,
+ prjfilename="GIS_Layers/Master_Sample_Frame_20140130",
+ out.shape="GRTS_Output/SAMO_IM_GRTS_Master_Frame"
+ )

```

```

Stratum: 1
Initial number of levels: 7
Current number of levels: 7
Current number of levels: 8
Final number of levels: 8
>

```

Vegetation Monitoring Sampling Frame

The vegetation monitoring sampling frame (subsample of the master sample) includes public and other conservation lands in the master sample with reliable access for long-term monitoring. Small isolated patches (i.e., less than 5 acres of contiguous public or conservation land), were excluded. (Polygons less than 5 acres were included if they were part of a contiguous area greater than 5 acres in total.) The feature class was derived from Tracts (1/28/2014) data with the following criteria:

Land owned and managed by:

- California Department of Parks and Recreation
- City of Calabasas Parks
- City of Malibu Parks
- City of Thousand Oaks Parks
- Conejo Open Space Conservation Agency

- Las Virgenes Municipal Water District
- Los Angeles County Parks
- Mountains Recreation and Conservation Authority
- Mountains Restoration Trust
- National Park Service
- Rancho Simi Recreation and Park District
- Santa Monica Mountains Conservancy
- University of California Reserve
- Ventura County Parks

Excluded from Vegetation Monitoring Sampling Frame:

Land owned or managed by the following was excluded:

- City of Los Angeles Parks
- National Park Service Easement
- Other City of Los Angeles
- Other Federal
- Other Los Angeles County
- Other Private
- Other State
- Private Park or Recreation Lands
- State Easement

Land owned or managed by following was excluded after examining specific instances:

- City of Agoura Hills Parks
- Misc. Public
- Other Locally Designated Open Space

Land and polygons excluded on an individual basis:

- Encino Reservoir
- Narrow riparian polygon
- Excluded polygon due to lack of access (Chatsworth Reservoir)
- Excluded polygon due to lack of access (Las Virgenes Reservoir)
- Excluded, not in master frame
- Narrow riparian polygon
- Wetland area at mouth of Malibu Creek (excluded)

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Appendix C: Power Analysis of Channel Islands National Park Data

Author:

Leigh Ann Harrod Starceovich, Statistical Contractor*

PO Box 1032

Corvallis, OR 97339

lah@peak.org

*Current address:

West Environmental and Statistical Consultants

456 SW Monroe Ave., Suite 106

Corvallis, OR 97333

Introduction

The Mediterranean Coast Network (MEDN) plans to monitor living vegetation in Cabrillo National Monument (CABR), Channel Islands National Park (CHIS), and Santa Monica Mountains National Recreation Area (SAMO). Metrics for monitoring vegetation include status and trend. An analysis of power to detect trends in vegetation over time informs the sampling design of the MEDN Terrestrial Vegetation monitoring program, with the ultimate goal of making efficient use of limited monitoring resources. Pilot data from CHIS and SAMO are used to obtain estimates of status and variance composition to inform a power simulation. Pilot data from CABR did not incorporate replication at a site over time, so random year effects were inestimable for these data. Therefore, the CABR pilot data were not used in this analysis of power to detect trend.

Outcomes of interest include absolute percent cover, species richness, and density for selected species and groups of species. Groups of interest include all native species, all non-native species, native shrubs, native forbs, non-native forbs, native perennial forbs, native annual forbs, native grasses, and non-native grasses. For simplicity, we will hereafter refer to these groups as life forms. A power analysis is conducted to inform decisions on the sampling design, specifically the revisit design. The trend test is based on a mixed model, which incorporates both fixed effects and random effects (Urquhart and Kincaid 1999; Piepho and Ogutu 2002). Fixed effects describe the mean of the outcome and may include the intercept and slope of the trend line. Random effects impact the variance of the outcome and represent sources of variation such as site-to-site variation and year-to-year variation. Variance estimates for these random effects are estimated with restricted maximum likelihood (REML). Power is assessed for a 3% annual trend observed over 12 and 24 years.

Nearly all of the species-level metrics and many of the life-form-level metrics exhibited large proportions of zeros, which violates assumptions of residual normality and equal variance for standard mixed models. Random site effects are inestimable using standard likelihood methods for analyzing zero-inflated outcomes and Bayesian approaches are time-consuming to incorporate in power simulations. The estimation of site-level effects is necessary to calculate power for specific revisit designs. Because a primary goal of this power analysis is to select a suitable revisit design,

estimation of variance components and site-level effects is of paramount importance. Therefore, power analyses are computed for outcomes meeting the assumptions of mixed models of trend so that revisit designs may be accurately compared.

Trend Model

A mixed model allows the estimation of fixed effects and of variance components for random effects. The linear mixed model of (possibly-transformed) outcomes is based on the approach proposed by Piepho and Ogutu (2002). The mixed model used in this study is given by:

$$y_{ijk} = \beta_0 + w_j \beta_1 + b_j + a_i + w_j t_i + e_{ijk},$$

where $i=1, \dots, m_a$; $j=1, \dots, m_b$; $k=1, \dots, m_i$;

m_a = the number of sites in the sample;

m_b = the number of consecutive years in the sample;

m_i = the number of subsamples at a site;

y_{ijk} = outcome of interest (possibly transformed),

w_j = constant representing the j^{th} year (covariate);

β_0 and β_1 = fixed intercept and slope of the linear time trend;

b_j = random effect of the j^{th} year, iid $N(0, \sigma_b^2)$, where σ_b^2 is the year-to-year variation;

a_i = random intercept of i^{th} site, iid $N(0, \sigma_a^2)$, where σ_a^2 is the site-to-site variation;

t_i = random slope of i^{th} site, iid $N(0, \sigma_t^2)$, where σ_t^2 is the variation among site-level slopes; and

e_{ijk} = unexplained error, iid as $N(0, \sigma_e^2)$, where σ_e^2 is the unexplained residual variation.

Revisit Designs

Revisit designs dictate the allocation of survey effort over time and space. Several revisit designs are examined in this power analysis (Figure C.1). The notation used here follows that of McDonald (2003). Design 1 is a [1-0] design consisting of a single panel of sites that are visited every year. Design 2 is a [1-0, 1-3] serially-alternating augmented design. It consists of one panel of sites that is visited annually, and four panels of sites that are visited on an alternating basis. Each of the alternating panels is visited on a four year cycle, with one monitoring year followed by three consecutive rest years. Design 3 is a [1-2] design consisting of three panels that are visited on an alternating basis. Panels are visited on a three year cycle with one monitoring year followed by two consecutive rest years. Design 4 is a [2-2] design consisting of four alternating panels. Two of the four panels are visited in each year. Panels are on a four year cycle with two consecutive monitoring years followed by two consecutive rest years. The final revisit design, Design 5, is a [2-4] design consisting of six alternating panels. Two of the six panels are visited in each year, and panels are on a six year cycle. Each panel is visited for two consecutive monitoring years then rested for four years.

The revisit designs examined in this report represent a range of choices, each with a different balance between the dual monitoring goals of trend detection and status estimation. Design 1, the [1-0]

design, has the highest theoretical power for trend detection because each site is visited annually so the sample is connected over time (Urquhart and Kincaid 1999). Design 3, the [1-2] revisit design, is not connected over time or space but incorporates three times more sites than the [1-0] for better spatial coverage in status estimation. The remaining three designs implement varying degrees of site replication over time and revisit cycle of different lengths. For example, the revisit cycle for the [1-0] design is only one year, but it takes 4 years to complete a cycle of the [(1-0), (1-3)] design. The [1-2], [2-2], and [2-4] designs require 3, 4, and 6 years, respectively, to complete a revisit cycle.

Design 1: [1-0]												
	Year											
Panel	1	2	3	4	5	6	7	8	9	10	11	12
1	X	X	X	X	X	X	X	X	X	X	X	X

Design 2: [(1-0),(1-3)]												
	Year											
	1	2	3	4	5	6	7	8	9	10	11	12
1	X	X	X	X	X	X	X	X	X	X	X	X
2	X				X				X			
3		X				X				X		
4			X				X				X	
5				X				X				X

Design 3: [1-2]												
	Year											
Panel	1	2	3	4	5	6	7	8	9	10	11	12
1	X			X			X			X		
2		X			X			X			X	
3			X			X			X			X

Design 4: [2-2]												
	Year											
Panel	1	2	3	4	5	6	7	8	9	10	11	12
1	X	X			X	X			X	X		
2		X	X			X	X			X	X	
3			X	X			X	X			X	X
4	X			X	X			X	X			X

Design 5: [2-4]												
	Year											
Panel	1	2	3	4	5	6	7	8	9	10	11	12
1	X	X					X	X				
2		X	X					X	X			
3			X	X					X	X		
4				X	X					X	X	
5					X	X					X	X
6	X					X	X					X

Figure C.1. The five revisit designs considered in this power analysis.

Simulating Trend

Initial data analysis indicated that linear modeling of the site-level means produced skewed residuals that do not meet the linear modeling assumptions of normality and equal variance. Therefore, the site-level means were logarithmically transformed, and residual diagnostics indicated an improved

fit. Because the outcomes are logarithmically transformed, the trend is modeled as a multiplicative change. Modeling the net trend, δ , over m_b years translates to an annual multiplicative change of:

$$p = \delta^{1/(m_b-1)} - 1.$$

The trend of the logged outcome is equal to $\log(p)$.

Power Analysis Approach

Power is approximated using an asymptotic approach for large-samples. Asymptotic approximations of power can give liberal results, especially for small sample sizes.

The variance of the vector of regression coefficients, $\hat{\beta}$, is calculated as follows:

$$\text{Var}(\hat{\beta}) = \left(\mathbf{X}' \Phi(\hat{\theta})^{-1} \mathbf{X} \right)^{-1},$$

where $\mathbf{X}$ is the fixed effects design matrix and $\Phi(\theta)$ is the variance of the outcome, y_{ij} . The variance of the outcome, $\Phi(\theta)$, takes the following form for the fullest model, with i denoting a site and j denoting a survey year:

$$\Phi(\theta) = \text{cov}(y_{ij}, y_{ij'}) = \begin{cases} \sigma_a^2 + w_j^2 \sigma_t^2 + 2w_j \sigma_{at} + \sigma_b^2 + \sigma_e^2, & i = i', j = j' \\ \sigma_a^2 + w_j w_{j'} \sigma_t^2 + (w_j + w_{j'}) \sigma_{at}, & i = i', j \neq j' \\ \sigma_b^2, & i \neq i', j = j' \\ 0, & i \neq i', j \neq j' \end{cases}$$

The estimate of the standard error for trend, $\hat{\sigma}_{\beta'_1}$, is calculated as the square root of $\text{Var}(\hat{\beta}_1)$ and is a function of the variance components from the pilot data. The power to detect a trend of effect size β'_1 is given by:

$$\text{Power}(\beta'_1) = \Phi\left(z_{\alpha/2} - \frac{\beta'_1}{\hat{\sigma}_{\beta'_1}}\right) + 1 - \Phi\left(z_{1-\alpha/2} - \frac{\beta'_1}{\hat{\sigma}_{\beta'_1}}\right),$$

where $\Phi(\cdot)$ represents the cumulative normal distribution function and z_q is the critical value of the standard normal distribution evaluated at the q^{th} percentile (Urquhart et al. 1998). A Type I error level of 0.10 is used in this power analysis. Note that this method does not currently account for the correlation of the random site and site-level slope effects, but this additional variation tends to be small.

About CHIS Vegetation Data

Existing data from CHIS are used to obtain estimates of status and variance composition for use in the large-sample power approximation. The pilot data were collected in five islands: Anacapa (ANI), Santa Barbara (SBI), Santa Cruz (SCI), San Miguel (SMI), and Santa Rosa (SRI). Within each island, 5 to 86 transects were surveyed each year for up to 21 of the 27 years spanning from 1984 to 2010 (Table C.1).

Table C.1. Sample sizes of years and transects for CHIS pilot data

CHIS Island	Survey years	Annual sample size of transects
ANI	1984-1988, 1990, 1993-1998, 2004-2010	5 to 16
SBI	1984-1988, 1990, 1993-1999, 2003-2005, 2007-2010	11 to 22
SCI	1988-1989, 2003-2010	6 to 43
SMI	1984-1988, 1990, 1993-1999, 2003-2010	5 to 16
SRI	1990, 1993-1999, 2003-2010	45 to 86

Summary of Percent Cover Calculations:

Define the following terms:

n_j = number of points on transect j ,

s = number of species,

$y_{ijk} = I(\text{species } i \text{ on point } k \text{ in transect } j)$,

$G = \{\text{set of species for a given guild}\}$,

$I_{Gijk} = I(y_{ijk} > 0, i \in G) = 1$ if species i on k th point of j th transect is in the guild of interest,

$I_{G,jk} = I\left(\sum_{i=1}^s I_{Gijk} > 0\right) = 1$ if any species in the guild of interest is found on k th point of j th transect,

$y_{.j}^G = \sum_{i=1}^s \sum_{k=1}^{n_j} I_{Gijk} = \text{total number of hits on transect } j \text{ in } G$,

$y_{.j}^{G*} = \sum_{k=1}^{n_j} I_{G,jk} = \text{unique points in transect } j \text{ in } G$, and

$m_j = \sum_{i=1}^s \sum_{k=1}^{n_j} y_{ijk} = \text{total number of hits of any species in } G \text{ on transect } j$.

Note that the notation for years is suppressed here, so assume that these calculations are made for a given year. The following metrics were used to obtain absolute and relative cover for the CHIS dataset (Table C.2).

Table C.2. CHIS percent cover statistics.

Suggested by	Absolute percent cover	Relative percent cover
Marti Whitter Robert Taylor	$100 * \frac{y_{.j.}^G}{n_j} \in [0, \infty)$	$100 * \frac{y_{.j.}^G}{m_j} \in [0, \infty)$
Tim Handley	$100 * \frac{y_{.j.}^{G^*}}{n_j} \in [0, 100\%]$	$100 * \frac{y_{.j.}^{G^*}}{m_j} \in [0, 100\%]$

Trend modeling

The linear mixed model proposed by Piepho and Ogutu (2002) was applied to the CHIS data by island and outcome. The fixed effects estimates and the variance estimates for random effects from the pilot data are provided in Tables C.3 through C.7 for the five islands. Several of the outcomes of interest were zero-rich, indicated by histograms of the outcomes and residual diagnostics from linear mixed models. Models for zero inflation could be applied and power to detect trends could be assessed, but random effects are inestimable with likelihood approaches for the nonlinear models used to account for zero-inflation. Site-level random effects must be estimable in order to compare revisit designs. Therefore, the outcomes for which variance component estimation is possible are examined in this power analysis since the comparison of revisit designs is a primary goal.

Table C.3. Transformations, fixed effects estimates, trend test results, and variance components estimates by outcome for Anacapa Island. Annual sample size ranges from 5 to 16 sites.

Outcome of interest	Functional type	Transformation	$\hat{\beta}_0$ Est. intercept	$\hat{\beta}_1$ Est. trend (SE)	Trend test p-value (two-sided)	$\hat{\sigma}_b^2$ (year-to-year variance)	$\hat{\sigma}_a^2$ (transect-to-transect variance)	$\hat{\sigma}_{at}$ (random transect and random slope covariance)	$\hat{\sigma}_t^2$ (random slope variance)	$\hat{\sigma}_e^2$ (residual variation)
Absolute percent cover	All natives	None	139.84	-3.3507 (0.7375)	0.0001	248.03	2860.69	-63.7541	4.1328	822.16
	All non-natives	None	86.6360	0.1344 (1.0504)	0.8993	1213.39	2171.96	-32.2174	1.7442	1349.03
	Native shrubs	Log	2.6023	-0.0423 (0.0110)	0.0036	0.0076	2.3243	-0.0270	0.0012	0.3336
	Native forbs	Log	4.0275	-0.0712 (0.0199)	0.0013	0.1941	0.4554	-0.0326	0.0034	0.2857
	Non-native forbs	None	5.1850	0.0029 (0.0450)	0.9486	2.2078	2.6444	-0.0394	0.0026	3.1547
	Native perennial forbs	None	50.8012	-1.3675 (0.4820)	0.0088	105.96	533.46	-27.2314	2.0079	238.17
	Native annual forbs	-								
	Native grasses	None	32.4281	-0.9889 (0.3286)	0.0076	20.5811	779.08	-28.7161	1.2348	161.68
	Non-native grasses	None	72.7405	-0.4602 (0.8905)	0.6111	922.47	1964.41	6.0867	0.5535	1133.53
Richness	All natives	Log	2.3102	-0.0153 (0.0068)	0.0321	0.0245	0.1689	-0.0013	0.0004	0.0326
	All non-natives	Log	1.7063	0.0018 (0.0078)	0.8226	0.0644	0.1013	-0.0019	0.0001	0.0887

Table C.4. Transformations, fixed effects estimates, trend test results, and variance components estimates by outcome for Santa Barbara Island. Annual sample size ranges from 11 to 22 sites.

Outcome of interest	Functional type	Transformation	$\hat{\beta}_0$ Est. intercept	$\hat{\beta}_1$ Est. trend (SE)	Trend test p-value (two-sided)	$\hat{\sigma}_b^2$ (year-to-year variance)	$\hat{\sigma}_a^2$ (transect-to-transect variance)	$\hat{\sigma}_{at}$ (random transect and random slope covariance)	$\hat{\sigma}_t^2$ (random slope variance)	$\hat{\sigma}_e^2$ (residual variation)
Absolute percent cover	All natives	None	63.3050	-1.0759 (0.4637)	0.0305	245.92	785.27	-5.0627	0.3021	471.32
	All non-natives	None	115.16	-1.8571 (0.8796)	0.0461	872.57	4171.77	-87.9658	1.9512	1253.22
	Native shrubs	—	—	—	—	—	—	—	—	—
	Native forbs	—	—	—	—	—	—	—	—	—
	Non-native forbs	—	—	—	—	—	—	—	—	—
	Native perennial forbs	—	—	—	—	—	—	—	—	—
	Native annual forbs	—	—	—	—	—	—	—	—	—
	Native grasses	—	—	—	—	—	—	—	—	—
	Non-native grasses	None	77.5499	-0.9911 (0.6767)	0.1569	513.55	2399.87	-44.2101	1.1037	768.36
Richness	All natives	Log	1.6153	-0.0009 (0.0061)	0.8828	0.0398	0.3038	-0.0003	0.0001	0.0656
	All non-natives	Log	1.6406	0.0029 (0.0047)	0.5432	0.0211	0.0572	0.0005	0.0001	0.0694

Table C.5. Transformations, fixed effects estimates, trend test results, and variance components estimates by outcome for Santa Cruz Island. Annual sample size ranges from 6 to 43 sites.

Outcome of interest	Functional type	Transformation	$\hat{\beta}_0$ Est. intercept	$\hat{\beta}_1$ Est. trend (SE)	Trend test p-value (two-sided)	$\hat{\sigma}_b^2$ (year-to-year variance)	$\hat{\sigma}_a^2$ (transect-to-transect variance)	$\hat{\sigma}_{at}$ (random transect and random slope covariance)	$\hat{\sigma}_t^2$ (random slope variance)	$\hat{\sigma}_e^2$ (residual variation)
Absolute percent cover	All natives	None	14.0164	1.9021 (0.6231)	0.0066	19.1604	2694.17	-99.0965	6.4798	89.5999
	All non-natives	None	62.7832	-0.1962 (0.6520)	0.7662	19.7647	7524.63	-173.92	4.6436	243.99
	Native shrubs	—	—	—	—	—	—	—	—	—
	Native forbs	—	—	—	—	—	—	—	—	—
	Non-native forbs	—	—	—	—	—	—	—	—	—
	Native perennial forbs	—	—	—	—	—	—	—	—	—
	Native annual forbs	—	—	—	—	—	—	—	—	—
	Native grasses	—	—	—	—	—	—	—	—	—
	Non-native grasses	None	55.3326	-0.2566 (0.6200)	0.6824	16.0956	7340.58	-182.46	5.1055	195.15
Richness	All natives	Log	1.0867	0.0234 (0.0064)	0.0037	0.0012	0.0923	0.0033	0.0001	0.0630
	All non-natives	Log	1.6885	-0.0080 (0.0167)	0.6344	0.0046	4.4105	-0.1616	0.0065	0.0858

Table C.6. Transformations, fixed effects estimates, trend test results, and variance components estimates by outcome for San Miguel Island. Annual sample size ranges from 5 to 16 sites.

Outcome of interest	Functional type	Transformation	$\hat{\beta}_0$ Est. intercept	$\hat{\beta}_1$ Est. trend (SE)	Trend test p-value (two-sided)	$\hat{\sigma}_b^2$ (year-to-year variance)	$\hat{\sigma}_a^2$ (transect-to-transect variance)	$\hat{\sigma}_{at}$ (random transect and random slope covariance)	$\hat{\sigma}_t^2$ (random slope variance)	$\hat{\sigma}_e^2$ (residual variation)
Absolute percent cover	All natives	None	103.54	-1.3094 (0.6590)	0.0556	339.46	2811.77	-82.5156	3.0745	376.60
	All non-natives	None	104.58	-2.4774 (0.7333)	0.0022	559.24	3310.85	-69.4302	2.0943	609.45
	Native shrubs	None	37.0985	-0.3068 (0.2869)	0.2970	20.2500	1493.00	-31.8285	1.0257	139.08
	Native forbs	Log	3.5810	-0.0365 (0.0125)	0.0072	0.1435	0.7296	-0.0118	0.0007	0.3442
	Non-native forbs	—	—	—	—	—	—	—	—	—
	Native perennial forbs	None	39.9764	-0.9494 (0.3593)	0.0138	53.1626	1417.11	-45.0936	1.4710	126.93
	Native annual forbs	—	—	—	—	—	—	—	—	—
	Native grasses	—	—	—	—	—	—	—	—	—
	Non-native grasses	—	—	—	—	—	—	—	—	—
Richness	All natives	None	6.8403	0.0397 (0.0322)	0.2290	0.7348	10.6964	-0.1485	0.0068	2.4537
	All non-natives	Log	1.8332	-0.0213 (0.0084)	0.0167	0.0679	0.1480	-0.0008	0.0003	0.0817

Table C.7. Transformations, fixed effects estimates, trend test results, and variance components estimates by outcome for Santa Rosa Island. Annual sample size ranges from 6 to 43 sites.

Outcome of interest	Functional type	Transformation	$\hat{\beta}_0$ Est. intercept	$\hat{\beta}_1$ Est. trend (SE)	Trend test p-value (two-sided)	$\hat{\sigma}_b^2$ (year-to-year variance)	$\hat{\sigma}_a^2$ (transect-to-transect variance)	$\hat{\sigma}_{at}$ (random transect and random slope covariance)	$\hat{\sigma}_t^2$ (random slope variance)	$\hat{\sigma}_e^2$ (residual variation)
Absolute percent cover	All natives	—	—	—	—	—	—	—	—	—
	All non-natives	—	—	—	—	—	—	—	—	—
	Native shrubs	—	—	—	—	—	—	—	—	—
	Native forbs	—	—	—	—	—	—	—	—	—
	Non-native forbs	—	—	—	—	—	—	—	—	—
	Native perennial forbs	—	—	—	—	—	—	—	—	—
	Native annual forbs	—	—	—	—	—	—	—	—	—
	Native grasses	—	—	—	—	—	—	—	—	—
	Non-native grasses	—	—	—	—	—	—	—	—	—
Richness	All natives	Log	1.7483	0.0062 (0.0047)	0.1972	0.0099	0.3551	-0.0066	0.0004	0.0616
	All non-natives	None	6.8368	0.0908 (0.0458)	0.0637	1.1124	11.8919	-0.2410	0.0175	2.8156

Power Analysis

Monitoring periods of 12 and 24 years were examined for a 3% annual change. The relationship between net trend and annual trend is illustrated in Table C.8. Because a two-sided test is used, this trend test would be used to test for changes in either direction. After 12 years of monitoring, an annual increase would result in a 43% increase in the population mean of the outcome and a 3% annual decline would reduce the population mean by about a third. After 24 years of monitoring, the population mean would either double or be reduced by about half. Power to detect increasing trends with a two-sided test is more conservative than detecting a decline (Gerrodette 1987), so increasing population means are examined in the simulation.

Table C.8. Relationship between net trend and annual trend.

Year	Net trend corresponding to a 3% annual increase	Net trend corresponding to a 3% annual decrease
3	1.09	0.91
6	1.19	0.83
9	1.30	0.76
12	1.43	0.69
15	1.56	0.63
18	1.70	0.58
21	1.86	0.53
24	2.03	0.48

The results of the power analysis are provided in Tables C.9 and C.10 and Figures C.2 through C.13. Power is summarized by outcome of interest, life form, revisit design, and net change for two levels of sample size (Tables C.9 and C.10), with darker highlighting for power approximations that exceed 90% than for those exceeding 80%. Table C.10 provides power to detect trend from a probabilistic sample of about half the maximum annual effort. This result would reflect approximate power for a design that allocated half the annual effort to a probability sample and half to the existing index sites. The power results for a half-sample of probabilistic sites are conservative since the index sites could also contribute to the trend analysis if modeling indicated that the annual means and variance composition were similar to those of the probabilistic sites. The index sites could be included in the trend model by including a site-level fixed effect indicating probabilistic or index and by modeling trend slopes separately for the two groups. This modeling approach would ensure that the index sites would not unduly influence the trend analysis. However, the index sites provide a long-term record of annual variability in CHIS and provide a valuable basis for the power analysis.

The results of the power analysis indicate several conclusions. First, the majority of the outcomes exhibited adequate power to detect a 3% annual trend with a two-sided trend test for a monitoring

period of 24 years. Only a few outcomes, with most from Santa Cruz Island, exhibit power above 0.80 for the 12-year trend test. No single functional type exhibited consistently good or poor power across islands. Second, the revisit design does not affect power substantially after 5 to 10 years of monitoring. Therefore, revisit designs with longer cycles between revisits are reasonable to consider, especially given the concerns with trampling effects. Finally, the reduction of the sample of probabilistic sites to half the effort does not appear to greatly impact the power to detect trend. One exception is the power analysis for San Miguel vegetation. In this analysis, the reduced sample size negatively impacts the power to detect trends in several outcomes. However, this difference is minimal for a monitoring time frame.

Table C.9. Power by CHIS island, outcome of interest, life form, revisit design, and net trend for a full sample of probability sites.

Island	Outcome of interest	Functional type	3% annual increase for 12 years					3% annual increase for 24 years				
			[1-0]	[(1-0), (1-3)]	[1-2]	[2-2]	[2-4]	[1-0]	[(1-0), (1-3)]	[1-2]	[2-2]	[2-4]
ANI n=16	Abs. percent cover	All natives	0.88	0.87	0.87	0.88	0.87	1.00	1.00	1.00	1.00	1.00
		All non-natives	0.22	0.22	0.22	0.22	0.22	0.78	0.78	0.78	0.78	0.78
		Native shrubs	0.64	0.61	0.62	0.63	0.59	1.00	1.00	1.00	1.00	1.00
		Native forbs	0.20	0.19	0.19	0.20	0.19	0.64	0.64	0.64	0.64	0.64
		Non-native forbs	0.33	0.33	0.33	0.33	0.33	0.96	0.96	0.96	0.96	0.96
		Native perennial forbs	0.49	0.48	0.48	0.49	0.48	1.00	1.00	1.00	1.00	1.00
		Native grasses	0.63	0.61	0.62	0.62	0.60	1.00	1.00	1.00	1.00	1.00
		Non-native grasses	0.21	0.21	0.21	0.21	0.21	0.76	0.75	0.75	0.76	0.75
	Sp. Rich.	All natives	0.69	0.68	0.68	0.69	0.68	1.00	1.00	1.00	1.00	1.00
		All non-natives	0.39	0.38	0.38	0.39	0.38	0.98	0.98	0.98	0.98	0.98
SBI n=23	Abs. percent cover	All natives	0.40	0.40	0.40	0.40	0.39	0.99	0.99	0.99	0.99	0.99
		All non-natives	0.39	0.38	0.38	0.39	0.38	0.98	0.98	0.98	0.98	0.98
		Non-native grasses	0.33	0.32	0.32	0.32	0.32	0.96	0.95	0.95	0.95	0.95
	Sp. Rich.	All natives	0.54	0.53	0.52	0.53	0.53	1.00	1.00	1.00	1.00	1.00
		All non-natives	0.74	0.74	0.74	0.74	0.73	1.00	1.00	1.00	1.00	1.00
SCI n=43	Abs. percent cover	All natives	0.25	0.24	0.24	0.25	0.24	0.68	0.68	0.68	0.68	0.68
		All non-natives	0.99	0.99	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00
		Non-native grasses	0.99	0.98	0.98	0.99	0.98	1.00	1.00	1.00	1.00	1.00
	Sp. Rich.	All natives	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		All non-natives	0.94	0.93	0.93	0.94	0.92	1.00	1.00	1.00	1.00	1.00
SMI n=16	Abs. percent cover	All natives	0.61	0.60	0.60	0.61	0.60	1.00	1.00	1.00	1.00	1.00
		All non-natives	0.45	0.45	0.44	0.45	0.45	1.00	1.00	1.00	1.00	1.00
		Native shrubs	0.76	0.74	0.74	0.75	0.73	1.00	1.00	1.00	1.00	1.00
		Native forbs	0.23	0.22	0.22	0.23	0.22	0.79	0.78	0.78	0.78	0.78
		Native perennial forbs	0.55	0.54	0.53	0.55	0.53	1.00	1.00	1.00	1.00	1.00
	Sp. Rich.	All natives	0.82	0.81	0.81	0.82	0.80	1.00	1.00	1.00	1.00	1.00
		All non-natives	0.37	0.37	0.37	0.37	0.37	0.98	0.98	0.98	0.98	0.98
SRI n=86	Sp. Rich.	All natives	0.96	0.96	0.96	0.96	0.96	1.00	1.00	1.00	1.00	1.00
		All non-natives	0.39	0.39	0.39	0.39	0.39	0.99	0.99	0.99	0.99	0.99

Table C.10. Power by CHIS island, outcome of interest, life form, revisit design, and net trend for a half sample of probability sites.

Island	Outcome of interest	Functional type	3% annual increase for 12 years					3% annual increase for 24 years				
			[1-0]	[(1-0), (1-3)]	[1-2]	[2-2]	[2-4]	[1-0]	[(1-0), (1-3)]	[1-2]	[2-2]	[2-4]
ANI n=8	Abs. percent cover	All natives	0.83	0.82	0.81	0.82	0.80	1.00	1.00	1.00	1.00	1.00
		All non-natives	0.21	0.21	0.21	0.21	0.21	0.75	0.75	0.75	0.75	0.75
		Native shrubs	0.45	0.43	0.43	0.44	0.41	0.98	0.98	0.98	0.98	0.98
		Native forbs	0.19	0.18	0.18	0.18	0.18	0.57	0.57	0.57	0.57	0.57
		Non-native forbs	0.31	0.31	0.31	0.31	0.31	0.94	0.94	0.94	0.94	0.94
		Native perennial forbs	0.44	0.44	0.43	0.44	0.43	0.98	0.98	0.98	0.98	0.98
		Native grasses	0.51	0.50	0.50	0.50	0.48	0.99	0.99	0.99	0.99	0.99
		Non-native grasses	0.21	0.20	0.20	0.21	0.20	0.73	0.73	0.73	0.73	0.72
	Sp. Rich.	All natives	0.65	0.64	0.64	0.65	0.63	1.00	1.00	1.00	1.00	1.00
		All non-natives	0.37	0.36	0.36	0.36	0.36	0.98	0.98	0.98	0.98	0.98
SBI n=12	Abs. percent cover	All natives	0.38	0.38	0.38	0.38	0.37	0.98	0.98	0.98	0.98	0.98
		All non-natives	0.37	0.37	0.36	0.37	0.36	0.98	0.98	0.98	0.98	0.98
		Non-native grasses	0.31	0.31	0.31	0.31	0.31	0.94	0.94	0.94	0.94	0.94
	Sp. Rich.	All natives	0.51	0.51	0.50	0.51	0.50	1.00	1.00	1.00	1.00	1.00
		All non-natives	0.70	0.69	0.69	0.70	0.68	1.00	1.00	1.00	1.00	1.00
SCI n=22	Abs. percent cover	All natives	0.22	0.21	0.21	0.22	0.21	0.55	0.54	0.54	0.55	0.54
		All non-natives	0.97	0.96	0.96	0.97	0.96	1.00	1.00	1.00	1.00	1.00
		Non-native grasses	0.96	0.94	0.95	0.95	0.94	1.00	1.00	1.00	1.00	1.00
	Sp. Rich.	All natives	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		All non-natives	0.83	0.80	0.81	0.82	0.78	1.00	1.00	1.00	1.00	1.00
SMI n=8	Abs. percent cover	All natives	0.62	0.61	0.61	0.62	0.56	1.00	1.00	1.00	1.00	1.00
		All non-natives	0.46	0.45	0.45	0.46	0.42	1.00	1.00	1.00	1.00	0.99
		Native shrubs	0.80	0.78	0.78	0.79	0.60	1.00	1.00	1.00	1.00	1.00
		Native forbs	0.23	0.23	0.23	0.23	0.21	0.80	0.80	0.80	0.80	0.72
		Native perennial forbs	0.57	0.55	0.55	0.57	0.47	1.00	1.00	1.00	1.00	0.99
	Sp. Rich.	All natives	0.84	0.83	0.83	0.84	0.73	1.00	1.00	1.00	1.00	1.00
		All non-natives	0.38	0.38	0.38	0.38	0.35	0.98	0.98	0.98	0.98	0.96
SRI n=43	Sp. Rich.	All natives	0.95	0.94	0.94	0.95	0.94	1.00	1.00	1.00	1.00	1.00
		All non-natives	0.39	0.38	0.38	0.39	0.38	0.98	0.98	0.98	0.98	0.98

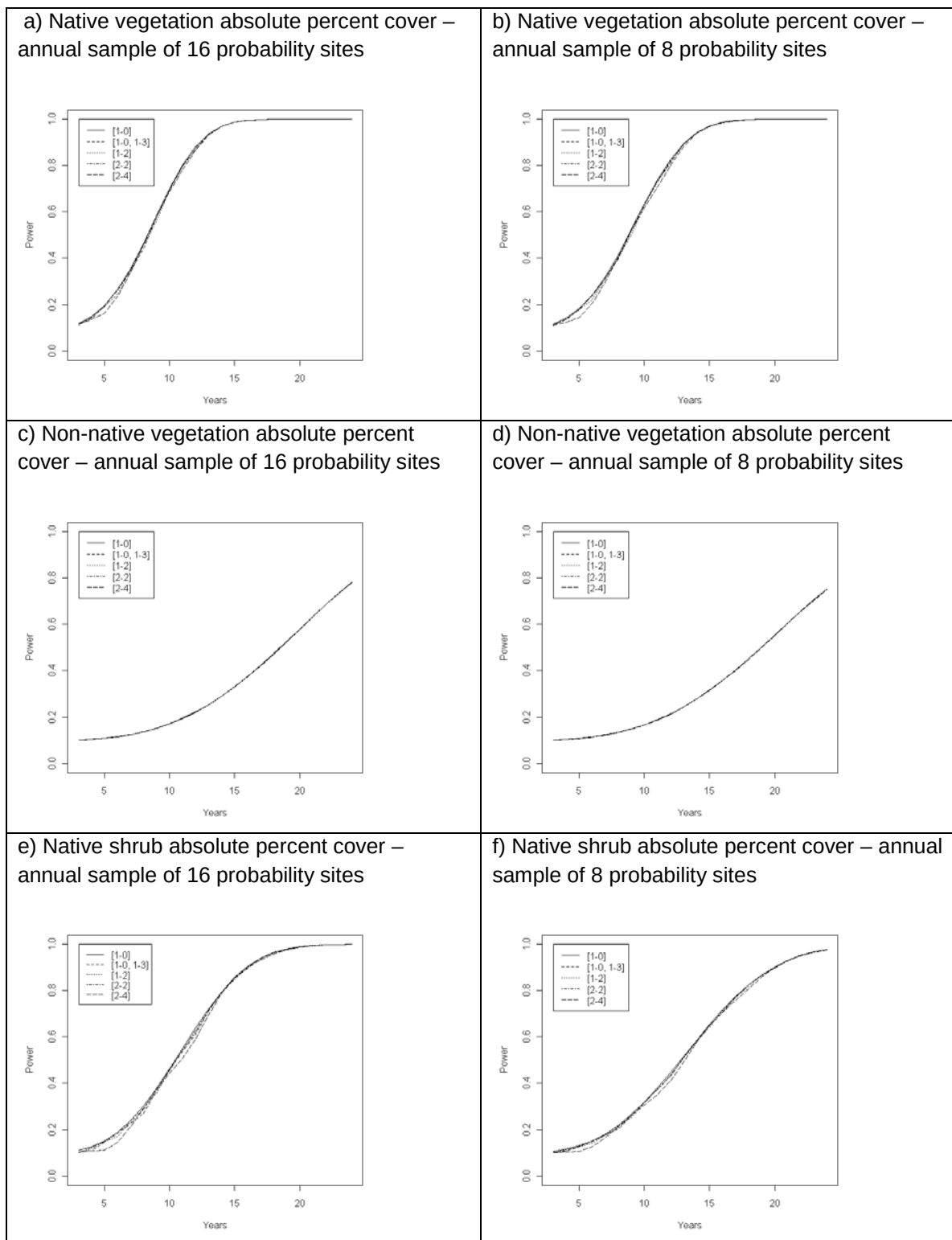


Figure C.2. Power to detect a 3% annual trend in Anacapa Island percent cover of native vegetation, non-native vegetation, and native shrubs in either direction with a Type I error level of 0.10 for two sample sizes.

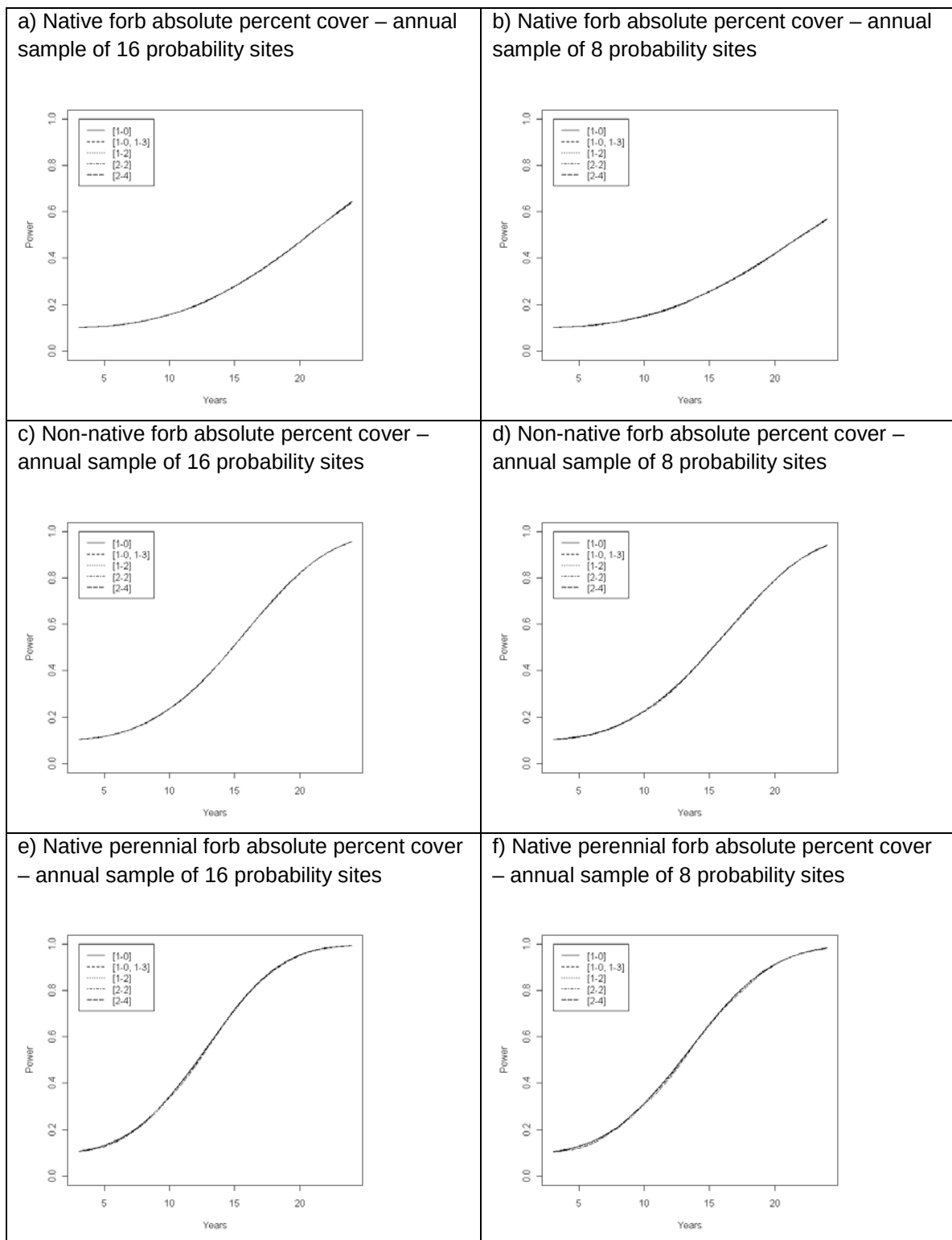


Figure C.3. Power to detect a 3% annual trend in Anacapa Island percent cover of native, non-native, and perennial forbs in either direction with a Type I error level of 0.10 for two sample sizes.

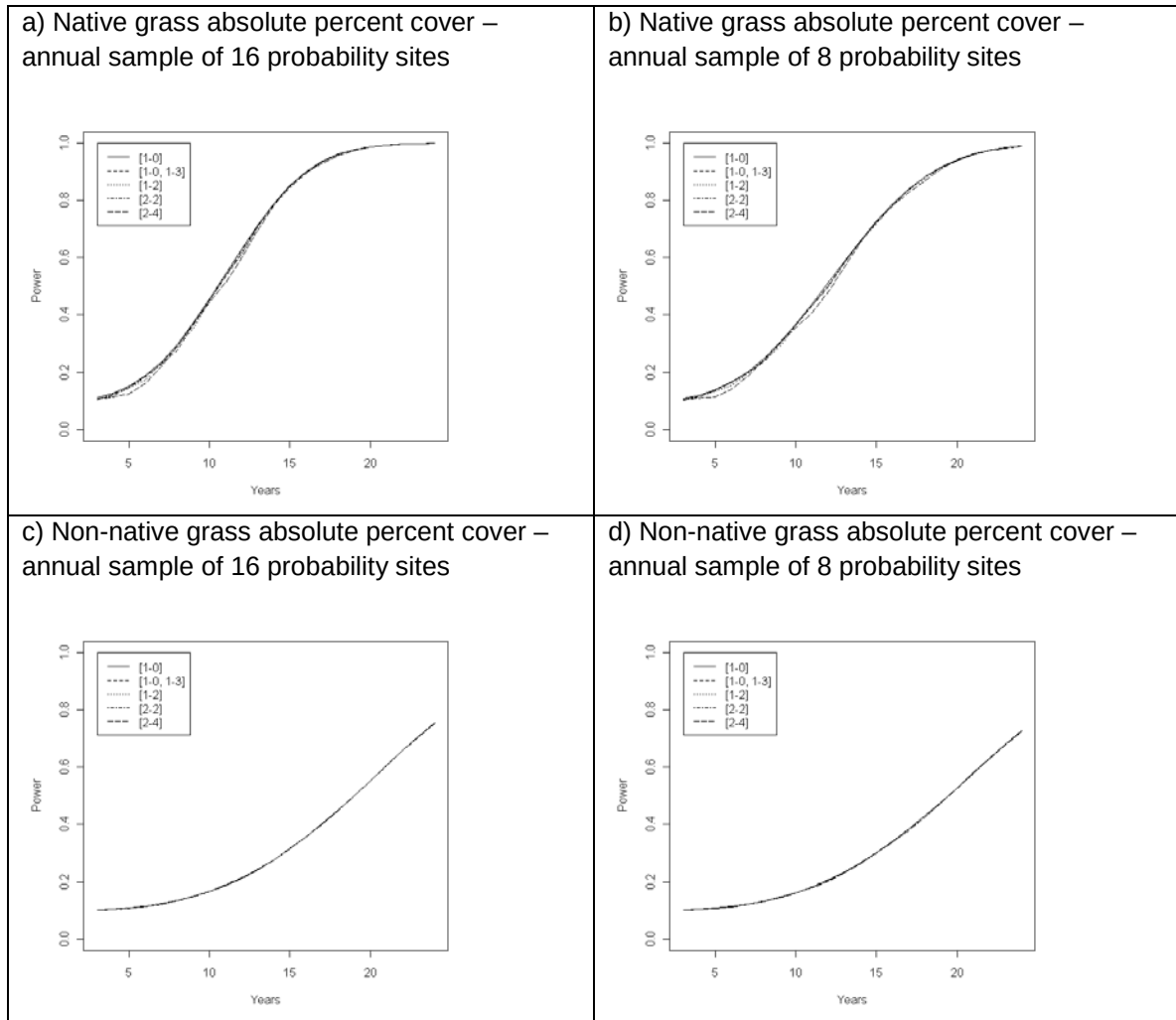


Figure C.4. Power to detect a 3% annual trend in Anacapa Island native and non-native grass percent cover in either direction with a Type I error level of 0.10 for two sample sizes.

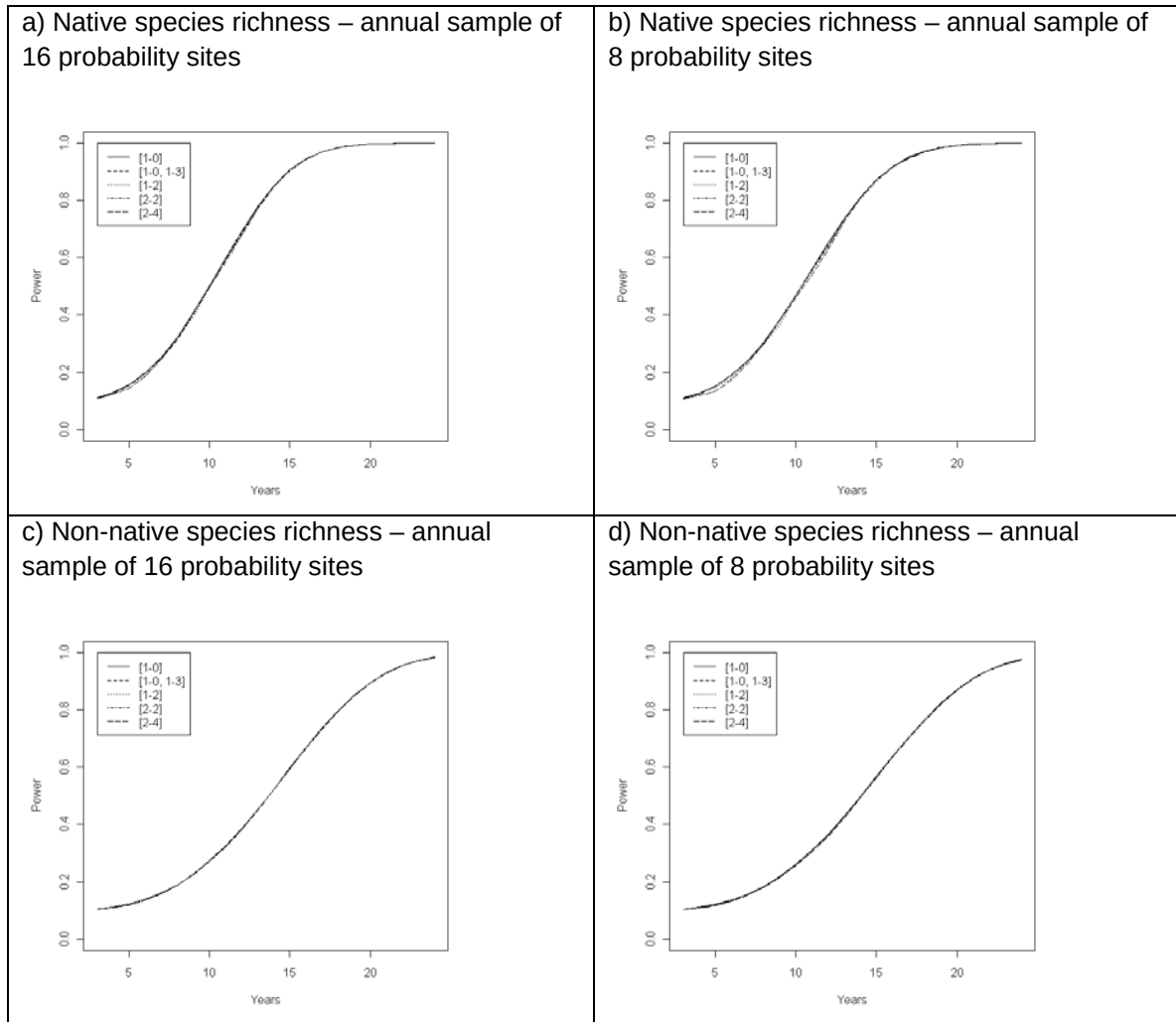


Figure C.5. Power to detect a 3% annual trend in Anacapa Island site-level native and non-native species richness in either direction with a Type I error level of 0.10 for two sample sizes.

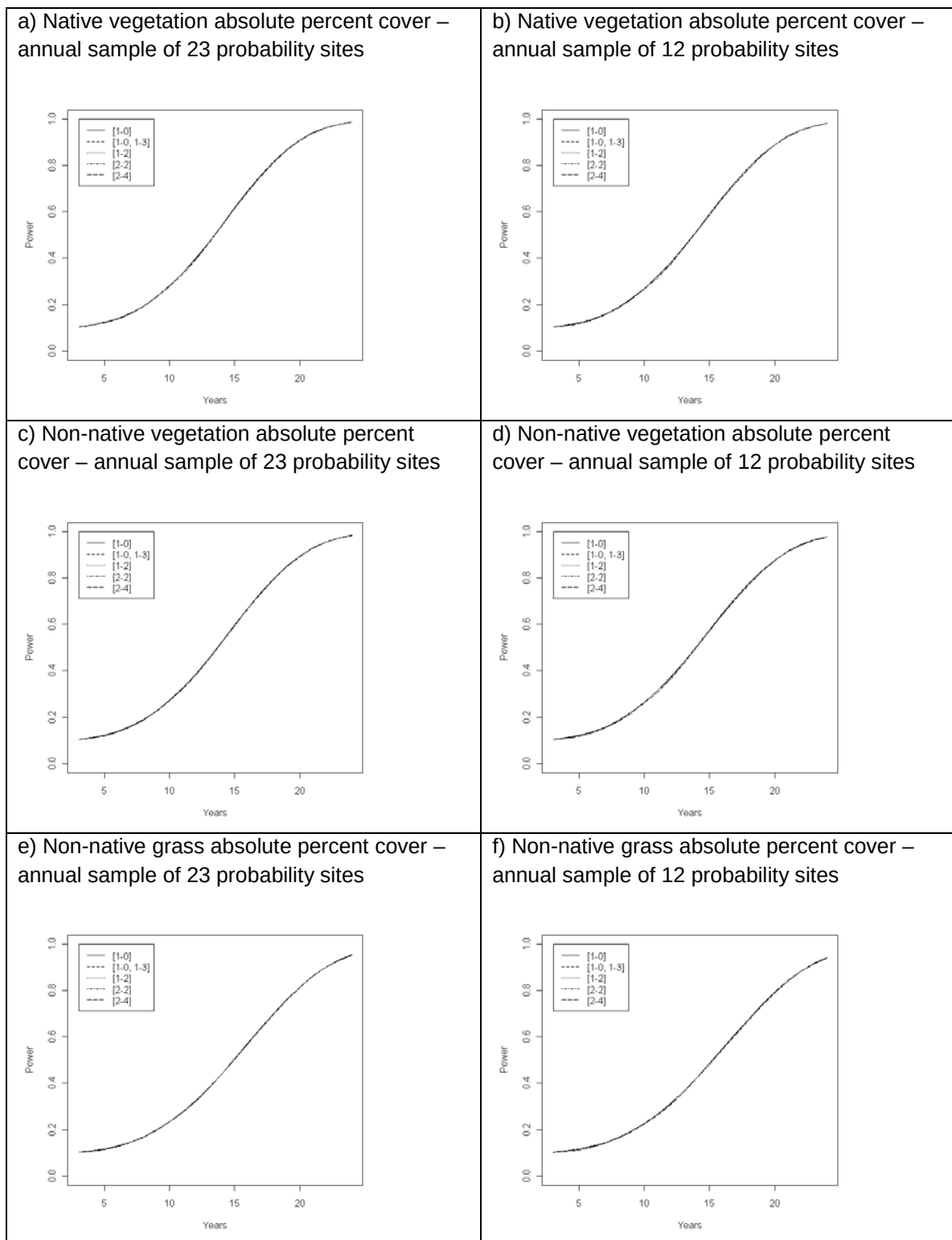


Figure C.6. Power to detect a 3% annual trend in all Santa Barbara Island percent cover in either direction with a Type I error level of 0.10 for two sample sizes.

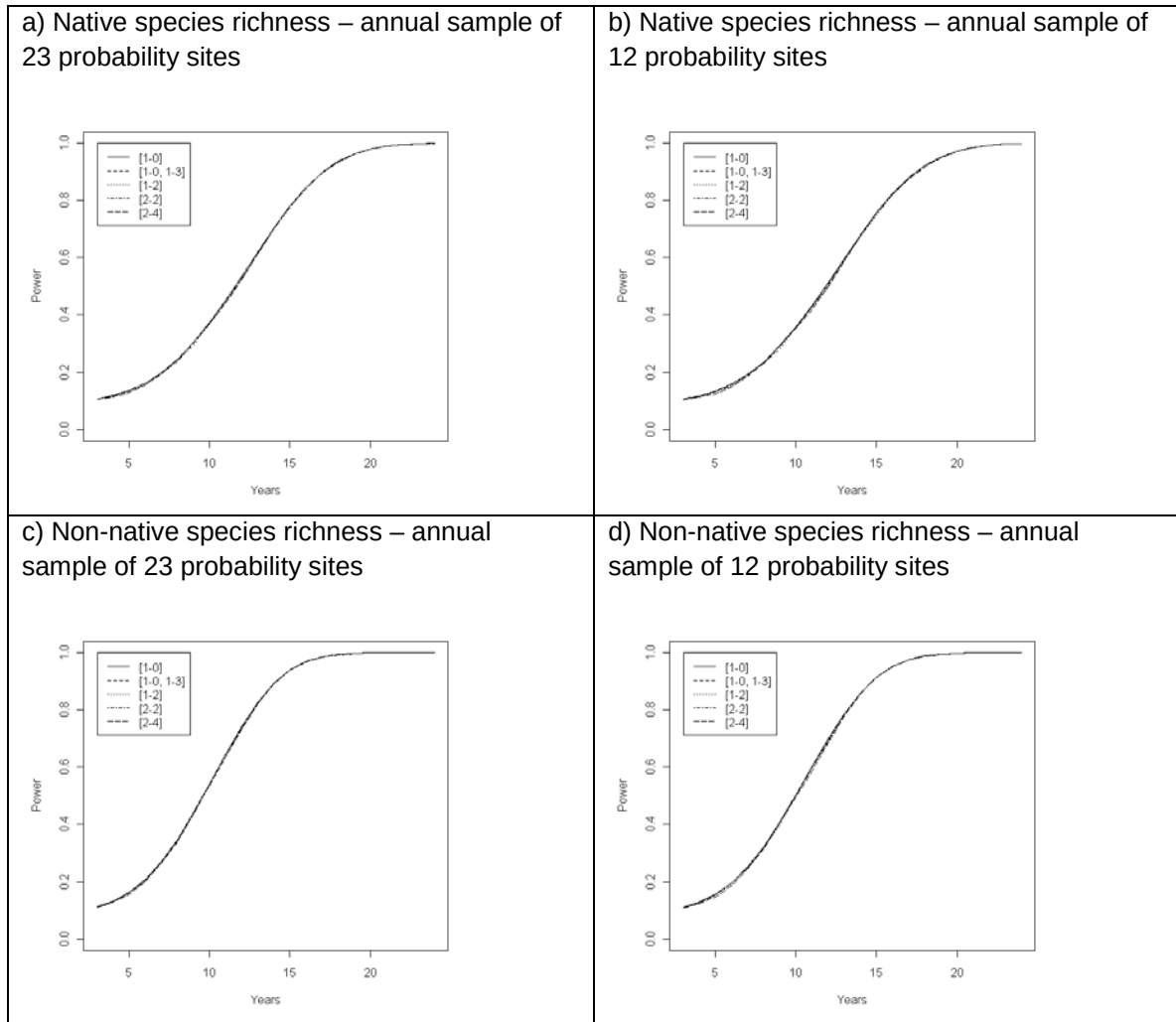


Figure C.7. Power to detect a 3% annual trend in Santa Barbara Island species richness in either direction with a Type I error level of 0.10 for two sample sizes.

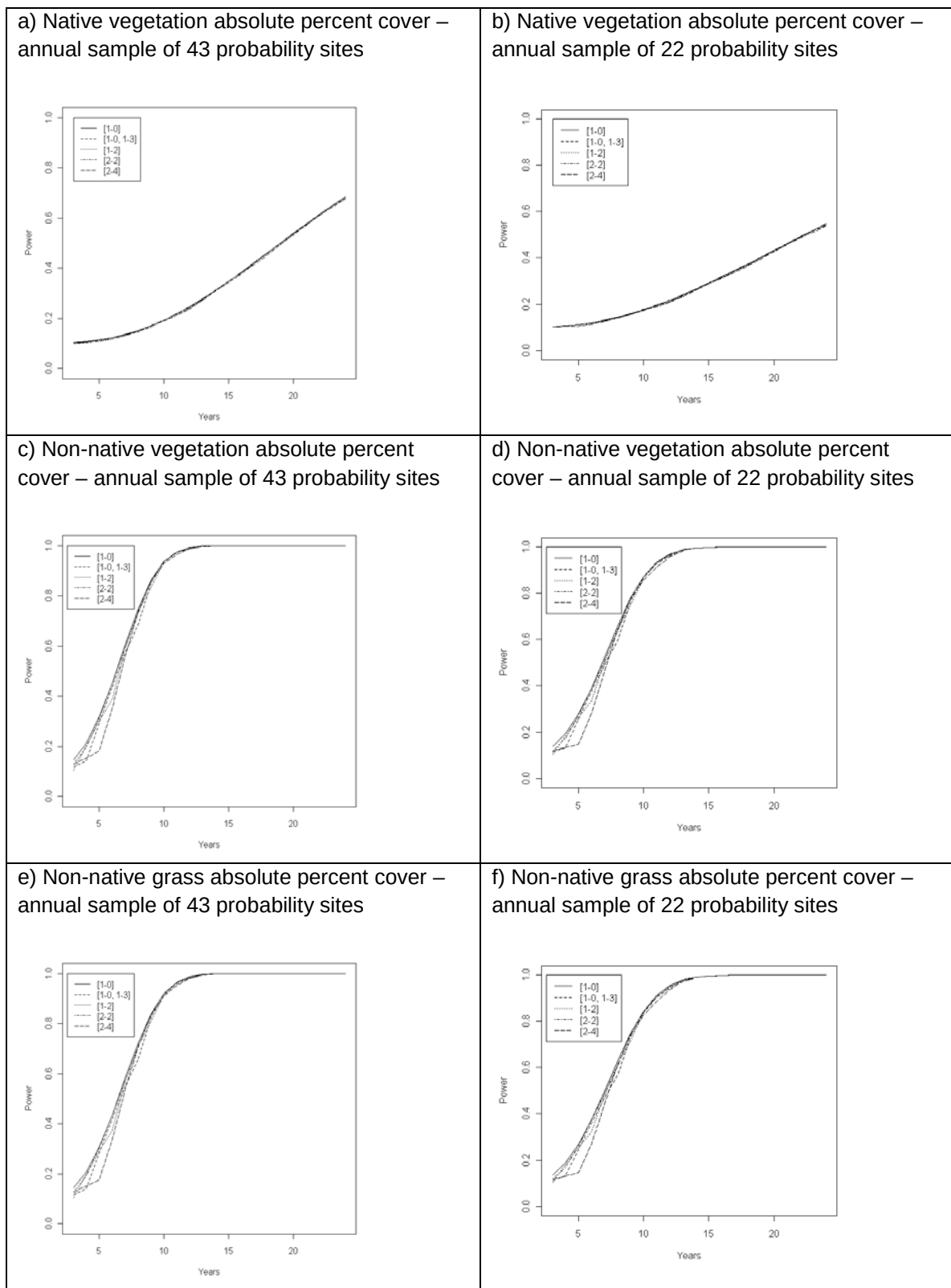


Figure C.8. Power to detect a 3% annual trend in all Santa Cruz Island percent cover in either direction with a Type I error level of 0.10 for two sample sizes.

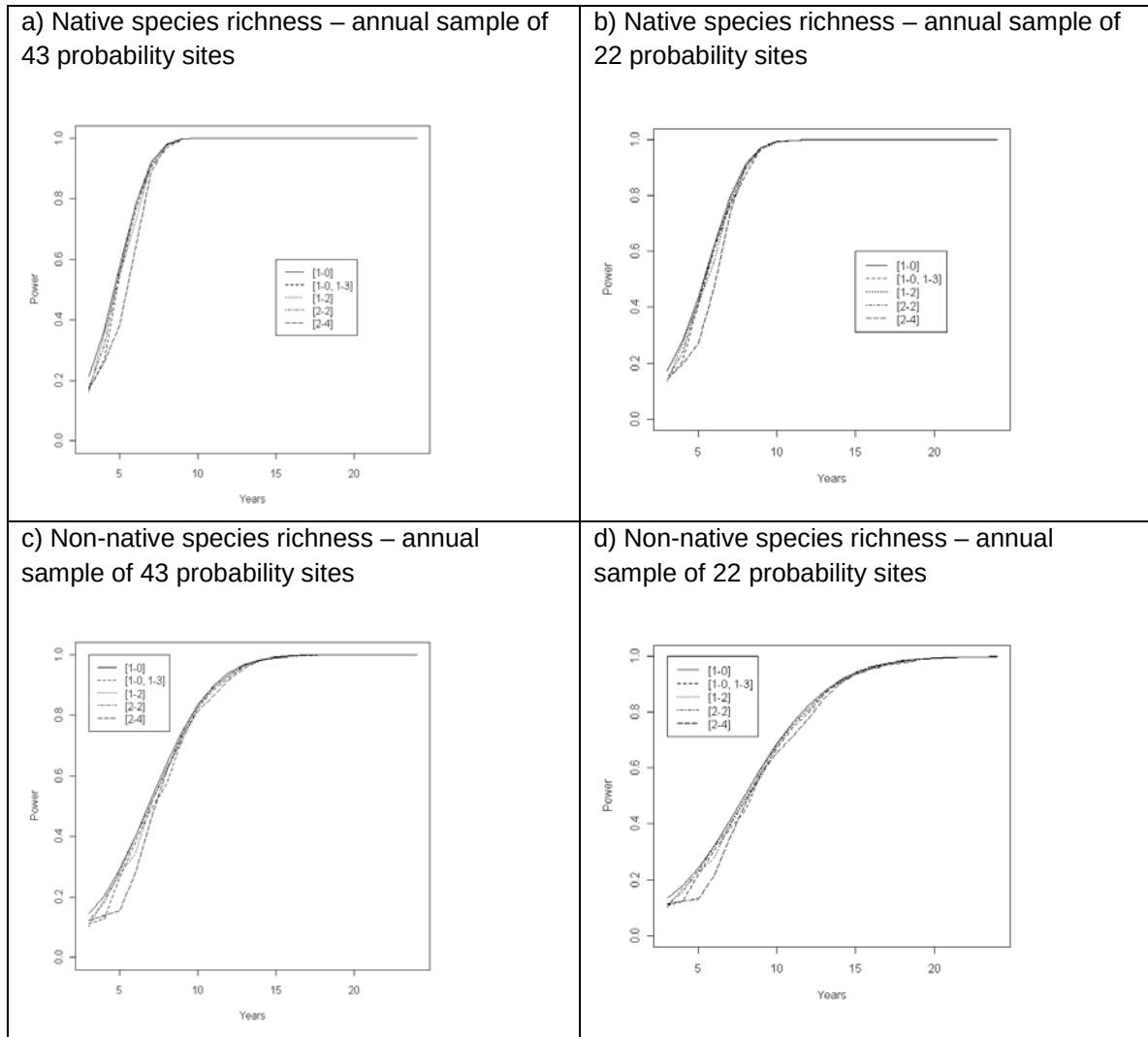


Figure C.9. Power to detect a 3% annual trend in Santa Cruz Island species richness in either direction with a Type I error level of 0.10 for two sample sizes.

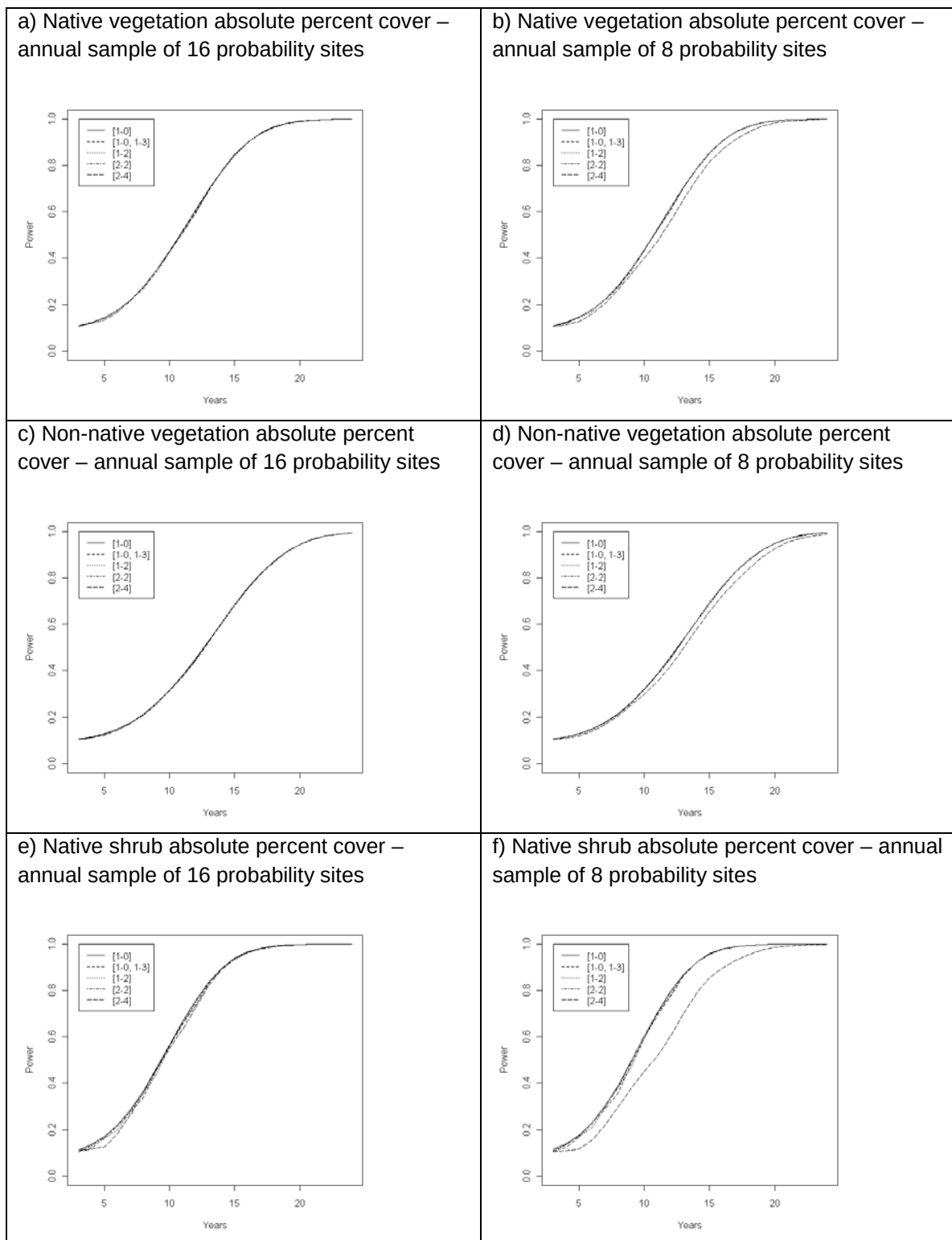


Figure C.10. Power to detect a 3% annual trend in San Miguel Island native vegetation, non-native vegetation, and native shrub percent cover in either direction with a Type I error level of 0.10 for two sample sizes.

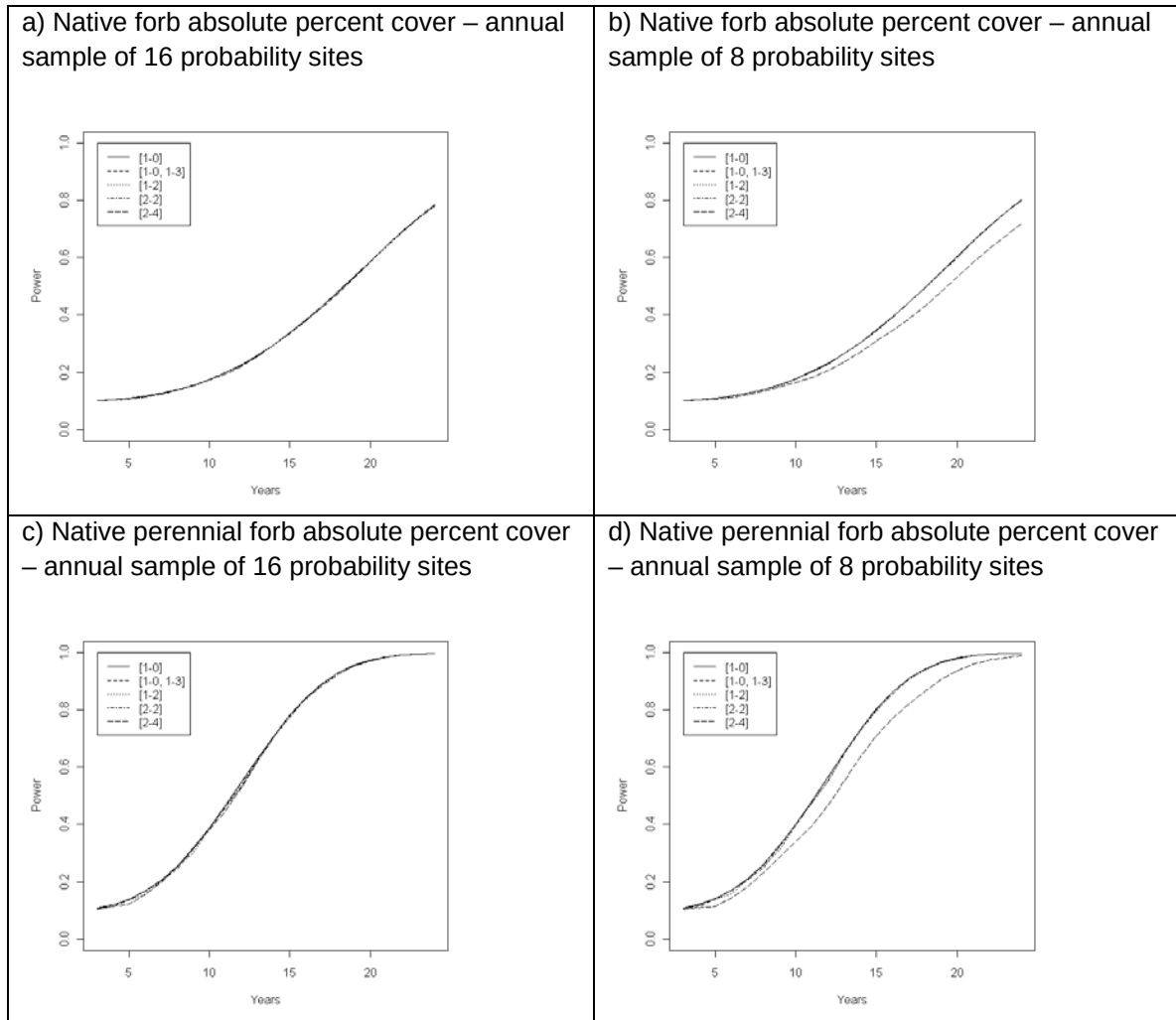


Figure C.11. Power to detect a 3% annual trend in all San Miguel Island native forb and native perennial forb percent cover in either direction with a Type I error level of 0.10 for two sample sizes.

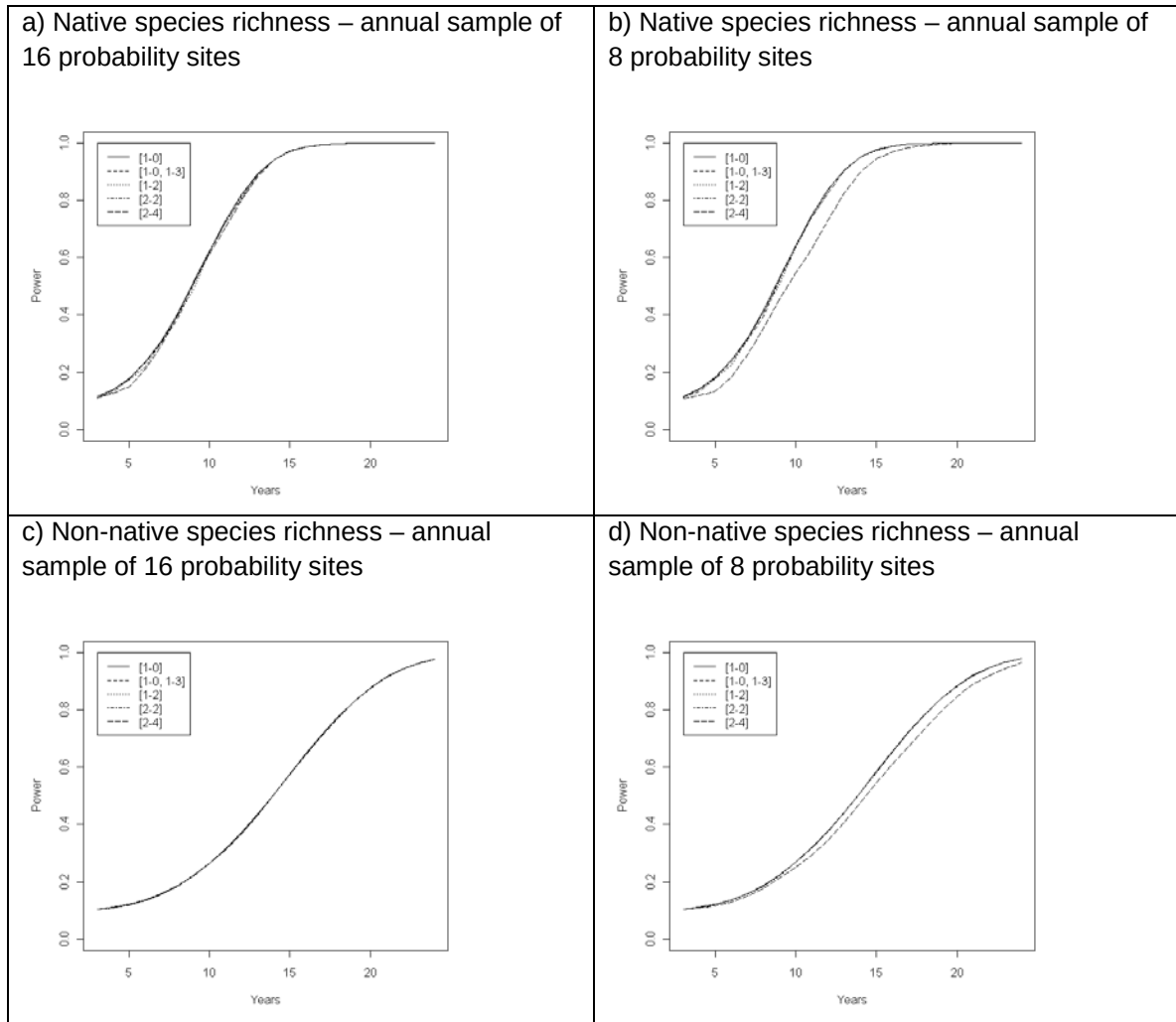


Figure C.12. Power to detect a 3% annual trend in San Miguel Island native and non-native species richness in either direction with a Type I error level of 0.10 for two sample sizes.

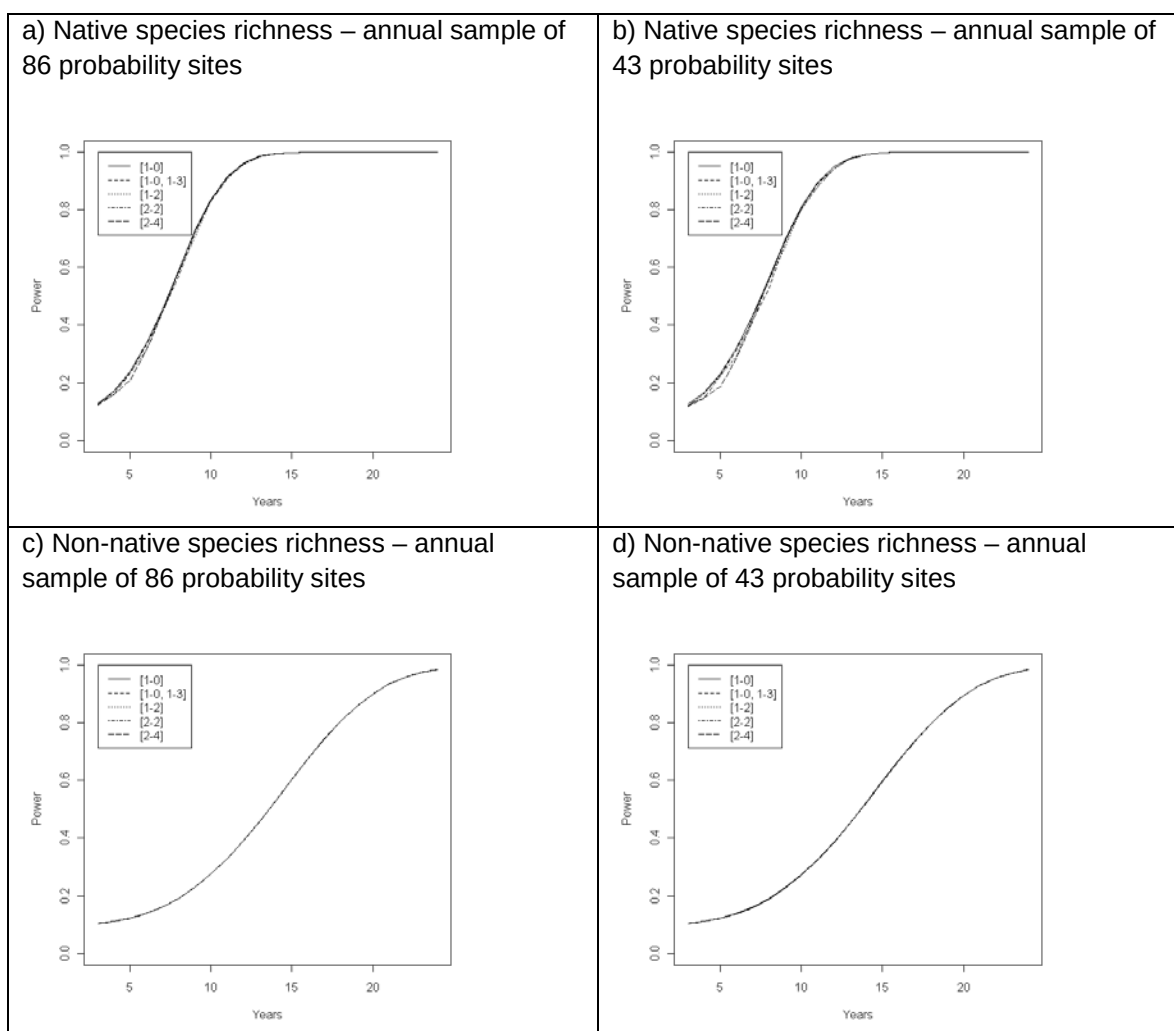


Figure C.13. Power to detect a 3% annual trend in Santa Rosa Island species richness in either direction with a Type I error level of 0.10 for two sample sizes.

Conclusions

This CHIS vegetation power analysis examined ability of various revisit designs to detect an annual trend of 3% within 12 to 24 years with at least 90% power. The outcomes with highest statistical power to detect trend included native percent cover for Anacapa Island; non-native percent cover and non-native grass percent cover, and native and non-native species richness for Santa Cruz Island; native shrub percent cover and native and non-native species richness for San Miguel Island; and native and non-native species richness for Santa Rosa Island. Applying variance estimates from the mixed model trend analysis CHIS species richness data indicates that 90% power for trend detection may be obtained for trend tests of SAMO native species richness if year-to-year variation is low, as in Santa Cruz Island.

Zero-inflated data were not examined in this power analysis because these data would not be helpful in informing decisions on revisit designs. Monitoring zero-inflated data allows for the possibility of two tests of trend: trend in the mean of the non-zero outcomes and trend in the probability of a zero.

Trend in the zero-inflation part of the mixture distribution will affect trend in the mean-distribution part, and vice-versa.

The absence of multiple-year monitoring data for CABR and SAMO prevented their inclusion in this analysis. Power may be reassessed in three to five years when variance components from these parks are fully estimable. The power analysis underscores the importance of consistent, long-term monitoring over time. For outcomes with relatively large year-to-year variation or residual variation, revisit designs and annual sample sizes do not impact the power to detect trend nearly as much as consistent sampling over time.

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Appendix D: Post-Fire Supplemental Vegetation Monitoring

Background and Objectives

Rationale for Supplemental Vegetation Monitoring Following Wildfires in the Mediterranean Coast Network

Fire is the most likely factor to cause rapid change in shrubland vegetation composition in all of the MEDN parks, even those with rare fire events. Mortality, survivorship, and recruitment of dominant shrub species can be affected by fire intensity, fire return interval, and pre- and post-fire climate, all of which can change post-fire community composition (Jacobsen et al. 2004; Keeley et al. 2005, 2005a; Pratt et al. 2010; Pratt et al. 2014). Colonization of native plants from outside burned areas plays little role in post-fire vegetation succession in southern California shrublands and the first two or three years of reestablishment and growth after a fire are the critical phase for determining shrub reestablishment (Keeley et al. 2005a; Keeley et al. 2006; Witter et al. 2007; Keeley and Brennan 2012; Pratt et al. 2014).

The future pattern of plant community dominance can therefore be best detected by measuring the in-situ survivorship and seedling recruitment in the first two to three years post-fire. Peak species diversity also occurs between one and two years post-fire and many of the unique post-fire herbaceous wildflowers disappear after this period (Keeley et al. 2005, 2005a). At SAMO, this post-fire native herbaceous flora contains approximately 100 species, or 30% of the native herbs (not all of these species are limited to the post-fire environment). At CHIS and CABR this flora is much less observed and much less understood.

Although fires have been much less frequent and limited in scope at CABR and CHIS than at SAMO, fires can occur under the right combination of ignition and climate conditions (NPS 2006a, 2006b), and have the potential to cause vegetation change at these parks. At CABR the effect of fire on various unique elements of the flora is unknown, particularly the succulent species unique to that park. Prescribed fire on SRI (1997) and a small wildfire on SCI (2006) have been shown to inhibit recovering coastal sage scrub (NPS 2008; Marti Witter and Timothy Handley, unpublished data). However, wildfires on both SCI and Santa Catalina Island (one of the Channel Islands south of CHIS) have stimulated germination of rare species present in the seed bank. The 1994 China Harbor escaped prescribed fire on SCI resulted in extensive germination of the endemic island rush-rose (*Helianthemum greenei*) (Kathryn McEachern, pers. obs). On Santa Catalina Island recent fires have also been followed by an extraordinary germination of native plants, some of which are rare and endangered or uncommon (Knapp 2005). As these examples show, merging the Terrestrial Vegetation long-term monitoring program with supplemental post-fire monitoring is essential to understanding vegetation dynamics and mechanisms of vegetation change, and to formulate useful management responses.

Monitoring in the first two years immediately post-fire is necessary to fully capture species diversity, to detect abrupt shifts in vegetation—especially those anticipated with climate change and extreme climate events, and to detect potential expansion of invasive species at this vulnerable period. We will respond to fire events at MEDN parks by temporarily increasing the frequency of monitoring at

Terrestrial Vegetation monitoring sites within the fire perimeter and by adding supplemental, fire-specific monitoring protocols. If the number of Terrestrial Vegetation monitoring sites is not sufficient for post-fire monitoring, we will add additional randomly chosen monitoring sites. After a fire, all sites within the fire perimeter will be monitored by vegetation and fire ecology staff under the cooperative supervision of the MEDN Fire Ecologist and the Botanist/Plant Ecologist at each of the parks. The plots will be visited each spring for the first two years post-fire, unless an extreme climatic event occurs that warrants an additional year of data collection. Terrestrial Vegetation monitoring sites will then return to their normal rotation within the long-term monitoring cycle and sites added specifically for post-fire monitoring will be dropped from the regular monitoring cycle.

Monitoring Objectives

Supplemental Post-Fire monitoring expands on the primary Terrestrial Vegetation monitoring objective to include fire effects:

Determine the effects of wildfire on species composition, richness, and abundance within the shrubland vegetation types of MEDN parks.

To achieve this objective we combine the methods of the Terrestrial Vegetation long-term monitoring protocol with the methods described in this supplemental Post-Fire vegetation monitoring appendix to quantitatively monitor the following plant and soil parameters:

- Foliar cover – all plant species.
- Stem density of shrubs – seedling, sapling, resprout, mature, dead.
- Species richness – list of all species occurring in a monitoring plot.
- Species frequency – calculated from species presence (richness) data for each site.
- Soil cover type – biological crust, litter, rock, soil.
- Fire severity – vegetation and soil.

These parameters will provide information on the changes in vegetation composition and structure that can be caused by demographic shifts after wildfire, the event most likely to cause abrupt vegetation changes in MEDN parks.

Sampling Design

Rationale for Sampling Design

We will utilize the monitoring sites for shrubland vegetation types established under the Terrestrial Vegetation monitoring protocol. These locations were chosen using a random spatially balanced sampling design that improves representation of a vegetation feature or covariate of interest according to the area occupied by that feature or covariate (Generalized Random Tessellation Stratified (GRTS) sampling with equal probability weighting; Stevens and Olsen 2003, 2004). Use of the existing Terrestrial Vegetation monitoring sites allows us to study short- and long-term fire effects on different species and plant community types and may provide insight into the processes underlying vegetation changes observed in the Terrestrial Vegetation long-term monitoring program.

Sampling Frequency

For any area burned by wildfire in any of the three parks, we will visit all burned monitoring sites employed in the Terrestrial Vegetation monitoring program, regardless of where they are positioned in the rotation cycle. If staffing resources permit, we may monitor additional sites, which will be selected by a supplemental GRTS draw at CHIS and CABR or from the existing master sample at SAMO.

We will monitor sites using these supplemental post-fire methods for the first two years after the fire, unless it is determined that conditions necessitate a third year of monitoring. After monitoring is completed, sites used in the Terrestrial Vegetation monitoring program will return to their normal rotation within the sampling cycle. Sites used to expand the post-fire sample size that are not part of the Terrestrial Vegetation monitoring program will be dropped, but reactivated when another fire burns the site.

Evaluation of the Protocol

We have developed this sampling and response design to meet our post-fire monitoring objectives based on published results from other studies (Keeley et al. 2005; Keeley and Fotheringham 2005; Keeley et al. 2005a, Keeley et al. 2005b; Deutschman et al. 2008). However, optimum sampling designs, optimum response designs, and necessary sample sizes cannot be fully determined prior to beginning work. We will use the data from the May 2013 Springs Fire (SAMO) monitoring conducted in 2014 and 2015 to evaluate necessary sample size, response design, and logistic feasibility. Thirty-four sites will be monitored: 31 from our Terrestrial Vegetation monitoring program and three additional sites from the SAMO master sample.

Seasonal Timing of Monitoring

Fire monitoring will be at the same time of year as monitoring for the Terrestrial Vegetation protocol, which is during the spring growing season in order to best capture information about herbaceous species. Selected plots may be resampled in late summer or fall to capture summer annuals and summer seedling mortality.

Response Design

Overview

Table D.1 summarizes Terrestrial Vegetation and supplemental Post-Fire monitoring response variables. The standard response measures are vegetation foliar cover, shrub density, species richness and frequency, and soil surface cover. The supplemental methods expand cover, density, and species richness measures to a larger plot area and add measurements to assess burn severity and fire-caused mortality.

Table D.1. Long-term vegetation monitoring and supplemental fire response measures for MEDN parks, showing measurements taken at each monitoring location.

Program	Measure	Population of interest	Technique employed
Terrestrial Vegetation long-term monitoring response measures	Cover (foliar)	All plant species Soil surface features	Line-point intercept transect 30 m transect, 100 points
	Density (includes mortality & recruitment)	All shrub & tree species	Counts of seedling, sapling, and mature plants; plus basal area for tree species. - Shrubs – 1 × 30 m belt plot > read as 6 contiguous 1 × 5 m plots - Trees – 10 × 30 m plot > read as 2 adjacent 5 × 30 m plots - Trunk diameter at 1.37 m (4.5 ft) height
	Species Richness & Frequency	All plant species	Species list 1 × 30 m belt plot > read as 6 contiguous 1 × 5 m plots subdivided into pairs of 1 × 1 m and 1 × 4 m plots
Post-Fire supplemental response measures	Cover (foliar)	All plant species with greater than 1% cover	Ocular estimate 30 × 10 m belt plot > read as 3 contiguous 10 × 10 m plots
	Pre-fire Shrub Density, Fire Mortality	All shrub & tree species	Counts of dead skeletons and resprouting shrubs or trees 30 × 10 m belt plot > read as 3 contiguous 10 × 10 m plots
	Live Shrub Density & Seedling recruitment	All shrub & tree species	Counts of shrub & tree seedlings and resprouts 1 × 30 m belt plot > read as 6 contiguous 1 × 5 m plots
	Species Richness & Frequency	All plant species	Species list 1 × 30 m belt plot (1 m² plots) > read as 6 separate 1 m² plots* 30 × 10 m belt plot (100 m² plots) > read as 3 contiguous 10 × 10 m plots

Supplemental Post-Fire Measurement Techniques

All Terrestrial Vegetation monitoring measures will be taken in addition to the following supplemental post-fire monitoring measurements.

Density of shrub skeletons and resprouts (shrub mortality)—YEAR 1

Shrub mortality can be calculated from the Terrestrial Vegetation monitoring protocol 1 × 30 m belt transect, but the sample size is too small to accurately estimate this parameter for most species. In the supplemental methods, mortality is monitored by counting all shrub and subshrub skeletons and resprouts rooted within a 10 × 30 m belt plot adjacent to the Terrestrial Vegetation monitoring line-point transect. The belt is divided into three 10 × 10 m subplots (Figure D.1). Plants are recorded by species and classified into three classes: live shrub, resprout, and dead skeleton. For species with clonal growth habits and multiple stems, physically discontinuous clumps of stems are counted as “individuals.” The 10 × 30 m belt mortality count is done only in the first year post-fire.

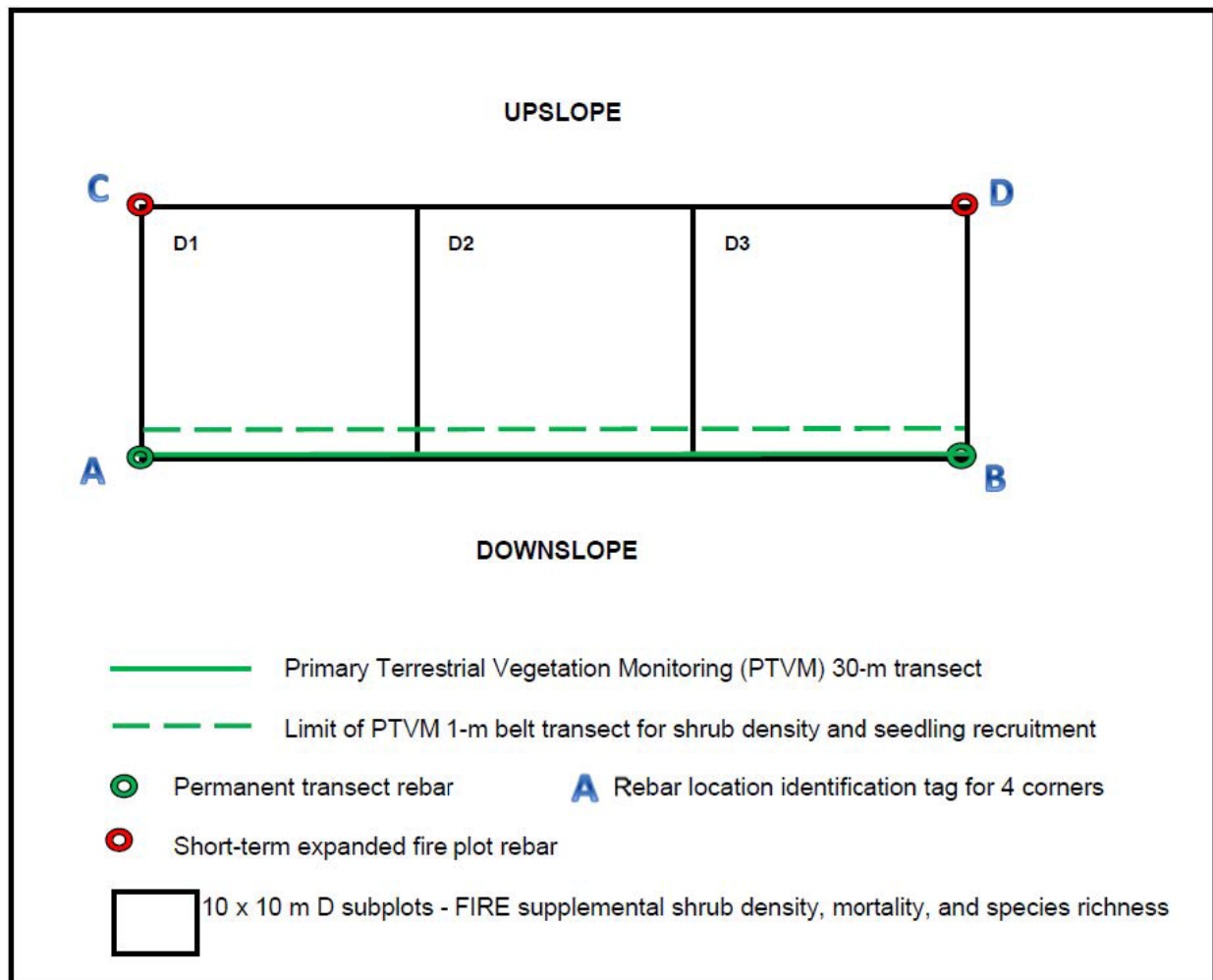


Figure D.1. Schematic representation of the layout of the 10 × 30 m post-fire sampling plot in relation to the primary terrestrial vegetation monitoring transect and 1-m belt. .

Density of shrubs—YEAR 2 (YEAR 3 if necessary)

Shrub density is measured with the Terrestrial Vegetation monitoring protocol 1 × 30 m belt transect (SAMO/CABR plant count, CHIS stem count).

Seedling recruitment—YEAR 1 and YEAR 2 (YEAR 3 if necessary)

Seedling recruitment is measured with the Terrestrial Vegetation monitoring protocol 1 × 30 m belt transect seedling count.

Species richness—YEAR 1 and YEAR 2 (YEAR 3 if necessary)

Species richness data for fire effects studies in Mediterranean shrublands are most commonly collected as nested 1 m² and 100 m² quadrats within a 1000 m² (0.1 ha) plot (Keeley 2003; Keeley et al. 2005a, 2005b). To make comparisons with other fire studies, we must replicate at least a subset of the 1000 m² plots. Our supplemental Post-Fire monitoring methods obtain richness in 1 × 1 m quadrats and also collect data on species richness in a set of 10 × 10 m quadrats. The six 1 × 5 m segments in the Terrestrial Vegetation protocol are each subdivided into 1 × 1 m (1 m²) and 1 × 4 m subplots. The 10 × 30 m belt transect is divided into three 10 × 10 m (100 m²) subplots (Figure D.1, D1-D3). This approach is consistent with the Deutschman et al. (2008) recommendations that studies where species diversity is important should maximize the number of sites and have fewer large quadrats. (Deutschman et al. (2008) found that 60%–80% of species richness in a 1000 m² quadrat was found in a smaller 400 m² quadrat.)

Fire severity—YEAR 1

Fire severity is measured using a 5-point scale that is modified from the NPS Fire Monitoring Handbook (NPS 2003). The scale ranges from 0 (unburned) to 4 (heavily burned). The vegetation scale reflects the amount of biomass consumed and the soil scale reflects the amount of consumption of soil organic matter and alteration of soil properties.

Field Methods

Locating, Establishing, and Revisiting Plots

During the field preparation period, if there has been a wildfire in the previous year at any of the MEDN parks (these usually occur during the fall), we will use fire perimeter and burn severity maps to identify the Terrestrial Vegetation monitoring sites that have burned. All burned sites will be included in the next year's spring monitoring schedule. If additional sites are required, they will be selected by a supplemental GRTS sampling at CHIS and CABR or from the existing master sample at SAMO.

At existing sites, additional monuments will be installed and the expanded plot monitored to include the supplemental protocols. If the site does not have a plot installed, it will be installed according to SOPs 5 and 5a. After a monitoring plot is installed, a site reference packet (SOP 1) will be created.

Training, Calibration and Consistency

At the start of the field season staff will be provided with a 5-day training program (SOP 2) followed by field training as work begins.

Field Data Review and Entry

Data on field forms should be entered as soon as feasible after collection and preferably by the person(s) who collected it. To minimize transcription errors, data entry should follow the procedures for team and individual entry described in SOP 9 and 10.

After the Field Season

All field data not entered during the field season will be entered into the database as soon as possible (within 30 days) after field surveys conclude. Data will be reviewed and verified under the direction of the Data Manager following SOPs 9 and 13.

Data Management

NPS fire data are stored in a national database, FFI (FEAT/FIREMON Integrated; Lutes et al. 2009), which is a joint United States Forest Service and NPS project that has long-term support from both agencies. However, to provide utility to the Terrestrial Vegetation long-term monitoring program, the data must also be placed in the database for that program. There are regional and national discussions between the I&M and Fire Management programs on how to integrate the two programs where there is overlap. We are currently testing methods to enter data from the fire protocols into the I&M database, with the ability to then import the data into the FFI database.

Data Analysis and Reporting

We will analyze and report on how fire has affected the status of or changes in the abundance of plant functional types (e.g., native shrubs, non-native annuals, post-fire endemics), the abundance of selected species, and community diversity. Summary fire data will be included as part of the report that will be compiled at the end of each calendar year summarizing data collected in all three parks. This report will describe the response of vegetation to fire through simple summary statistics, descriptions of interesting or unusual observations, and basic interpretation of that year's findings. A single report will be prepared for all three parks in the MEDN.

At the end of the fire monitoring period for a given fire (or group of fires), an in-depth report will be published that will summarize all fire monitoring efforts up to the date of publishing, describe status and changes in vegetation as the result of fire, interpret these vegetation changes, and provide a critical review of the monitoring effort. This review will allow for adaptation of Post-Fire monitoring methods to fit changing programmatic goals, or changing environmental conditions. The Fire Ecologist will have responsibility for summary and analysis of data and preparation of the reports.

Personnel Requirements and Training

Roles and Responsibilities

Post-fire plot monitoring will be performed for two years after a fire by a combination of Terrestrial Vegetation and Fire Monitoring staff, with crew composition varying as resources allow. Work will be conducted under the supervision of the MEDN Fire Ecologist in coordination with the Terrestrial Vegetation monitoring program staff. Staff duties are summarized in Table 9 of the Terrestrial Vegetation monitoring protocol. Specific duties of the MEDN Fire Ecologist are

- In consultation with I&M staff, plan and execute field visits.
 - Prepare guide materials for site visits.
 - Direct training and ensure safety of field teams (specific to post-burn environment).
 - Ensure calibration and consistency of team members.
- Oversee data collection and entry; verify accurate data transcription into database.

- Oversee and/or perform data summary, analysis, and reporting.

Based on a typical range of fire sizes in the Santa Monica Mountains, we anticipate anywhere between 20 and 50 plots will require monitoring after a given fire at SAMO. Fires at CHIS and CABR have been historically small and very infrequent, so it is not possible to predict monitoring requirements for these parks.

Crew Qualifications and Training (Staffing)

Crew qualifications and training will be as described in the Terrestrial Vegetation protocol and SOP 2. In the first year after fire, when the post-fire plots need to be established and pre-fire mortality counts made, it is most efficient to work with a four-person crew in teams of two each. First, all four crew members work together to set up the expanded plot. Then one team measures along the Terrestrial Vegetation transect (as modified for post-fire monitoring), while the second team measures the expanded 10 × 30 m post-fire monitoring belt (SOPs 7 and 7a).

In the second year post-fire, when mortality counts do not need to be made in the 10 × 30 m belt, a two person crew is sufficient to implement both Terrestrial Vegetation and Post-Fire monitoring methodologies. The SAMO Fire Ecologist will participate as a crew member and will seek funding from the regional fire program to support the additional crew requirements.

Operational Requirements

The operational requirements and needs follow those described in the Terrestrial Vegetation monitoring protocol. The annual schedule of major tasks is summarized in Table 10 of the protocol narrative.

Supplemental Costs

This monitoring protocol is a cooperative effort between the Fire Management Program for the MEDN network, the MEDN I&M Program, and the Resource Management Programs at each of the three network parks.

The total cost for the additional work required for post-fire monitoring will vary with the size of fire and specific logistics and difficulties accessing the burned sample sites. The extent of post-fire monitoring performed will depend on funding availability (an economy will be realized where post-fire plots are scheduled to be monitored as part of the Terrestrial Vegetation monitoring cycle). A proposed budget will be prepared after a wildfire and funds will be sought to conduct the supplemental monitoring. Under the existing fire management business rules, first-year monitoring can be supported by fire suppression accounts as part of the assessment of a fire's impacts. The MEDN Fire Management Program will apply for additional funds from available funding sources to support second-year monitoring.

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Appendix E: Template for Annual Terrestrial Vegetation Monitoring Report

This appendix contains a proposed template for an annual report. It summarizes content and shows proposed tables and graphics, but does not utilize the formatting required for a Natural Resources Report.

The annual report will be prepared as a Natural Resources Report. Guidance on content, format and style; a report template; and a manuscript submittal checklist can be found at the Natural Resources Publications Management website: <http://www.nature.nps.gov/publications/nrpm/>.

The report will be organized into four main sections (Introduction, Methods, Results and Discussion), followed by three appendices containing separate tabular and graphical data summaries for each of the three MEDN parks. Suggested figures and tables are listed below

Figures

Figure E.1. Map showing locations of sites monitored in 20XX at [PARK].

Figure E.2. Absolute foliar cover (%) of various plant groups observed during 20XX monitoring at [PARK].

Figure E.3. Relative plant cover by nativity in plant communities at [PARK] observed during 20XX monitoring.

Figure E.4. Relative plant cover by nativity and lifeform in plant communities at [PARK] observed during 20XX monitoring.

Figure E.5. Absolute foliar cover of all species and of all native species for each of the last 6 years of monitoring at [PARK].

Figure E.6. Density of native and non-native shrubs for each of the last 6 years of monitoring at [PARK].

Tables

Table E.1. Potential [PARK] monitoring sites that were visited and rejected in 20XX.

Table E.2. [PARK] monitoring sites installed in 20XX.

Table E.3. [PARK] sites monitored in 20XX.

Table E.4. [PARK] sites scheduled for monitoring, but not monitored in 20XX.

Table E.5. Burned sites monitored at [PARK] in 20XX.

Table E.6. Species richness (per transect) observed during 20XX monitoring of [PARK] vegetation.

Table E.7. Absolute foliar cover of plant groups and soil surface cover (%) observed during 20XX of [PARK] vegetation.

Table E.8. Density (number / hectare) of shrubs and trees observed during 20XX monitoring of [PARK] vegetation.

Table E.9. Absolute foliar cover (%), density (number / hectare), and frequency (%) of target monitoring species observed during 20XX at [PARK].

Introduction (Background and Objectives)

This section provides the background and objectives of the MEDN Terrestrial Vegetation monitoring program. It is a highly abbreviated version of the Background and Objectives section of the protocol narrative. It should include a regional map showing the location of each of the three parks (Figure 1 in the narrative) and a brief summary of the importance of MEDN vegetation and the monitoring need, followed by a statement of monitoring objectives.

Methods Section

This section is divided into two subsections. The first subsection provides brief descriptions of the following:

1. Sampling procedure.
2. Response design (with plot schematic as in Figure 12 of the narrative).
3. Response measures (foliar cover, density, richness, frequency, etc.).
4. Measurement techniques.
5. Response metrics (plant functional types and individual species).
6. Data QA/QC procedures.

The second subsection provides information on plot installation and data collection at each park. It includes the following, described separately for each park:

1. Site assessment and new plot installation.
 - Number of potential sites visited, and new plots installed.
 - Name and position of individuals who performed the work.
 - Dates that the work was performed and person-hours required to perform the work.
 - Brief discussion of reasons plots were rejected and any other difficulties encountered.
 - Number of plots installed and number of plots remaining to be installed. Expected date when all plots will be installed.
 - Reference to Tables E.1 and E.2 in the report appendix, which provide specific information on each potential plot location rejected and each new plot installed.
2. Monitoring activities
 - Number of sites monitored, and number of sites scheduled for monitoring but not monitored.
 - Name and position of individuals who performed the work.

- Dates that the work was performed and person hours required to perform the work.
- A brief discussion of noteworthy happenings during the monitoring: practical difficulties, alterations to the protocol, injuries, etc.
- Reference to Tables E.3 and E.4 in the report appendix, which provide specific information on each plot monitored and each plot scheduled for monitoring, but not monitored.
- Map similar to Figure E.1 showing sites monitored and sites scheduled for monitoring, but not monitored.

3. Additional monitoring activities

- CHIS index sites: Descriptions, map and reference to tables in appendix constructed in the same way as Tables E.3 and E.4 described above.
- Post-fire monitoring: Descriptions as above, map, and reference to Table E.5.

4. Data Management

At the end of each field day, the datasheets from that day were checked by [name(s)] to ensure legibility, completeness, and correct use of species codes. After the end of the field season, the 20XX vegetation monitoring data were entered into a customized MS Access database. This work was conducted by [name(s)] between [date] and [date]. Secondary checking of the entered data (verification) was later conducted by [name(s)] between [date] and [date]. Results from validation queries executed by the Program Leads from each park along with the Data Manager showed [summarize results]. All data was certified by [names] and archived by the Data Manager.



Figure E.1. Map showing locations of all sites monitored in 20XX at CABR. Sites designated as “not monitored” are sites that were scheduled for monitoring this year, but could not be accessed.

Results Section

Findings for each of the three parks will be described separately. The following descriptions, tables, and graphs will be included in this section:

1. Provide a brief summary of the following attributes broken out by community types appropriate for each park.
 - Species richness: by nativity. Reference Table E.6 in appendix.
 - Absolute foliar cover: by growth form (and life history, if of interest). Reference Table E.7 and Figure E.2 in report appendix.
 - Soil surface cover: by cover type. Reference Table E.7 in appendix.
 - Shrub and Tree Density: by size class. Also describe tree basal area. Reference Table E.8 in appendix.

2. Brief description of native and non-native species occurrence as they are represented by growth form (and life history, if of interest) within the plant communities occurring at each park. Reference Figures E.2, E.3, and E.4; and Tables E.6, E.7, and E.8 in the appendix.
3. For each target species, provide a brief summary of absolute foliar cover, density (if a shrub or tree), and frequency, broken out by community types appropriate for each park. Reference Table E.9 in appendix.
4. Provide a brief summary of changes in foliar cover and density of growth forms and nativity within plant communities observed over the most recent 6 years of monitoring. The purpose of this section is *not* to provide a trend analysis with statistical tests for change. Rather, it is to provide the reader with a sense of how summary data (mean and standard deviation) have varied over the 5 years preceding the reading. Reference Figures E.5 and E.6 in the appendix.
5. Highlight any interesting or unusual findings, such as an unexpected or dramatic change in an individual species or a growth/life form, notable phenologic events, or detection of a new species.

Discussion Section (including conclusions)

Provide any interpretation and discussion of results with respect to potential causal mechanisms and management implications. Compare and contrast findings at the three MEDN parks. Compare across vegetation types and across parks within vegetation type.

Describe possible studies that may be necessary to investigate questions raised by the data.

Report Appendices

Create a separate appendix for each of the three parks showing summary graphs and tables.

Table E.1. Potential [PARK] monitoring sites that were visited and rejected in 20XX.

Site ID	UTM & location (NAD 83, Zone 11)	Reason for rejection	Brief description of site	Personnel
38482	N477432; E3615496 500m southwest of ZZ	Unexploded ordnance with pelicans nesting on top.	Coastal sage scrub.	B. Otanist, I. Ntern
etc.				

Table E.2. [PARK] monitoring sites installed in 20XX.

Site ID	Panel	UTM & Location (NAD 83, Zone 11)	Brief description of site	Personnel
22394	A	N477065; E3615408 Eastern side of ridge, just north of WWII observation bunker	Coastal sage scrub. Mostly <i>Salvia</i> spp. Relatively undisturbed. Unburned since 1952.	B. Otanist, I. Ntern
etc...				

Table E.3. [PARK] sites monitored in 20XX.

Site ID	Panel	UTM & Location (NAD 83, Zone 11)	Brief description of site	Personnel
11386	A	N477242; E3615021 20m northwest of WWII gun carriage	Weedy. Mostly mustards. History of past disturbance.	E. Cologist, I. Ntern
etc.				

Table E.4. [PARK] sites scheduled for monitoring, but not monitored in 20XX.

Site ID	Panel	UTM & Location (NAD 83, Zone 11)	Reason not monitored	Personnel
11386	A	N477607; E3614456 80m northwest of south radar installation	Nesting black-crowned night herons	E. Cologist, I. Ntern
etc.				

Table E.5. Burned sites monitored at [PARK] for 3 years post-fire.

Site ID	Panel	UTM & Location (NAD 83, Zone 11)	Brief description of site	Personnel
11386	A	N477607; E3614456 50m southwest of park entrance road	CSS pre-burn. Very weedy, few native forbs.	E. Cologist, I. Ntern
etc.				

Table E.6. Species richness (per transect) observed in 20XX monitoring of [PARK] vegetation.

Species	Nativity	All Sites (N= 100)					Chaparral (N = 42)					Coastal Sage Scrub (N = 37)				
		mean	±	sd	min	max	mean	±	sd	min	max	mean	±	sd	min	max
All	All	13.0	±	0.7	6.0	16.0	14.4	±	0.6	4.0	21.0	16.3	±	1.2	3.0	19.0
	Native	8.5	±	0.7	1.0	12.0	10.2	±	3.1	7.0	18.0	10.3	±	1.4	7.0	13.0
	Non-native	4.7	±	0.5	3.0	8.0	4.2	±	0.5	3.0	8.0	6.0	±	0.7	2.0	8.0
Grasses	All	5.0	±	0.4	2.0	16.0	4.4	±	2.9	2.0	8.0	6.0	±	0.7	1.0	8.0
	Native	2.0	±	2.2	1.0	14.0	2.0	±	2.1	1.0	6.0	2.0	±	0.3	1.0	5.0
	Non-native	3.0	±	1.5	1.0	8.0	2.4	±	0.6	1.0	5.0	4.0	±	2.1	0.0	8.0
Forbs	All	3.0	±	0.4	1.0	6.0	5.0	±	0.7	3.0	6.0	4.2	±	0.5	1.0	6.0
	Native	1.5	±	0.4	0.0	5.0	3.2	±	0.6	3.0	4.0	3.2	±	0.6	1.0	5.0
	Non-native	1.5	±	0.2	1.0	4.0	1.8	±	0.5	1.0	4.0	1.0	±	0.5	0.0	4.0
Shrubs	All	4.0	±	0.4	1.0	5.0	4.0	±	0.5	1.0	7.0	6.0	±	0.2	2.0	9.0
	Native	4.0	±	0.4	1.0	5.0	4.0	±	0.4	1.0	7.0	5.0	±	0.3	2.0	8.0
	Non-native	0.0	±	NA	0.0	0.0	0.0	±	NA	0.0	0.0	1.0	±	0.2	0.0	4.0
Trees	All	1.0	±	0.5	1.0	6.0	1.0	±	0.4	0.0	3.0	0.1	±	0.3	0.0	2.0
	Native	1.0	±	0.5	0.0	4.0	1.0	±	0.4	0.0	3.0	0.1	±	0.3	0.0	2.0
	Non-native	0.2	±	0.2	0.0	2.0	0.0	±	NA	0.0	0.0	0.0	±	NA	0.0	0.0

Table E.7. Absolute foliar cover of plant groups and soil surface cover (%) observed during 20XX monitoring at [PARK]. For each sample unit, absolute cover was calculated for each species group as the total (summed) cover of all species in the group. Descriptive statistics were calculated using all sample units in the sample-unit group.

Species	Nativity	All Sites (N= 100)					Chaparral (N = 42)					Coastal Sage Scrub (N = 37)				
		mean	±	sd	min	max	mean	±	sd	min	max	mean	±	sd	min	max
All	All	80.2	±	34.5	38.0	125.0	75.0	±	41.8	38.0	125.0	90.5	±	19.1	77.0	104.0
	Native	106.9	±	29.6	51.0	149.0	107.5	±	32.6	51.0	149.0	105.7	±	22.9	74.0	140.0
	Non-native	95.1	±	35.2	42.5	157.5	86.9	±	32.9	42.5	157.5	111.7	±	36.5	75.0	157.5
Grasses	All	70.0	±	28.6	38.0	104.0	59.8	±	28.7	38.0	101.0	90.5	±	19.1	77.0	104.0
	Native	86.3	±	28.1	35.0	140.0	79.5	±	25.6	35.0	121.0	100.1	±	28.4	63.0	140.0
	Non-native	80.7	±	35.0	27.5	157.5	67.3	±	23.4	27.5	120.0	107.5	±	40.8	70.0	157.5
Forbs	All	10.2	±	16.3	0.0	37.0	15.3	±	18.4	0.0	37.0	0.0	±	0.0	0.0	0.0
	Native	20.6	±	14.3	0.0	49.0	28.1	±	11.0	12.0	49.0	5.6	±	5.9	0.0	15.0
	Non-native	14.4	±	12.8	0.0	42.5	19.6	±	12.4	2.5	42.5	4.2	±	5.2	0.0	12.5
Shrubs	All	0.0	±	0.0	0.0	0.0	0.0	±	0.0	0.0	0.0	0.0	±	0.0	0.0	0.0
	Native	0.8	±	2.0	0.0	7.0	0.0	±	0.0	0.0	0.0	2.5	±	2.8	0.0	7.0
	Non-native	0.3	±	0.8	0.0	2.5	0.0	±	0.0	0.0	0.0	0.8	±	1.3	0.0	2.5
Trees	All	5.8	±	14.3	0.0	35.0	0.0	±	0.0	0.0	0.0	17.5	±	24.7	0.0	35.0
	Native	8.6	±	15.8	0.0	51.0	2.1	±	3.0	0.0	10.0	21.5	±	22.3	0.0	51.0
	Non-native	9.2	±	15.7	0.0	50.0	3.1	±	3.0	0.0	10.0	21.3	±	23.7	0.0	50.0
Soil Surface	Crust ¹	5.8	±	14.3	0.0	35.0	0.0	±	0.0	0.0	0.0	17.5	±	24.7	0.0	35.0
	Litter / Thatch	10.2	±	16.3	0.0	37.0	15.3	±	18.4	0.0	37.0	0.0	±	0.0	0.0	0.0
	Wood	0.8	±	2.0	0.0	7.0	0.0	±	0.0	0.0	0.0	2.5	±	2.8	0.0	7.0
	Pebble	20.6	±	14.3	0.0	49.0	28.1	±	11.0	12.0	49.0	5.6	±	5.9	0.0	15.0
	Rock	5.8	±	14.3	0.0	35.0	0.0	±	0.0	0.0	0.0	17.5	±	24.7	0.0	35.0
	Bare Soil	8.6	±	15.8	0.0	51.0	2.1	±	3.0	0.0	10.0	21.5	±	22.3	0.0	51.0

¹Crust can be algae / bacteria, lichen or moss.

Table E.8. Density (number / hectare) of shrubs and trees observed during 20XX monitoring of [PARK] vegetation.

Species	Nativity	All Sites (N= 100)					Chaparral (N = 42)					Coastal Sage Scrub (N = 37)				
		mean	±	sd	min	max	mean	±	sd	min	max	mean	±	sd	min	max
Shrubs - Native	Seedling	80.2	±	34.5	38.0	125.0	75.0	±	41.8	38.0	125.0	90.5	±	19.1	77.0	104.0
	Sapling	86.3	±	28.1	35.0	140.0	79.5	±	25.6	35.0	121.0	100.1	±	28.4	63.0	140.0
	Mature -Plants	0.8	±	2.0	0.0	7.0	0.0	±	0.0	0.0	0.0	2.5	±	2.8	0.0	7.0
	Mature -Stems	106.9	±	29.6	51.0	149.0	107.5	±	32.6	51.0	149.0	105.7	±	22.9	74.0	140.0
	Mature - Dead	95.1	±	35.2	42.5	157.5	86.9	±	32.9	42.5	157.5	111.7	±	36.5	75.0	157.5
Shrubs - NonNative	Seedling	70.0	±	28.6	38.0	104.0	59.8	±	28.7	38.0	101.0	90.5	±	19.1	77.0	104.0
	Sapling	86.3	±	28.1	35.0	140.0	79.5	±	25.6	35.0	121.0	100.1	±	28.4	63.0	140.0
	Mature -Plants	20.6	±	14.3	0.0	49.0	28.1	±	11.0	12.0	49.0	5.6	±	5.9	0.0	15.0
	Mature -Stems	0.8	±	2.0	0.0	7.0	0.0	±	0.0	0.0	0.0	2.5	±	2.8	0.0	7.0
	Mature - Dead	80.7	±	35.0	27.5	157.5	67.3	±	23.4	27.5	120.0	107.5	±	40.8	70.0	157.5
Trees - Native	Seedling	10.2	±	16.3	0.0	37.0	15.3	±	18.4	0.0	37.0	0.0	±	0.0	0.0	0.0
	Sapling	20.6	±	14.3	0.0	49.0	28.1	±	11.0	12.0	49.0	5.6	±	5.9	0.0	15.0
	Mature	14.4	±	12.8	0.0	42.5	19.6	±	12.4	2.5	42.5	4.2	±	5.2	0.0	12.5
	Mature - Dead	106.9	±	29.6	51.0	149.0	107.5	±	32.6	51.0	149.0	105.7	±	22.9	74.0	140.0
	Basal Area	14.4	±	12.8	0.0	42.5	19.6	±	12.4	2.5	42.5	4.2	±	5.2	0.0	12.5
Trees - NonNative	Seedling	0.0	±	0.0	0.0	0.0	0.0	±	0.0	0.0	0.0	0.0	±	0.0	0.0	0.0
	Sapling	0.8	±	2.0	0.0	7.0	0.0	±	0.0	0.0	0.0	2.5	±	2.8	0.0	7.0
	Mature	0.3	±	0.8	0.0	2.5	0.0	±	0.0	0.0	0.0	0.8	±	1.3	0.0	2.5
	Mature - Dead	106.9	±	29.6	51.0	149.0	107.5	±	32.6	51.0	149.0	105.7	±	22.9	74.0	140.0
	Basal Area	0.3	±	0.8	0.0	2.5	0.0	±	0.0	0.0	0.0	0.8	±	1.3	0.0	2.5

Table E.9. Absolute foliar cover (%), density (number / hectare), and frequency (%) of target monitoring species observed during 20XX at [PARK].

Species	Vegetation Type	Number of Sites	Foliar Cover (%)					Density (individuals / hectare)					Frequency (%)
			mean	±	sd	min	max	mean	±	sd	min	max	
<i>Adenostoma fasciculatum</i>	All Communities	45	80.2	±	34.5	38.0	125.0	75.0	±	41.8	38.0	125.0	90
	Chaparral	30	70.0	±	28.6	38.0	104.0	59.8	±	28.7	38.0	101.0	52
	Coastal Sage	10	10.2	±	16.3	0.0	37.0	15.3	±	18.4	0.0	37.0	25
	Grassland	0	0.0	±	0.0	0.0	0.0	0.0	±	0.0	0.0	0.0	0
	Woodland	3	86.3	±	28.1	35.0	140.0	79.5	±	25.6	35.0	121.0	91
	Riparian	2	5.8	±	14.3	0.0	35.0	0.0	±	0.0	0.0	0.0	18
<i>Artemisia californica</i>	All Communities	30	80.2	±	34.5	38.0	125.0	75.0	±	41.8	38.0	125.0	91
	Chaparral	5	70.0	±	28.6	38.0	104.0	59.8	±	28.7	38.0	101.0	91
	Coastal Sage	25	10.2	±	16.3	0.0	37.0	15.3	±	18.4	0.0	37.0	35
	Grassland	2	5.8	±	14.3	0.0	35.0	0.0	±	0.0	0.0	0.0	18
	Woodland	2	86.3	±	28.1	35.0	140.0	79.5	±	25.6	35.0	121.0	91
	Riparian	1	5.8	±	14.3	0.0	35.0	0.0	±	0.0	0.0	0.0	18
<i>Nassella pulchra</i>	All Communities	30	80.2	±	34.5	38.0	125.0	Not Recorded					91
	Chaparral	5	70.0	±	28.6	38.0	104.0	Not Recorded					63
	Coastal Sage	25	10.2	±	16.3	0.0	37.0	Not Recorded					32
	Grassland	2	5.8	±	14.3	0.0	35.0	Not Recorded					20
	Woodland	2	86.3	±	28.1	35.0	140.0	Not Recorded					91
	Riparian	1	5.8	±	14.3	0.0	35.0	Not Recorded					18
<i>Etcetera</i>	All Communities	45	80.2	±	34.5	38.0	125.0	75.0	±	41.8	38.0	125.0	91
	Chaparral	30	70.0	±	28.6	38.0	104.0	59.8	±	28.7	38.0	101.0	69
	Coastal Sage	10	10.2	±	16.3	0.0	37.0	15.3	±	18.4	0.0	37.0	55
	Grassland	0	0.0	±	0.0	0.0	0.0	0.0	±	0.0	0.0	0.0	0
	Woodland	3	86.3	±	28.1	35.0	140.0	79.5	±	25.6	35.0	121.0	91
	Riparian	2	5.8	±	14.3	0.0	35.0	0.0	±	0.0	0.0	0.0	18

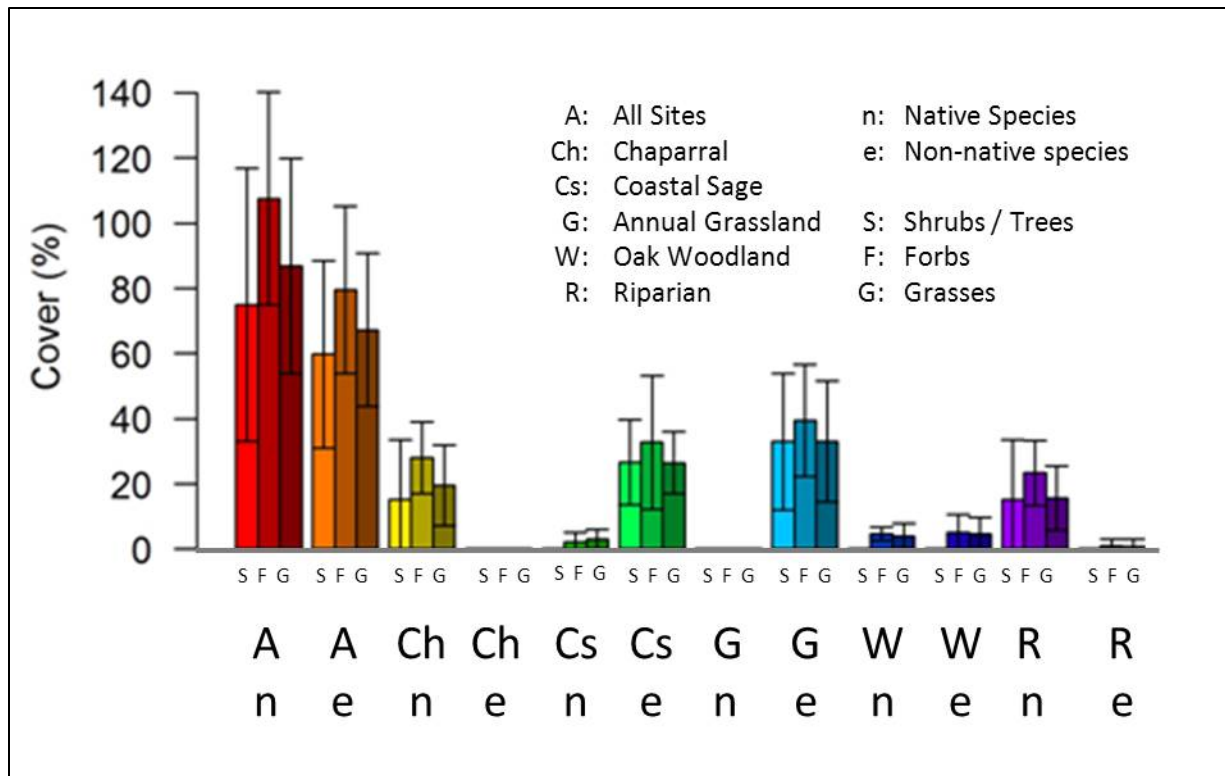


Figure E.2. Absolute foliar cover (%) of plant growth forms, as observed during 20XX monitoring at CABR. Colored bars show mean values, while error bars extend ± 1 s.d. from the means.

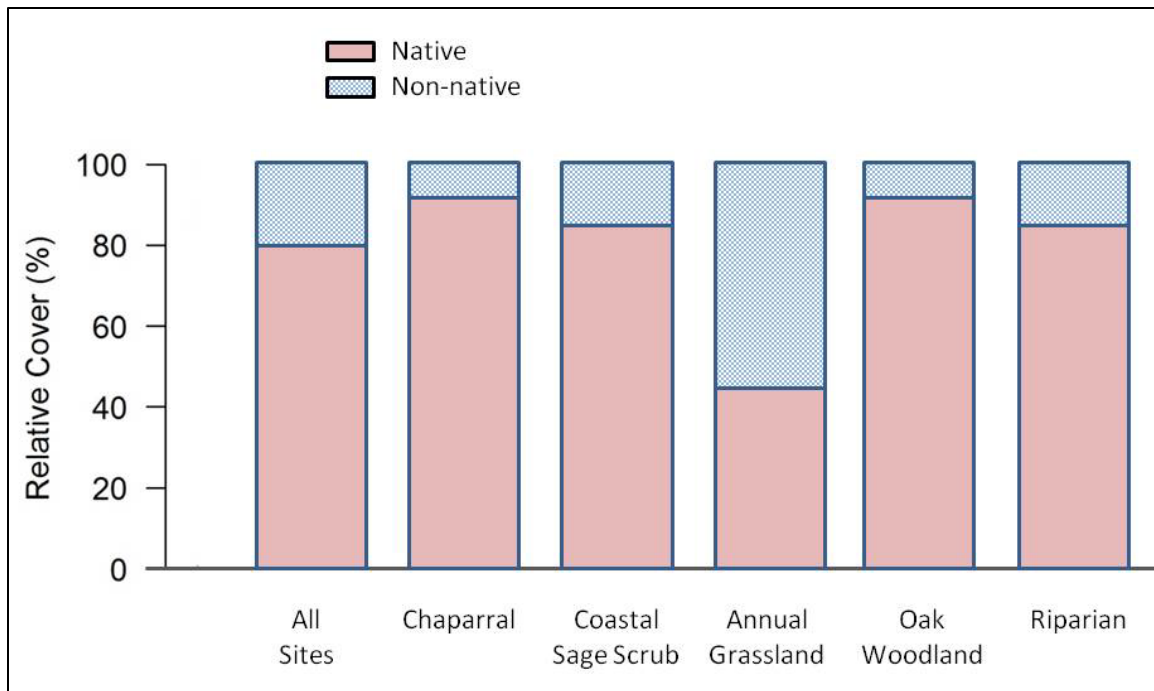


Figure E.3. Relative plant cover by nativity across major vegetation types in 20XX monitoring at CABR. Bar component heights show mean values. For each sample unit, absolute cover was calculated for each species group as the total (summed) cover of all species in the group. Absolute cover values were relativized by sample unit. Sample units were then grouped together in various ways, and descriptive statistics were calculated using all sample units in the sample-unit group.

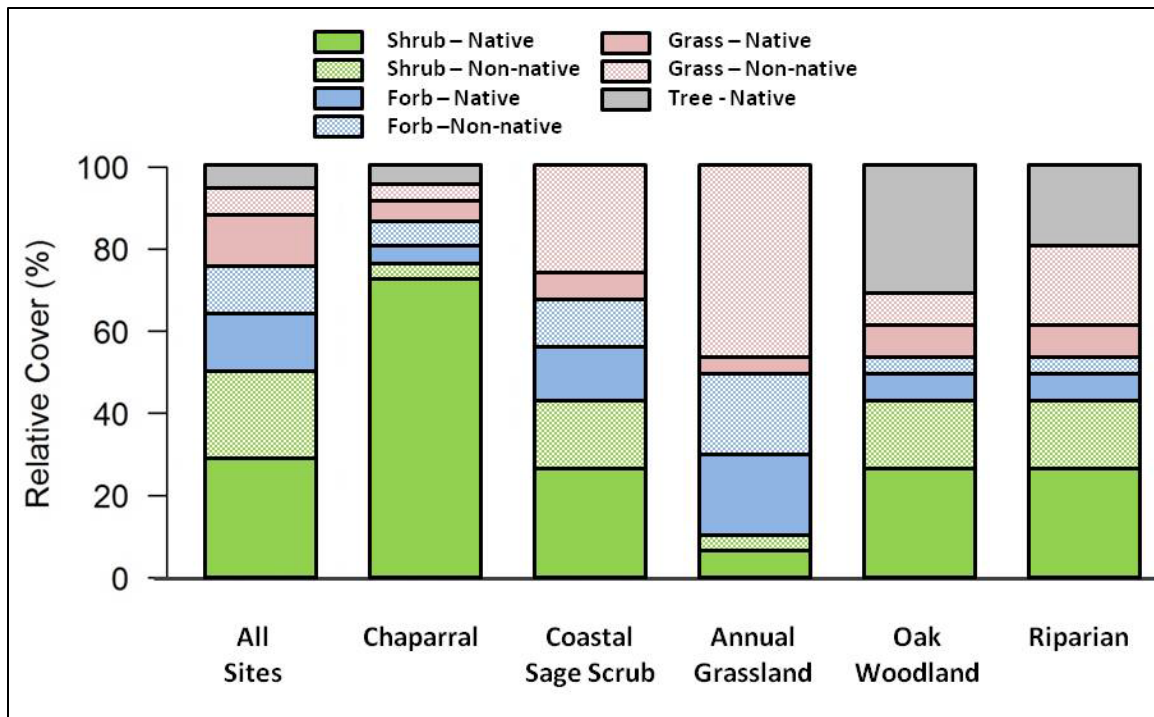


Figure E.4. Relative plant cover by nativity and lifeform in plant communities at [PARK] observed during 20XX monitoring. Bar component heights show mean values. For each sample unit, absolute cover was calculated for each species group as the total (summed) cover of all species in the group. Absolute cover values were relativized by sample unit. Sample units were then grouped together in various ways, and descriptive statistics were calculated using all sample units in the sample-unit group.

Trend summary

Cover

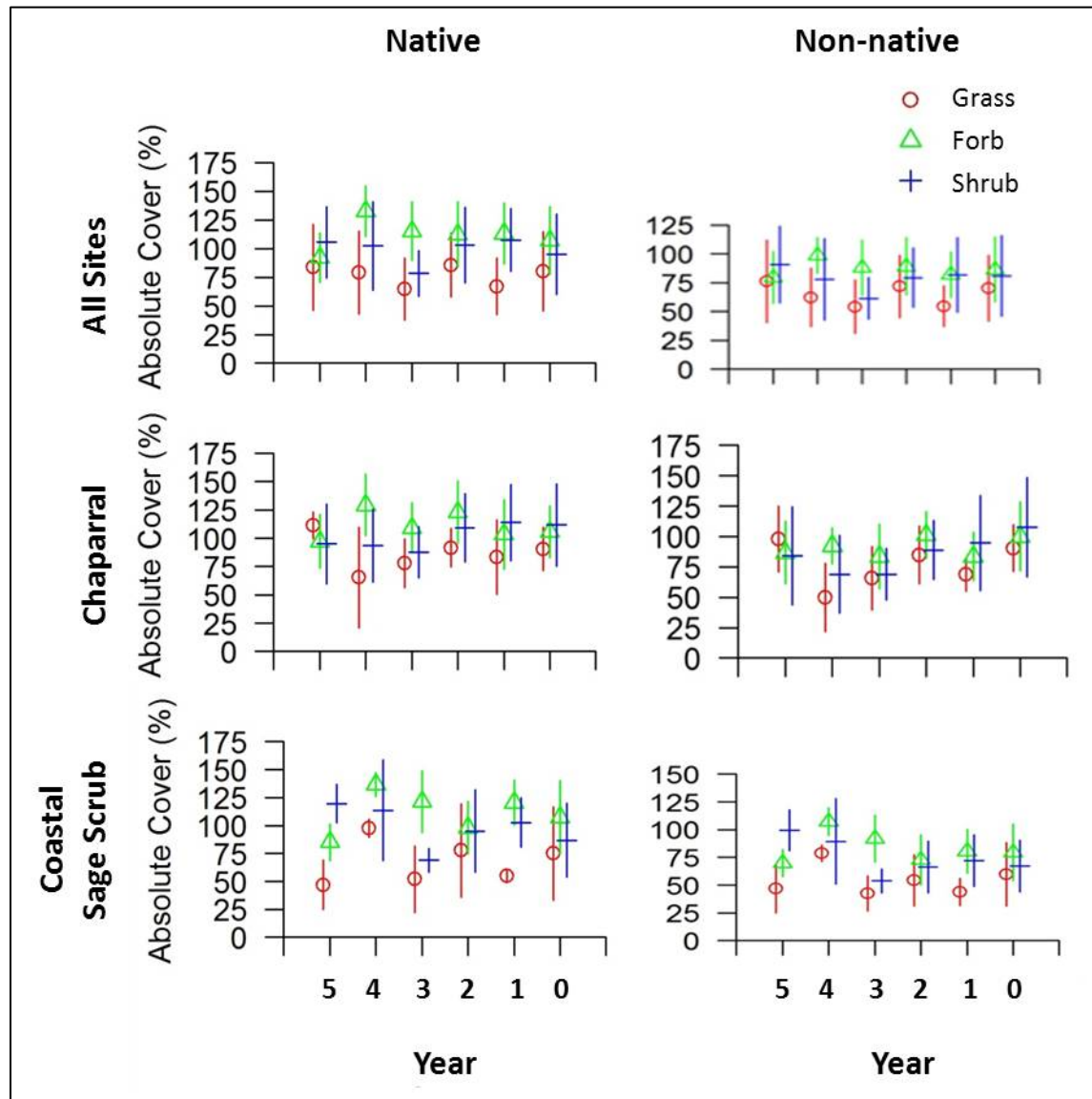


Figure E.5. Absolute foliar cover of all native and all non-native species for each of the last 6 years of monitoring at [PARK]. Years progress left to right from past to current. Symbols show mean values. Error bars extend ± 1 standard deviation from the mean.

Density

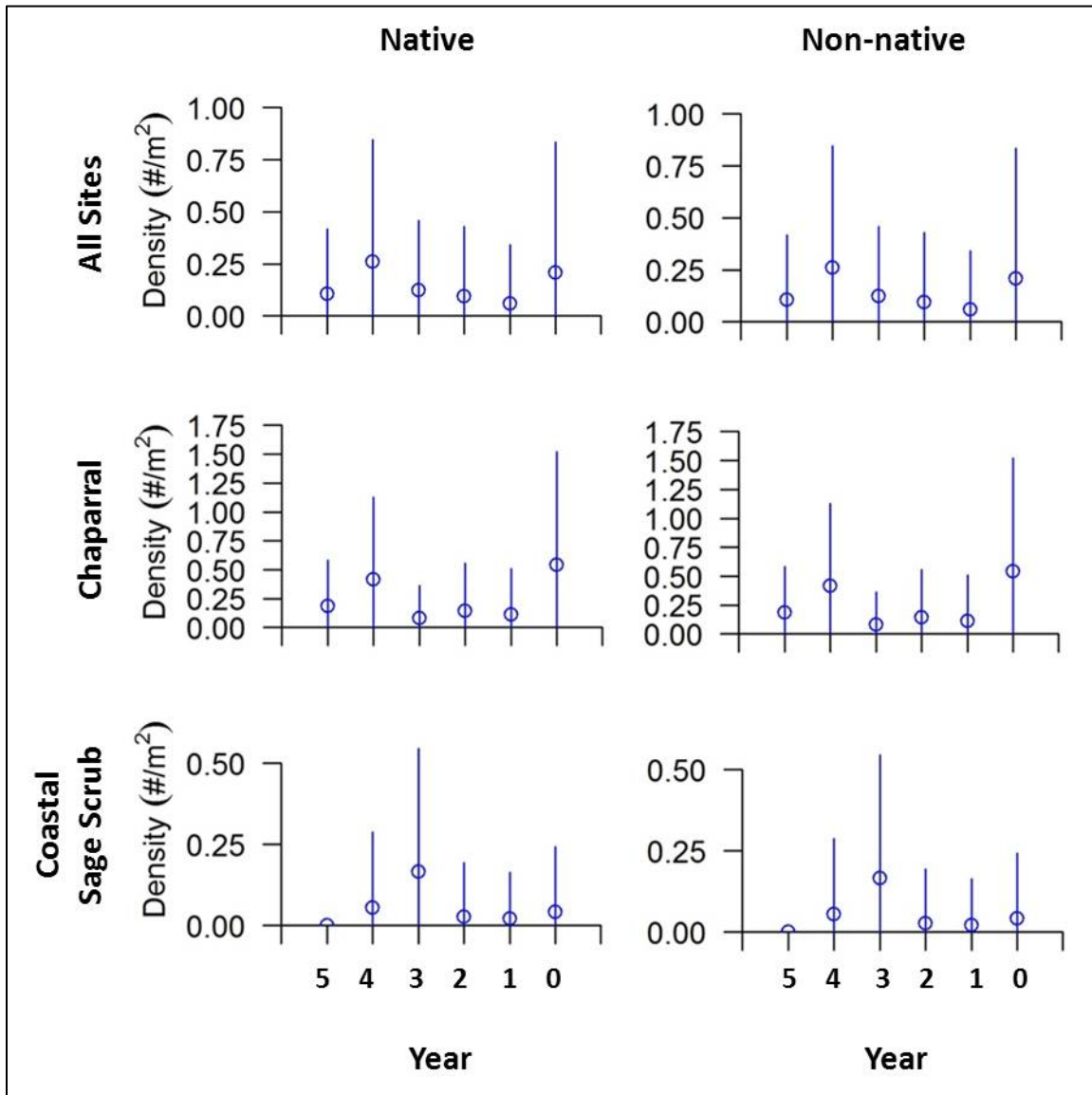


Figure E.6. Density of native and non-native shrubs for each of the last 6 years of monitoring at [PARK]. Years progress left to right from past to current. Symbols show mean values. Error bars extend ± 1 standard deviation from the mean.

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

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Natural Resource Stewardship and Science

1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov

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