Coastal Sage Scrub and Chaparral Community Monitoring Plan for Western San Diego County

Report Prepared for:

San Diego Association of Government Regional Habitat Conservation Taskforce

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Cover: Cover photograph (taken by Emily Perkins). Chaparral shrublands at Cleveland National Forest, taken 12 June 2023.

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Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
hectare (ha)	2.471	Acre

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as °F = (1.8 × °C) + 32.
Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as °C = (°F – 32) / 1.8.

Datum

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).
Horizontal coordinate information is referenced to the (North American Datum of 1983 [NAD 83]).

Supplemental Information

Abbreviations

AECOM	Architecture, Engineering, Construction, Operations, and Management
AMF	Arbuscular Mycorrhizal Fungi
ANOVA	Analysis of Variance
CA	California
CDFW	California Department of Fish and Wildlife
CFP	California Floristic Provence
cm	Centimeter
CSS	Coastal Sage Scrub
EPA	Environmental Protection Agency
FS	Facultative Resprouter
GIS	Geographic Information Systems
GPS	Global Positioning System
ha	Hectares
HALT	Hobbs Active Light Trigger
IBI	Index for Biological Integrity
IMG	Inspect and Manage
kg	Kilogram
MHCP	Multiple Habitats Conservation Program
MSCP	Multiple Species Conservation Program
MSPA	Management and Monitoring Strategic Plan Roadmap Area
MSP Roadmap	Management and Monitoring Strategic Plan Roadmap
N	Nitrogen
NCCP	Natural Community Conservation Planning
nMDS	Non-metric Multidimensional Scaling
NNG	Non-native grass
OR	Obligate Resprouter
OS	Obligate Seeder
PERMANOVA	Permutational Multivariate Analysis of Variance
PIR	Passive Infrared
r	Correlation coefficient
RAP	Rangeland Analysis Platform
SANDAG	San Diego Association of Governments
SC-MTX	South Coast Multi-taxa Database
SD	Standard Deviation
SDE	Spatial Database Engine
SDMMP	San Diego Management and Monitoring Program
SDSU	San Diego State University
SLATS	Statewide Landcover and Trees Study
SPOT	Satellite pour l'Observation de la Terre
SQL	Structured Query Language
UAS	Unmanned Aerial Systems
USGS	U.S. Geological Survey
USFWS	U.S. Fish and Wildlife Service
VF	Vegetation Focused
VTM	Vegetation Type Map
yr	Year

Definitions

Camera Traps – Motion sensor or time series cameras installed at fixed plots across the landscape to capture photo or video of fauna passing by or environmental changes over time.

Category VF Species – As defined in the 2017 Management and Monitoring Strategic Plan Roadmap (MSP Roadmap; SDMMP and TNC 2017, page V1.2-34), "species with limited distribution in the [Management Strategic Plan Area] MSPA and/or having specific vegetation characteristics that need to be managed for persistence on Conserved Lands in the MSPA."

Conserved Lands – As defined in the 2017 Management and Monitoring Strategic Plan (MSP Roadmap; SDMMP and TNC 2017, page xxvii), "Conserved lands are those lands that are legally conserved to (1) Protect natural habitats, species, and open space (including agricultural lands that are important components of the regional habitat preserve design); (2) Contribute to the existing and planned regional habitat preserve system; and (3) Managed to protect the open space or natural resources into the future. The conservation occurs through public or private acquisitions, conservation easements, land dedications, mitigation, mitigation banks, covenants, or other mechanisms that ensure the land will not be developed." The Conserved Lands geodatabase tracks lands conserved in western San Diego County.

Core Monitoring – Core monitoring consists of an office analysis of existing datasets to identify past change in coastal sage scrub and chaparral. This includes gathering datasets and running analysis to identify locations of change and key drivers of change.

Core+ Monitoring – Core+ monitoring includes field surveys of permanent plots where plant species information (composition, structure, and percent cover) is collected in the field and using Unmanned Aerial Systems (UAS) imagery. It also includes soil sample collections, identification of cryptogamic crust, and herbaceous species quadrats to measure cover.

Core++ Monitoring – Core++ consists of animal community monitoring and targeted plant and animal surveys. First, a rapid assessment protocols and targeted surveys will be employed to assess animal diversity by taxa. Next, specialized surveys for target plant and animal species will be completed in plots where the species were identified using the vegetation protocol or rapid assessment.

Ecological Integrity – As defined in the 2022 State of the Preserve Report (Preston et al. 2022, page vii), "The ability of an ecological system to support and maintain a community of organisms that has species composition, diversity, and functional organization comparable to natural habitats within a region. Measuring the ecological integrity of a specific system at a specific location requires comparing aspects of the ecosystem with undisturbed reference sites or by comparing with measures of historic range of variation for that system. These comparisons give an indication of how degraded the system is at a particular site and define its ecological integrity."

Eco-subregions – Polygon areas that divide up a larger ecoregion into parts with similar climate and vegetation types.

Ecosystem – As defined in the 2022 State of the Preserve Report (Preston et al. 2022, page vii), "Plant and animal species plus their physical surroundings."

Facultative Seeder – A facultative seeder is a shrub that can either resprout or grow from fire-germinated seeds.

Forb – A flowering, herbaceous plant.

Inspect and Manage (IMG) protocol – A standard protocol for collecting information about target rare plant species occurrences and habitat and threat covariates that may affect the species' status and distribution. This protocol has been in use for over 10 years to consistently collect rare plant data across San Diego County.

Management and Monitoring Strategic Plan for Conserved Lands in Western San Diego County: A Strategic Habitat Conservation Roadmap (MSP Roadmap) – As defined in the 2022 State of the Preserve Report (Preston et al. 2022, page vii), "The MSP Roadmap (along with an online MSP Portal available at sdmmp.com) provides management and monitoring goals and objectives for species, vegetation communities, and threats across the regional preserve system on Conserved Lands in western

San Diego County. The MSP Roadmap covers 5-year planning horizons and is evaluated every 5 years to update and prioritize the species list, management categories, and management and monitoring objectives. There have been three planning horizons of the MSP thus far (2012-2016, 2017-2021, and 2022-2026)."

MSP Roadmap Area (MSPA) – As defined in the 2022 State of the Preserve Report (Preston et al. 2022, page vii), "Area of western San Diego County covered by the MSP Roadmap and comprising the regional preserve system. This includes Conserved Lands extending from the Eastern Peninsular Mountain Range peaks west to the coast and from the northern border with Orange and Riverside counties south to the International Border with Mexico."

MSP Species – As defined in the 2017 Management and Monitoring Strategic Plan (MSP Roadmap; SDMMP and TNC 2017) "The 111 species included in the 2017-2021 MSP Roadmap. These species include 57 plants, 7 invertebrates, 1 fish, 3 amphibians, 5 reptiles, 30 birds, and 8 mammals."

Multiple Habitat Conservation Program (MHCP) – As defined in the 2022 State of the Preserve Report (Preston et al. 2022, page vii), "A comprehensive conservation planning process that addresses the needs of multiple plant and animal species in northwestern San Diego County. The MHCP is a subregional habitat conservation planning program that was approved in 2003 for 61 Covered Species and their habitats for seven cities. Only the City of Carlsbad has completed an MHCP subarea plan, received a permit from the Wildlife Agencies, and is implementing the plan."

Multiple Species Conservation Program (MSCP) – As defined in the 2022 State of the Preserve Report (Preston et al. 2022, page vii), "A comprehensive conservation planning process that addresses the needs of multiple plant and animal species in southwestern San Diego County. The MSCP is a subregional habitat conservation planning program that was approved in 1998 for multiple jurisdictions to conserve 85 Covered Species and their habitats. Currently, San Diego County and the Cities of San Diego, Poway, Chula Vista, and La Mesa have completed MSCP subarea plans. Separate MSCPs for North County and East County are under development."

Natural Community Conservation Planning (NCCP) Program – As defined in the 2022 State of the Preserve Report (Preston et al. 2022, page vii), "CDFW's NCCP (Natural Community Conservation Plan) program is an effort by the State of California and numerous private and public partners that takes a broad-based ecosystem approach to planning for the protection and perpetuation of biological diversity. A NCCP identifies and provides for the regional or area wide protection of plants, animals, and their habitats, while allowing compatible and appropriate economic activity."

Obligate Seeder – Shrubs that are obligate seeders have seeds that are fire-germinated and begin to sprout following fire. Adult plants may die in the fire and are replaced by seedings that grow slowly over time.

Obligate Resprouter – Shrubs that are obligate respouters resprout from the existing plant after fire. This allows plants to use deep root systems to obtain nutrients and regrow quickly after fires.

Rapid Assessment Protocols – A set of protocols to be completed in the field at set plot locations that are designed to quickly identify the full range of animal species present. Protocols differ based on the targeted taxa.

Shrubland communities – In San Diego County, shrubland communities include coastal sage scrub and chaparral vegetation types.

Southern California Multi-Taxa Database (SC-MTX) – As defined in the 2022 State of the Preserve Report (Preston et al. 2022, page vii), "The SC-MTX is a publicly accessible, multiple-species database created by the U.S. Geological Survey in collaboration with the SDMMP that houses both land management and biological monitoring data collected in the South Coast Ecoregion of southern California (includes all or portions of Santa Barbara, Ventura, Los Angeles, San Bernardino, Riverside, Orange, and San Diego counties). The purpose of the SC-MTX is to centralize and standardize monitoring and management data collected by multiple entities, including federal, state, and local agencies, and make the data accessible to stakeholders."

Vegetation Type Mapping (VTM) Weislander Dataset – A collection of data (points and polygons) that describe the vegetation communities and species from the early 1930s. These data are available in digital format.

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Coastal Sage Scrub and Chaparral Community Monitoring Plan for Western San Diego County

By Emily Perkins, Philip Gould, Jennifer Kingston, Chris Brown, Kristine Preston, and Robert Fisher

Executive Summary

Western San Diego County is dominated by shrublands supporting biologically diverse native plant and animal communities. Widespread urbanization has led to regional habitat loss and fragmentation, and many species in these shrubland communities are rare, threatened, or endangered. Large-scale, multiple-species conservation planning has resulted in a regional preserve system that focuses on these shrubland communities. Several large-scale threats are leading to type conversion from shrub-dominated to non-native invasive annual grass-dominated vegetation. To understand the changes that are occurring to native shrublands, we have developed a vegetation monitoring program with several components at multiple spatial scales, focused on quantifying coastal sage scrub (CSS) and chaparral vegetation community characteristics. Several drivers of change associated with type conversion of native shrubland to non-native annual grassland have been identified by previous research including increasing fire frequency, nitrogen deposition from air pollution, and prolonged and intense drought associated with changing climate.

Loss of ecological integrity indices have been proposed as useful measures of the threat of degradation and type conversion of shrublands in San Diego County. For this study, ecological integrity is defined as a system's ability to maintain species' relationships and functions comparable to natural habitat in the region. Previous studies have identified the percent cover of invasive non-native annual grasses as a proxy for overall ecological degradation (loss of integrity) that is consistent across native taxonomic groups. Increased cover of non-native grass is associated with lower integrity of the shrubland vegetation community as shrub-associated plant and animal species are replaced by species preferring grassy and disturbed habitats.

The objectives of this CSS and chaparral vegetation community monitoring plan are to:

1) Determine the distribution, composition, structure, and integrity of CSS and chaparral vegetation communities on conserved lands in western San Diego County,
2) Identify whether these attributes of the vegetation communities are changing over time, and
3) Evaluate relationships of known drivers of change (threats) and environmental factors in association with changes in vegetation community attributes.

The CSS and chaparral vegetation community monitoring program is divided into four components: 1) vegetation mapping, 2) GIS/remote sensing office analysis of landscape-scale data, 3) permanent field plots using Unmanned Aerial Systems (UAS) and field data collections, and 4) animal and target species surveys and rapid assessment protocols.

The first component, which is not detailed in this vegetation monitoring plan, aims to map vegetation communities every 10-15 years based on a classification developed for western San Diego County. High resolution aerial imagery will be used to update the 2012 vegetation map and expand it across the entire study area.

The second component uses remote sensing models to annually track ecological integrity of shrublands across the study area and will include a map of areas of change and areas of stability over several decades. These landscape-scale integrity classifications will be used to analyze ecological processes, threats, and abiotic factors relative to changes to shrubland ecological integrity over time and space.

The third component includes field surveys of 100 permanent plots across areas historically mapped as shrublands. Surveys in the 1930s mapped vegetation types using plot data. By using this historical classification map, we included areas that have already type-converted from shrubland to non-native annual grassland. The plots were split between CSS (55 plots) and chaparral (45 plots) and stratified into four geographical eco-subregions to guarantee coverage over small patches of habitat along the heavily developed coast. Surveys will include the collection of UAS imagery at a very high resolution. Species-level identifications will be made from the imagery based on a plant list compiled of all species detected in the plot during a thorough field survey by botanists, combined with geo-referenced samples of plant species locations. In addition, herbaceous cover will be estimated in the field using nine 1-m diameter circles (one per subplot) to obtain ocular estimates of cover for each plant species within the circle frame. Soil samples will be collected and analyzed for important element compositions. These data will be analyzed to evaluate plot-level ecological integrity based on species composition and cover. Repeated monitoring will allow evaluation of changes in vegetation attributes over time with known drivers or threats and other environmental factors. In addition, analyses will focus on indicator species and various measures of biological diversity for the vegetation communities.

Finally, animal species and rare plants will be assessed using either taxa-based rapid assessment protocols or specialized species-specific protocols for rarer species. The purpose of these assessments is to document the status, habitat, and threat covariates of specific species and confirm the species composition and diversity of animal taxonomic groups (e.g., pollinators). Diversity and abundance of animal species at vegetation plots will be used to refine measures and thresholds of ecological integrity. Rapid assessment protocols for animal taxonomic groups can include multiple detection methods such as, camera traps, cover boards, and bird point counts. Pollinators will be monitored at plots using a protocol currently being developed in conjunction with but separately from this plan. Target rare plant species will be monitored using the regional Inspect and Manage (IMG) protocol that measures the status of rare plant occurrences and habitat and threat covariates over time. Species-specific animal survey methods will be refined as these species are prioritized for future monitoring.

The goal of this monitoring program is to classify CSS and chaparral vegetation community integrity, identify areas of degradation across western San Diego County, and characterize drivers, and environmental factors associated with loss of ecological integrity. A combination of vegetation mapping, landscape-scale remote sensing, and field plots will be used to address all the aspects of our research questions. Data compiled and collected will be available to conservation partners to help inform future management decisions.

Introduction

Western San Diego County is dominated by shrubland vegetation communities, including coastal sage scrub (CSS) and chaparral. Human activities have led to large-scale modifications to the natural environment over the past 100 years, which has affected native plant and animal communities and altered ecological processes (Tracey et al. 2018, Underwood et al. 2009, Westman 1981a). This monitoring plan is part of a larger vegetation community monitoring program. This plan focuses on historic shrubland areas and aims to identify, map, and analyze areas of change and areas of stability in plant species composition and cover. The plan can be used to better understand the responses of these vegetation communities to the human-modified environment and altered ecological processes.

Climate and biogeography

A Mediterranean climate, dynamic physical landscape, and overlapping ecotones have made San Diego County a biodiversity and evolutionary hotspot for many taxa (Myers et al. 1990, Cowling et al. 1996, Dobson et al. 1997, Vandergast et al. 2008, Baldwin et al. 2014). Located within the California Floristic Provence (CFP), an area globally recognized for high plant diversity and endemism, the southwest region of the CFP boasts relatively high species richness and among the highest concentrations of endemic plant species (Stebbins and Major 1965, Underwood et al. 2009, Burge et al. 2016). The warm, dry summers and mild, wet winters, typical of Mediterranean-type ecosystems, are the foundation for this global hotbed of non-tropic biodiversity (Myers 1990, Myers et al. 2000), particularly regarding plant species (Cowling et al. 1996, Kraft et al. 2010, Kruckeberg 1986, Westman 1981b).

San Diego County's unique heterogenous topography is also a significant driver of regional biodiversity (Qi and Yang 1999, Westman 1981b). The dynamic landscape of San Diego County demonstrates topographic variability from its western coastal habitats, through inland valleys and foothills, over mountain ranges, and into eastern desert reaches, resulting in a range of environmental conditions supporting a variety of vegetation communities (Franklin et al. 2009). Additionally, as part of the southwest CFP region, San Diego County shares high regional similarity to both the California central west CFP and the Baja CFP regions (Burge et al.

2016). This geography creates overlapping ecotones, representing the southern-most range for many species within the continental U.S. and the northern-most range of many species' endemic to the Baja Peninsula (Reimann and Exequiel 2007, Baldwin et al. 2012, Kraft et al. 2010 Savage 1960).

Shrub-dominated chaparral and CSS ecosystems are the most widespread vegetation communities within San Diego County (CalFire 2015, County of San Diego 2021, Preston et al. 2022). Characterized by woody, evergreen, drought, and fire-resistant shrubs intermixed with annual and perennial herbaceous cover, chaparral and CSS plants exhibit high evolutionary and ecological diversity (Underwood et al. 2018). Furthermore, these shrubland communities provide wide spatial variability in plant species composition, dictated by slope direction (Underwood et al. 2023), fire history (Wells et al. 2004, Keeley et al. 2005a), and elevation (Mooney et al. 1974) or coastal to inland gradients (Vasey et al. 2014; Westman 1981b). Shrub-dominated systems hold abundant plant diversity and function as an irreplaceable habitat-type supporting rich animal assemblages (Franklin et al. 2009; Underwood et al. 2018), including many endemic and endangered species in San Diego County (Preston et al. 2022). Additionally, these chaparral and CSS communities provide valuable ecosystem services such as carbon sequestration and flood control (Underwood et al. 2018).

Shrubland communities and biodiversity in San Diego County are increasingly affected by global and landscape scale threats (Preston et al. 2022). Urbanization throughout the state has resulted in significant declines to chaparral and CSS communities (Minnich and Dezzani 1998, Sauvajot et al. 1998, Witzum and Stow 2004). In coastal San Diego County, CSS used to be the most widespread habitat type but has experienced a 70% reduction in size compared to historic conditions, due to urbanization and other development (City of San Diego 1998). Further anthropogenic threats such as changes to historic fire regime (Keeley and Brennan 2012, Lippitt et al. 2013, Syphard et al. 2019a-b, Storey et al. 2021a), nitrogen deposition (Talluto and Suding 2008, Fenn et al. 2010, Cox et al. 2014, Allen et al. 2016), and global climate change (Beltrán et al. 2014, Jennings et al. 2018, Underwood et al. 2018, Storey et al. 2021b, Keeley et al. 2022) continue to threaten these shrubland communities. As such, it is important to regionally conserve, monitor threats, and manage the ecological integrity, biodiversity, and natural ecological processes of these rich communities within San Diego County (Zedler et al. 1996, Vandergast et al. 2008, Jennings et al. 2018, Underwood et al. 2018, Tracey et al. 2018).

Legal conservation framework

The Natural Community Conservation Planning (NCCP) Act of 1991 was enacted by the State of California with the goal of shifting from an individual to a regional conservation approach that focused on conserving intact ecosystems, to better ensure the long-term conservation of covered plant and animal species, while still allowing for economic activity (CDFG 1991, Pollak 2001). The NCCP Act involved voluntary adoption and encouraged collaboration between local, state, and federal government agencies with private economic interests to create regional conservation plans. In collaboration with other jurisdictions, San Diego County participated in the first coordinated effort under the NCCP Act: The Southern California CSS NCCP pilot program (CDFG and CRA 1993; Pollak 2001). Two subregional conservation plans: the southwest county Multiple Species Conservation Program (MSCP) and the northwest county Multiple Habitat Conservation Program (MHCP), were produced in collaboration with local partners and experts (City of San Diego 1998, AMEC et al. 2003). A third regional plan is currently under development by the County of San Diego for the northern un-incorporated area of the County outside of the areas covered by the MSCP and MHCP plans.

Recommendations from these subregional plans as well as an update to the NCCP Act (CDFG 2002), which mandated that conservation plans implement a management component, prompted the San Diego Association of Governments (SANDAG) to include some funding for regional management and monitoring as part of a half-cent sales tax for transportation projects. This initiative was passed by voters in 2004 and led to the establishment of SANDAG's Environmental Mitigation Program and a Memorandum of Understanding with the U.S. Fish and Wildlife Service (USFWS) and California Department of Fish and Wildlife (CDFW) to fund and coordinate these efforts within San Diego County (SANDAG 2004). Under this program, the San Diego Management and Monitoring Program (SDMMP; established 2008) facilitates partner participation and coordination. The SDMMP team, in collaboration with partners, prepared *The Management and Monitoring Strategic Plan for Conserved Lands in Western San Diego County: A Strategic Habitat Conservation Roadmap* (MSP Roadmap; SDMMP and TNC 2017). "The

MSP Roadmap is a comprehensive landscape-scale adaptive management and monitoring framework for prioritized species and vegetation communities in western San Diego County" (Preston et al. 2022) and is focused on the conserved lands within the Management Strategic Plan Area (MSPA; fig 1).

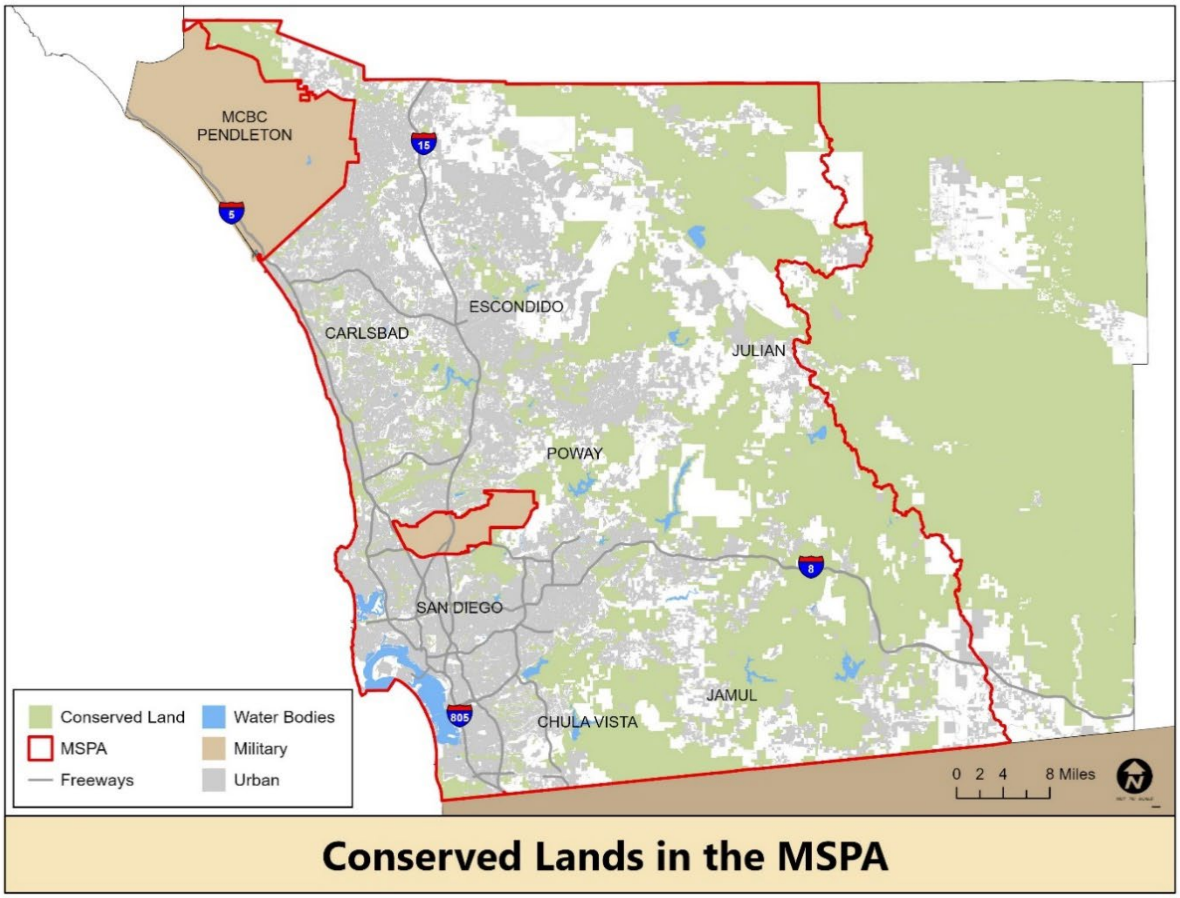

Figure 1: Map of conserved lands in the Management and Monitoring Strategic Plan Area (MSPA; SDMMP 2023, SANDAG 2023, County of San Diego 2000, and SDMMP and TNC 2017.

Shrublands and ecological integrity

As of 2022, there were 670,189 acres of conserved lands within the MSPA; of this area, shrub-dominated vegetation communities compose 74.7%, between chaparral (61.5%) and CSS (13.1%) (Preston et al. 2022). One of the objectives of the MSP Roadmap is to create a long-term vegetation monitoring plan for the mosaic of chaparral and CSS vegetation communities. This plan will focus on tracking community composition, structure, and ecological integrity over time in relation to climate (i.e., drought) and disturbance from fire (SDMMP and TNC 2017). Separate monitoring plans for additional vegetation communities will be developed in the future.

According to Karr and Dudley (1981), ecological integrity within an ecosystem is “the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitat of the region.” An important aspect of ecological integrity is whether these characteristics fall within an “acceptable level of variation” from historic levels and will persist over time (Parrish et al. 2003). As conservation plans incorporate monitoring and management components and seek to determine if conserved lands have resulted in preservation of ecological integrity, Parrish et al. (2003) proposed the framework “measures of conservation success” first introduced by The Nature Conservancy. This framework uses an ecological scorecard to track focal conservation targets, focusing on a small number of key ecological attributes, and measurable indicators of those attributes, to assess target status within conserved lands.

Although community-level metrics such as species richness and evenness are frequently used as attributes (Wurtzebach and Schultz 2016), a study of CSS communities in Orange and San Diego Counties found that these generic attributes and singular, focal target species approaches fail to accurately track loss of ecological integrity compared to a comprehensive multi-taxa index for biological integrity (IBI; Diffendorfer et al. 2007). However, complex IBIs are often costly and impractical (Wurtzebach and Schultz 2016), especially for regional preserve systems.

When developing the CSS community IBI, study authors found that native shrub cover and richness were the most significant vegetation metrics negatively correlated with non-native exotic annual grass cover (a proxy for level of site disturbance and declining ecological integrity; Diffendorfer et al. 2007). For this reason, pilot vegetation monitoring studies for San Diego County’s MSCP plan included native shrub cover and non-native grass cover in a longer list of functional indicators tracked within the regional preserve system (Deutschman and Strahm 2012). More recently, a relatively simple yet elegant framework emerged for monitoring the integrity of shrub-dominated ecosystems. Lawson and Keeley (2017) developed a conceptual model that characterizes the loss of ecological integrity (or level of ecological degradation) of chaparral and CSS communities by percent cover of non-native annual grasses. This conceptual model distills the most important responses demonstrated during previous studies (Diffendorfer et al. 2007, Deutschman and Strahm 2012) while balancing the need for conservation plans to be practical and cost-efficient in their tracking of key ecological attributes at multiple preserves and spatial scales (Parrish et al. 2003, Wurtzebach and Schultz 2016). Furthermore, this framework was built on more than a decade of shrubland ecology research. Percent shrub cover was considered as an additional measure of ecological integrity; however, shrub cover is not linearly related to integrity, and higher shrub cover does not always indicate higher ecological integrity. A range of shrub cover across the landscape is necessary to accommodate a range of habitat types. Instead, percent cover of non-native invasive grasses has a linear relationship with loss of ecological integrity and was found to be negatively correlated with native shrub species richness and cover.

Thresholds, or cutoff values, for the percent cover of non-native grasses to define high, moderate, and low integrity were proposed by Lawson and Keeley (2017). To further evaluate and refine the use of percent cover of non-native annual grasses and the thresholds for this measure of ecological integrity, this monitoring plan will collect data on plant and animal communities at plots historically classified as CSS and chaparral. Collected data will be used to investigate the correlations between non-native annual grass cover with native plant cover, community composition, and diversity; with targeted plant and animal species distributions and abundance; and with the abundance, composition, and diversity of selected taxonomic groups (e.g., birds) or functional groups (e.g., pollinators). With this information, we will evaluate the use of non-native grasses as a measure of loss of ecological integrity and propose thresholds of cover values where a decline in native biodiversity is significant.

Threats to ecological integrity

The Lawson and Keeley (2017) conceptual model captures how invasive non-native grass cover corresponds to thresholds of shrub to annual grassland vegetation type-conversion and the associated drivers. A primary driver for conversion from chaparral/CSS to grassland is increased fire frequency and short fire return intervals (Keeley and Brennan 2012, Lippitt et al. 2013, Cox et al. 2014, Syphard et al. 2019a-b, Storey et al. 2021a, Lucas et al. 2017, Pratt et al. 2014).

Shrublands in southern California are adapted to fire frequencies of 30-40 years (Keeley 1992, Keeley and Fotheringham 2001, Regan et al. 2010). Comparison of fire frequency on conserved lands in San Diego County between 1965 and 2019 found chaparral and CSS vegetation communities have burned much more frequently over the last 30 years (Preston et al. 2022).

As non-native grasses outcompete the fire-depleted soil seed bank and slow recruitment of shrub seedlings, high annual grass cover feeds fire fuel load, creating a positive feedback loop between fire and annual grasses that leads to attenuation of shrubs and local extirpation of chaparral/CSS communities (Brooks et al. 2004, Keeley and Brennan 2012, Linder et al. 2018). In addition to an altered fire regime, there are other threats to the ecological integrity of San Diego County shrublands, such as nitrogen deposition from air pollution (Fenn et al. 2010, Allen et al. 2016; Valliere et al. 2019), and changing climate with increasing temperatures and long periods of intensive drought (Lucas et al. 2017, Venturas et al. 2016).

Shrub reproductive strategies with fire

Community recovery from wildfire involves complex successional patterns due to different reproductive modes among shrub species (Keeley et al. 2005a-b, Keeley et al. 2006; Franklin et al. 2006, Lucas et al. 2017, Venturas et al. 2016). Obligate seeding (OS) shrubs return after fire as seedlings, typically following winter rains, due to fire-stimulated germination of seeds stored in the soil seed bank (Keeley 1991, Keeley et al. 2006, Enright et al. 2014, Underwood et al. 2023). As adult OS shrubs die during fire, the total biomass of these shrubs sharply declines and recovery occurs slowly over time as a new cohort of seedlings mature (Keeley et al. 2006, Underwood et al. 2023). When the new seedling cohort has matured to adults, they are able to set seeds annually, which will remain dormant in the soil seed bank until the next fire-stimulated germination (Keeley 1991, Keeley et al. 2006). Altered fire regimes that see increased fire frequency and shorten fire return intervals make OS shrubs vulnerable to local extinction when fires are more frequent than the time it takes for shrubs to mature and replenish the soil seed bank (Regan et al. 2010, Enright et al. 2014, Keeley and Pausas 2022).

In contrast, obligate resprouter (OR) shrubs regenerate by resprouting immediately postfire, often drawing from deep, carbohydrate-rich roots to sprout from underground buds or epicormic buds in canopy stems (Keeley et al. 2006, Bradshaw et al. 2011, Enright et al. 2014, Keeley and Pausas 2022, Underwood et al. 2023; Lucas et al. 2017). Although this reproductive mode allows OR shrubs to reach pre-fire biomass and maturity relatively quickly (Underwood et al. 2023), the functional group is still sensitive to shortening fire intervals. The seeds of OR shrubs do not persist in the soil seedbank. Newly set seeds will only germinate in the absence of fire under suitable climate and soil moisture conditions (Keeley 1991, Underwood et al. 2023). Underscoring the threat of increasing fire frequency, Keeley et al. (2006) found that no significant seedling recruitment occurred in some OR shrubs until five years postfire. Although resprouting makes OR shrubs less vulnerable to local exclusion by nonnatives, altered fire regimes may result in future extirpation due to decreased genetic pool of seeds and a simplified population structure as seedling recruitment declines (Levin 1990, Keeley et al. 2006, Enright et al. 2014).

In most CSS and chaparral communities, facultative resprouter (FS) shrubs are the most abundant shrub group, before and after fires (Underwood et al. 2023; Lucas et al. 2017). This is unsurprising given that FS shrubs both maintain the ability to resprout postfire, while also having adapted fire-stimulated seed germination (Keeley et al. 2006, Enright et al. 2014, Keeley and Pausas 2022, Underwood et al. 2023). However, FS shrubs tend to resprout less forcefully than OR shrubs and FS seedlings are often less successful overtime than OS seedlings (Underwood et al. 2023) and can also experience drastic population declines after repeated short-interval fires (Zedler et al. 1983).

Unlike the native CSS and chaparral plants that are adapted to reproduce under historic fire frequencies, non-native grasses do not have fire-stimulated seed germination or resprouting abilities, but instead succeed through seed dispersal as post-fire colonizers (Pausas and Keeley 2014, Linder et al. 2018). They are especially successful under altered fire regimes with increased fire frequency and short fire return intervals (Keeley 2005, Keeley and Brennan 2012). Herbaceous cover increases rapidly in the years after fire and then decreases gradually as shrubs grow and recover with time since last fire (Keeley et al. 2005b, Underwood et al. 2023). While this spike in post-fire herbaceous cover includes native perennials resprouting and native annual forb seedlings in addition to non-natives (Keeley et al. 2005b), non-native grasses and mustards can expand rapidly with thick thatch that threatens shrubland community recovery.

These post-fire colonizers begin to change the fire regime and create a positive grass-fire feedback loop when dry and flammable non-native grasses decrease the fire fuel load (lower biomass compared to mature shrubs) and burn quickly. This decreases overall fire intensity, such that non-native grass seeds survive in the soil seed bank after low intensity fires and rebound even faster after each subsequent fire, further increasing fire frequency (Brooks et al. 2004, Keeley and Brennan 2012, Enright et al. 2014, Linder et al. 2018). With shorter fire intervals, annual grasses outcompete the fire-depleted soil seed bank (OS shrubs) and slow recruiting (OR, FS shrubs) shrub seedlings leading to shrub attenuation and type conversion to grasslands (Brooks et al. 2004, Keeley et al. 2006, Keeley and Brennan 2012, Lippett et al. 2016, Lawson and Keeley 2017, Linder et al. 2018).

Other drivers of shrubland vegetation type conversion

Increased nitrogen deposition caused by high levels of transportation emissions in southern California also forms a positive feedback loop with non-native annual grasses and is a significant background driver in CSS and chaparral type-conversion to grassland (Talluto and Suding 2008, Fenn et al. 2010, Cox et al. 2014, Allen et al. 2016, Valliere et al. 2019). This conversion is facilitated by frequent fire but can also happen in the absence of fire due to high levels of air pollution fertilizing soils (Talluto and Suding 2008, Cox et al. 2014, Valliere and Allen 2016). Soil nitrogenization decreases arbuscular mycorrhizal fungi (AMF) root colonization and spore production (Allen et al. 2016). Native shrubs depend on AMF for survival, and a decrease in AMF richness and abundance has been associated with a reduction in shrub cover and an increase in invasive grass cover (Allen et al. 2016, Valliere and Allen 2016). One study showed type conversion of CSS to grassland at sites in inland southern California was associated with a critical load of at least 11 kg N/ha/yr, in shallower, more westerly facing slopes (Cox et al. 2014, Allen et al. 2014).

The effects of nitrogen in the soil may also be dependent on other threats, making the effects more severe where multiple threats are present. Mycorrhizal fungi communities change significantly after a fire and are not fully recovered at one year post burn (Pulido-Chavez et al 2022, Fox et al. 2022). Drought also impacts the effects of nitrogen on shrubs. Areas with higher nitrogen concentrations have more growth in shrub leaf area but are more vulnerable to drought. Sites with higher nitrogen concentrations were more likely to see shrub mortality and dieback during a prolonged drought (Valliere et al. 2017). Soil texture and soil moisture play a role in determining the effects of high nitrogen concentrations on shrub and non-native invasive grass cover where higher soil moisture may mitigate negative impacts from soil nitrogenization and support fungi and bacteria in the soils (Pulido-Chavez et al 2022, Fox et al. 2022). Finally, other elements present in the soil may mitigate the impacts of increased nitrogen such as carbon, potassium, calcium, and phosphorous but these impacts vary significantly by species and region (Sollenberger et al. 2016; Valliere et al. 2019).

In addition to changes in fire regime and increased nitrogen deposition driving vegetation-type conversion, climate change is a significant driver in conversion of shrub to grassland, as shrubs become less competitive and habitat conditions become unsuitable (Beltrán et al. 2014, Jennings et al. 2018). Syphard et al. (2019a) found that in San Diego County, decreases in soil water availability and increased evapotranspiration drove chaparral decline. While OR shrubs decrease in relative abundance compared to OS and FS shrubs with increasing climate water deficits (Underwood et al. 2023), certain shrub species may be more susceptible to drought than others (Keeley et al. 2005a). Meanwhile, shrub dieback under dry conditions also increases the risk of severe, widespread fire (Keeley et al. 2022), thereby changing the fire regime and threatening all shrub functional groups, but especially OS shrubs (Beltrán et al 2014, Enright et al. 2014). Drought also slows the recovery of shrubs after fire (Storey et al. 2021b), which further encourages annual grass proliferation (Linder et al. 2018). Climate change models predict increased temperatures, more frequent drought, and reduced coastal marine layer in California, and these conditions have been found to cause and/or further exacerbate all the conversion of shrub to grassland (Jennings et al. 2018).

Changes to shrubland animal community integrity

Changes in vegetation integrity typically result in corresponding changes to the diversity and composition of animal assemblages, but effects vary by taxa and may occur on different spatial and time scales than vegetation communities (Diffendorfer et al. 2007, Vandergast et al. 2008, Underwood et al. 2018). An example is a large-scale post-fire study conducted by U.S. Geological Survey documenting vegetation and faunal responses to the 2003 fires across San Diego County. While many taxa experienced loss to species richness and diversity (vegetation, Rochester et al. 2010a; herpetofauna, Rochester et al. 2010b; scorpions and solifugids, Brown et al. 2010; small mammals, Brehme et al. 2010; ants, Matsuda et al. 2011), other taxa only experienced changes in species composition but not loss to diversity (birds, Mendelsohn et al. 2008; bats, Rochester et al. 2010c). Some taxa did not experience significant changes (carnivores, Turschak et al. 2010). As noted in the Parrish et al. (2003) "measures of conservation success," to comprehensively track ecological integrity over time, it is helpful to track a selection of focal conservation targets, their associated ecological attributes, and indicators of those attributes.

The MSP Roadmap includes monitoring objectives for specific animal taxonomic groups (e.g., pollinators) to assess species composition and diversity and inform ecological integrity status at vegetation monitoring plots (SDMMP and TNC 2017). MSP Vegetation Focus (VF) Species are selected in the MSP Roadmap for targeted monitoring in association with CSS, chaparral, and grassland vegetation monitoring. Management for these species is linked to vegetation community enhancement and restoration rather than species-specific management (SDMMP and TNC 2017).

Information to inform management

The data and analysis from this effort will directly inform land management in several ways. First, a landscape-scale map of ecological integrity over time will identify areas of concern. Locations with low integrity that are a high priority for either target plant or animal species, connectivity, or high fire risk may be prioritized for invasive species control or restoration. Second, a better understanding of thresholds of non-native annual grass cover in relation to both plant and animal diversity and abundance will provide goals and targets for ongoing and new restoration. Third, an analysis of the factors associated with high integrity will provide managers insight into the factors that can aid recovery after fire or drought. This could help managers target actions immediately after a fire or prioritize invasive management and restoration. Fourth, the evaluation of protocols will provide all stakeholders in the region with a unified and quick way to assess ecological integrity and vegetation and animal richness. Finally, the methods used to select survey locations will allow managers to determine where their property falls in relation to ecological integrity throughout the rest of the preserve system.

Vegetation and ecological integrity monitoring

We developed this CSS and chaparral vegetation monitoring plan for conserved lands in western San Diego County involving GIS/remote sensing and field-based vegetation monitoring, with complementary VF Species and animal taxonomic group monitoring (for greater detail see Section 2.4.2 Adaptive Monitoring Approach in the MSP Roadmap, SDMMP and TNC 2017). The guiding research questions for this vegetation monitoring plan are:

For vegetation communities:

1. What is the distribution, composition, structure, and integrity of CSS and chaparral vegetation communities in the MSPA?

2. How are these attributes of the vegetation community changing over time?

3. What threats and abiotic factors are associated with changes in vegetation community attributes? Specifically, what factors are associated with a decline in ecological integrity and type conversion?

4. How well does the proposed measure of ecological integrity (non-native annual grass cover) align with changes in the native plant community? What thresholds are important for predicting decline in native plant species richness and abundance?

For animal taxonomic groups and VF plant and animal species:

1. What is the status and distribution of VF plant and animal species, and is it changing over time?

2. What is the distribution, status, composition, and diversity of animal taxonomic groups, and is it changing over time?

3. What vegetation, threat, habitat, and abiotic attributes are associated with changes in 1) VF plant and animal species status and distributions and 2) species composition and diversity of animal taxonomic groups?

4. How well does the proposed measure of ecological integrity (non-native annual grasses cover) align with changes in the animal community? What thresholds are important for predicting decline in native animal species richness and abundance?

Field-based vegetation studies in the MSPA

Decades of previous research provide a foundation to build from, and this plan brings together several specific research projects into a single, comprehensive plan to understand shrublands in San Diego, how they are changing, and why. The first recorded vegetation mapping occurred in San Diego County in the 1930s, referred to as the Wieslander Vegetation Type Map (VTM) dataset. This was part of a survey of natural vegetation initiated by the U.S. Forest Service in 1926 to provide data in support of statewide land use and fire protection policies (https://calisphere.org/collections/150/). Plots across San Diego County were measured, and species-level information was recorded. Polygon maps of vegetation communities were also created from the plot information. These data are available through a Cal Berkeley project that digitized sites and polygon information (Kelly et al. 2005, Kelly et al. 2008, https://calisphere.org/collections/150/). Additional plots in San Diego County were digitized from physical records and provided for analysis (Taylor 2004, Taylor 2005).

Vegetation monitoring has continued either through vegetation-focused projects or as a part of a specific animal or taxa research. In the 1990s, the U.S. Geological Survey completed vegetation surveys at pitfall traps designed to study herpetofauna communities (Fisher et al. 2008). Data from these surveys include transects with species-level information at all heights along the transects at plots near pitfall traps. Original surveys were completed over several years beginning in 1995. A small number of plots were re-surveyed in the early 2000s.

In 2016, 2020, and 2024, coastal California gnatcatcher studies included a component to measure vegetation cover (Kus and Houston, 2021). A total of 454 sites were completed in both years. Vegetation data included species-level information for only a select number of shrub species but was collected in a manner that allows for calculations of percent shrub and percent non-native grass cover.

Several studies have been completed testing vegetation collection methods in the field. In 2008, San Diego State University (SDSU) compared field methods for accuracy, time, and cost (Deutschman et al. 2008). This study found that a transect design was the fastest and most cost-effective way to collect accurate data. However, this study did not include the use of Unmanned Aircraft Systems (UAS). In 2020, AECOM conducted a pilot study to test UAS methods for vegetation collection while incorporating a transect design. With the advances in UAS image-collecting technology, imagery with a 0.5-cm resolution was collected and used to identify plant species. This UAS approach was determined to be more cost-effective than walking transects and caused less damage to the plot (Appendix 1). Grass and forb species were not identifiable from the imagery, but percent non-native grass was calculated solely from the imagery.

GIS-based remote sensing vegetation datasets

Studies assessing remote sensing automated methods of functional group classification have been tested nationally and locally (Lippitt et al. 2017, Rogan et al. 2007, Hamada et al. 2011, Allred et al. 2021, Goulden et al. 2023). Lippitt et al. (2017) tested methods to identify shrub and herbaceous cover from Satellite pour l'Observation de la Terre (SPOT) imagery (10-m resolution, 5 bands) and had high accuracy when assessing vegetation functional group (grass, subshrub, true shrub, and tree). This imagery is not regularly collected for San Diego and is not a long-term solution for repeated landscape-scale mapping. The study identified spatial and radiometric resolutions as having a large impact on the accuracy of the classification, meaning more reliable but lower resolution imagery, like Landsat (Earth Resources Observation and Science (EROS) Center, 2020), may have limitations in what information can be obtained.

In 2021, the Rangeland Analysis Platform (RAP) was created to host a series of Landsat-derived data including annual layers for percent shrub, percent annual herbaceous, and percent perennial herbaceous cover (Allred et al. 2021; Earth Resources Observation and Science (EROS) Center, 2020). The RAP is available from 1986-2021 (currently) for the entire United States and has a 90% accuracy rate at a national level, (Allred et al. 2021). Within San Diego

County, the accuracy is of the RAP is comparable to the accuracy at the national level, but the separation between annual herbaceous, perennial herbaceous, and bare ground cover could not be determined from available information. Additional data to separate annual and perennial herbaceous cover could expand the utility of the RAP. One component of this monitoring plan will be to collect field data that will help validate or further refine the RAP.

Data collected and lessons learned from these studies were incorporated into the final design of this monitoring plan. A combination of methods was implemented to cover the various aspects of our research questions and utilize the strengths of each method presented. This plan incorporates analysis from external data sources, including those mentioned above and others, as well as UAS and field-collected data at permanent plots. A full description is provided below.

Methods

Overview of methods

The research questions will be addressed with 1) a combination of data compilation/analysis of GIS data layers to characterize environmental conditions, types and levels of threats, and species and vegetation distributions in the regional preserve system (Core monitoring); 2) remote sensing products to evaluate ecological integrity (Core and Core+ monitoring); and 3) field-based vegetation and taxa monitoring (Core+ and Core++ monitoring; SDMMP and TNC 2017; fig 2). Remote monitoring will be used to analyze historical survey data and incorporate annual satellite imagery to produce GIS layers that map the MSPA vegetation communities and categorize CSS and chaparral habitats into vegetation integrity classes based on the Lawson and Keeley (2017) conceptual model of annual non-native grass cover. Cutoff values for these classes have been proposed for both CSS and chaparral. Part of this monitoring plan will be to evaluate thresholds and refine classes where necessary. These data will serve as a tool to track landscape-scale changes over time.

Field-based and UAS vegetation monitoring surveys will be completed every 5 years by a team of botanists and an UAS pilot. This team will collect field-based vegetation data (Appendix 1) on conserved lands within the MSPA at long-term, permanent plots selected from gradients of north to south/east to west and by vegetation classification. Field survey data will be used to

Research Question component	Methods for Vegetation	Methods for Animals
Distribution	Outside of this report's scope- mapping of vegetation types	Full distribution outside of this reports' scope. Targeted surveys for select species on selected plots.
Composition and structure	Field mapping with UAS imagery and transects	Rapid assessments by taxonomic group plus targeted surveys for select species
Integrity	Combination of field mapping and remote sensing sources (RAP)	Evaluate percent cover and its relationship to animal composition through rapid assessment
Threats	GIS data on fires, drought, recreation, nitrogen deposition, etc.	
Abiotic factors	GIS data on topography and general soil type with soil samples from field	
Evaluation of thresholds	Field mapping/UAS imagery with animal rapid assessments to evaluate ecological integrity measure and thresholds against full community biodiversity	
Validation of remote sensing	Field plots align w/ LANDSAT- compare field and RS percent cover values	

Figure 2: A diagram showing the overall approach that will be used to address each component of the research questions for both vegetation and animal communities.

validate satellite imagery, characterizing vegetation integrity classes at the community level and provide finer-scale data on plant species composition, structure, and function to monitor the response of these plant communities to landscape-scale threats (type conversion drivers: fire, nitrogen deposition, soil water availability, climate change, etc.). Supplemental rapid assessment field surveys will be conducted at vegetation monitoring plots to determine the distribution and status of VF plant and animal species and composition and diversity of animal taxonomic groups over time.

Annual analysis of existing datasets (Core Monitoring)

Landscape-scale datasets will be analyzed annually to demonstrate the current distribution of ecological integrity, how and where it has changed, and what factors are associated with changes in integrity. Several external datasets from GIS and remote sensing sources will be used. A list of necessary data sources is available in table 1. Each year, the most recent data available will be collected. For each dataset, areas of significant change will be identified. Percent cover of various land cover types, from the RAP data (Allred et al. 2021) will help identify areas of change in ecological integrity. Percent of annual herbaceous cover and shrub cover will be mapped throughout the MSPA at 30-m pixel resolution. These cover estimates will be analyzed with threat measurements to better understand vegetation community responses to landscape-scale threats. Three annual monitoring metrics from each year of geospatial data monitoring will be reported and include:

- Percent cover of annual herbs and shrubs within CSS and chaparral habitat to inform questions about distribution and integrity,
- Change in percent cover relative to rolling average, minimum and maximum values on record, and 1986 baseline to inform questions about change in communities over time, and
- Non-metric multidimensional scaling (nMDS) plots and analyses using the BIO-ENV (called bioenv function in R package; Oksanen et al. 2022) analysis, to identify independent variables associated with vegetation change in a multi-dimensional space.

Annual visualizations from the analysis will include:

- Map of percent cover over the MSPA (SDMMP and TNC 2017) and in eco-subregions (County of San Diego Land Use and Environmental Group 2000, Allred et al. 2021)
- Percent cover trends
- nMDS plots (package vegan, Oksanen et al. 2022)

Change in percent cover

To evaluate changes in geospatial percent cover with multi-dimensional data (multiple years and multiple cover types), a multi-year permutational multivariate analysis of variance (PERMANOVA, Legendre and Anderson 1999, Anderson 2014, and Oksanen et al. 2022) design will be implemented, that tests for differences in site-level dissimilarity indices between years. Site dissimilarity is measured as the Euclidean distance between all combinations of site pairs (Eq. 1).

$$d_{jk} = \sqrt{\sum_1^n \left(x_{ij} - x_{ik}\right)^2} \qquad \text{(Equation 1)}$$

Here, x_{ij} and x_{ik} refer to the percent cover value of cover class *i* at sites *j* and *k*. Euclidean dissimilarity is then modeled as a function of year, for CSS and chaparral sites separately. Any detection of a significant effect of year on dissimilarity scores would indicate significant community change over time.

In addition, BIO-ENV tests to determine the best subset of environmental variables via maximum rank correlation will be implemented. These tests quantify the degree to which dissimilarity scores covary with environmental variables (table 1), via maximum rank correlation. Furthermore, the significance of the best subset of environmental covariates will be determined using a Mantel test.

nMDS plots

Patterns in nMDS plots and a cluster analysis to determine how sites cluster in MDS space will be investigated (package vegan, Oksanen et al. 2022). This analysis

Table 1: GIS-based variables used to analyze ecological integrity of CSS and chaparral shrublands in response to threats and environmental attributes.

Variable Name	Measurement	GIS File Type and Resolution	Time period covered	Annually Updated	Type of Variable for Analyses	Citation
Rangeland Analysis Platform (RAP)	Vegetation: percent cover by functional group	Raster, 30m	1986-present	Yes	Vegetation response variable, measure of ecological integrity	Allred et al. 2021
CalFire Fire Perimeters	Fire: mapped extent; fire return interval	Polygon	1885-present	Yes	Explanatory variable, threat	CalFire 2022
Monitoring Trends in Burn Severity (MTBS)	Fire: burn severity	Raster, 30m	1984-present	Yes	Explanatory variable, threat	Eidenshink et al. 2007
Palmer's Drought Severity Index or other drought index	Climate; drought severity	Raster, 4km	1979-present	Yes	Explanatory variable, threat	Huntington et al. 2017
Nitrogen Deposition	Nitrogen; amount of nitrogen deposited from air pollution	Raster, 12km	2002-2019	Yes	Explanatory variable, threat	U.S. EPA 2021
Precipitation	Climate; average annual precipitation	Raster, 270m	1980-present	Yes	Explanatory variable, abiotic factor	Flint and Flint 2012
Monthly Max Temperature	Climate: average monthly maximum temperature	Raster, 270m	1980-present	Yes	Explanatory variable, abiotic factor	Flintand Flint 2012
Monthly Min Temperature	Climate: average monthly minimum temperature	Raster, 270m	1980-present	Yes	Explanatory variable, abiotic factor	Flint and Flint 2012

Variable Name	Measurement	GIS File Type and Resolution	Time period covered	Annually Updated	Type of Variable for Analyses	Citation
Soil Type and Texture	Soils: type and texture	Polygon	NA	No	Explanatory variable, abiotic factor	O'Green 2022
Vegetation classification	Vegetation Type	Polygon	1930s, 1995, 2012, est. 2023 update	No	Used to restrict analysis to CSS and chaparral	1930s (Taylor, 2005), 1995 (City of San Diego, 1998), and 2012 (AECOM, 2014)
Species detections from other studies	Species: location records	Points	NA	Varies	Used to refine ecological integrity measures and map distribution of target species	*Varies annually based on available survey data
Vegetation cover from other field studies	Vegetation: species composition and % cover for species and functional groups, native vs non-native, dead vs live shrub, and other classifications	Points	NA	Varies	Dependent variables through time from previous studies, used to refine ecological integrity, aid in sample design, calculate change	*Varies annually based on available survey data
Elevation & other topographic variables	Topography	Raster, 10m	2015	No	Explanatory variable, abiotic factor	U.S. Geological Survey 2015
Trails and recreation	Recreation: intensity of human use?	Polygons	2023-present	Yes	Explanatory variable, threat	Strava 2023

technique allows us to view data patterns by reducing the data dimensionality and presenting the data in a graph where points that are more similar to each other are plotted closer together. Similarity is measured as a multi-variate distance between multiple percent cover variables. This analysis will allow us to visualize changes in vegetative cover, while summarizing the characteristics of clusters present in the data.

Additionally, the spatial and temporal covariates that are most highly correlated (rank correlation) with community dissimilarity will be determined using the function bioenv in package vegan (Oksanen et al. 2022), based on the BIO-ENV method described by Clarke and Ainsworth (1993). This method determines the best subset of environmental variables, such as fire history, climate, nitrogen deposition, or soil characteristics (table 1) to explain variation present in the dissimilarity matrix, as well as summarizing the strength and direction of each covariate’s effects on dissimilarity.

Field and UAS data collection (Core+ Monitoring)

Field methods

In 2020, AECOM conducted a pilot study to test UAS imagery for plant species identification to measure species composition and cover (Appendix 1). This method was designed to be cost-efficient and low impact on the plots and used a hybrid approach which involved collection of high-resolution imagery (<0.5 cm) with field data by botanists. Plots were 90 m by 90 m with nine 30 m by 30 m subplots. At each plot, a team set up UAS equipment and control points, completed the flight to collect imagery, and created a list of every plant species present at the plot (FAA 2024, de Castro et al. 2021). The plant list was created by wandering the plot on foot, identifying each new species, and taking a sub-meter GPS point and photograph for at least one location. The outputs from the exercise included a list of species and a representative location for each species present. The species list and imagery were collected in the spring to maximize capturing flowering (Appendix 2).

Plant species identification was obtained from the imagery using the Statewide Landcover and Trees Study (SLATS) transect design (Kuhnell et al. 1998; fig 3). This design was developed to use with Landsat imagery (Earth Resources Observation And Science (EROS)

Center, 2020). Each 90 m plot has a total of 27 transects and 405 points (every 2 m along the transects) scored to the species level, where possible, or to substrate type if there is no plant at the point. Dead shrubs should be identified to the species level, if possible. If not, they should be identified as dead standing biomass and labeled as “dead shrub” or “dead tree” if the form can be identified (Appendix 3).

Herbaceous cover cannot always be identified to species level from the imagery. Modifications to the original protocol will include nine 1-m diameter circles per 90 m plot (1 in each of the 9 subplots) where herbaceous species composition and cover values will be collected in the field (Appendix 2). Cover estimates will use an ocular estimation for each species, with special consideration for rare species. A “trace” value of 0.2 percent should be entered for rare species that are present in the plot. See Appendix 2 for full protocol details.

Soil samples will be collected at the center of each of the sub-plots. (Appendix 2). The samples from each of the sub-plots will be combined into a single container (one per 90-m^2 plot). The sample should be from the soil surface (starting at the mineral soil, below any top cover) down to 10 cm (Pulido-Chavez et al. 2022). Soil samples should be stored in air-tight containers and sent to a laboratory frozen for analysis of bacterial and fungal species (Edwards et al. 2024). Soil data will also be used to identify plots with excessive nitrogen from atmospheric nitrogen deposition. Other elements and chemical compounds will be measured to identify relationships between nitrogen and potential mitigating components. Soil physical and chemical properties that will be tested for include total N, NO_3, NH_4, P, K, Ca, Mg, Na, pH, organic matter, and soil texture. Field collection sheets are provided in Appendix 3.

Another concern raised in the UAS pilot study (Appendix 1) was the inability to capture species information under the vegetation canopy. Traditional transects often provide readings for all height levels at a point-intercept where a plant touches. With UAS imagery, only the top of the canopy is captured by the imagery. To validate the use of UAS data to measure grass cover, we used the U.S. Geological Survey (USGS) pitfall dataset (Fisher et al. 2008) to simulate the data that would be captured using just the top of the canopy and compared it to the total cover (canopy and under-canopy). Our objective was to determine the extent to which under-canopy grass cover was related to total grass cover.

We found total cover of non-native grass was highly correlated with canopy cover of non-native grass (r = 0.89, 95% CI: 0.86 - 0.91). The correlation between canopy cover of non-native grass and the proportion of under-canopy that had non-native grass was not as strong (r = 0.64, 0.56 - 0.71). We interpret this as evidence that 1) canopy cover of non-native grass, as measured by top-down imagery, is representative of total non-native grass cover and 2) the dominance of non-native grass under-canopy is also linked to canopy cover of grass; however, there may be greater uncertainty in under-canopy non-native grass cover, compared to total grass cover. Therefore, using UAS imagery with herbaceous field plots will likely represent most of the non-native grass cover present.

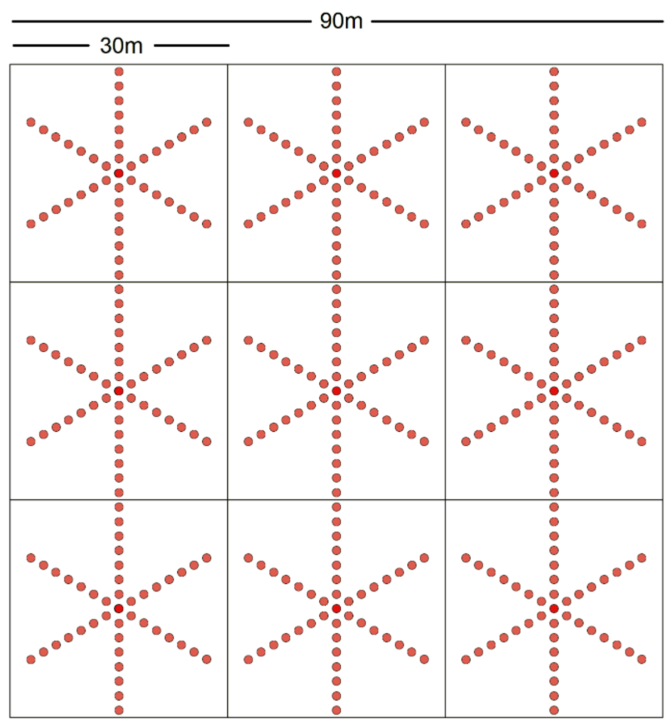

Figure 3: SLATS transects design with 90 m x 90 m plot with 9 30 m x 30 m subplots.

Biosecurity measures

To reduce damage to the plots and the spread of invasive species, surveyors must use caution when traveling from one plot to another. Surveyors should follow the plans created in "Preventing the Spread of Invasive Plants: Best Management Practices for Land Managers 3rd edition" (Cal-IPC 2012). A copy of this manual is available to download: https://www.cal-ipc.org/resources/library/publications/landmanagers/. Clothes and equipment should be cleaned or switched out between plots, especially when moving from a plot with invasive species.

Analysis of field data

To evaluate community change in species presence and percent cover, an analysis of collected field data will be completed every 5 years. The main goal of this analysis is to summarize species composition, percent cover, traits (height, reproductive strategy, etc.), and species evenness. Instead of generalizing changes in integrity at the landscape-level (like the Core Monitoring), this analysis will identify changes in community composition and cover at the species-level and identify factors associated with change at randomly selected plots. These analyses will include: nMDS cluster analysis, PERMANOVA, and BIO-ENV analyses (package vegan, Oksanen et al. 2022), as well as additional analysis of community diversity, indicator species (package indicspecies; De Caceres and Legendre 2009), trait diversity, and joint-species distributions (package spOccupancy, Doser et al. 2022).

nMDS Plots

Community change will be analyzed by calculating percent cover of native versus non-native plant functional groups and by evaluating species composition over time using nMDS plots, with year-specific clusters. The plots will display the change in community Bray-Curtis dissimilarity (Eq. 2, Jackson 1993) over time, clustering years with similar compositions together, while years that differ more substantially will be further separated. The significance of inter-year deviation and the factors associated with change will be explored in PERMANOVA analysis.

PERMANOVA and BIO-ENV change detection

The PERMANOVA tests will describe the species composition and percent cover of native vs non-native plant functional groups for CSS and chaparral plots separately. The BIO-ENV tests will characterize what threats and factors are associated with observed changes. Both PERMANOVA and BIO-ENV tests will deviate from the analysis of change in percent cover because dissimilarity measures of species data will be estimated using Bray-Curtis dissimilarity (Eq. 2, Jackson 1993).

$$d_{jk} = \frac{\sum_i^n |x_{ij} - x_{ik}|}{\sum_i^n (x_{ij} + x_{ik})} \qquad \text{(Equation 2)}$$

Here, x_{ij} and x_{ik} refer to the presence or percent cover data of species i at plots j and k. As in the analysis of percent cover data, dissimilarity will be evaluated as a function of time, for CSS and chaparral plots separately.

Relationships between Bray-Curtis dissimilarity and environmental drivers will be implemented using BIO-ENV tests (table 1). Environmental variables that are best associated with spatial and temporal change in vegetation communities will be reported and interpreted.

Community diversity analysis

Following analyses of community dissimilarity, four measures of community diversity will be evaluated: alpha, gamma, and beta diversity (Whitaker 1960), and Shannon's diversity measures (Shannon and Weaver 1963). Alpha diversity is the mean species richness at a plot. Gamma diversity is the total species richness within our dataset. Beta diversity is equivalent to gamma diversity divided by alpha diversity, or the number of plots required to include all species present, if no species was shared among plots. Shannon's diversity measures the overall diversity of a community by considering both species richness and the abundance of each species. Furthermore, the diversity of vegetative traits (growth form, reproductive form, etc.) within communities will be summarized by tallying the total number of unique traits per plot (trait diversity) and tallying the number of species with each trait in the community (trait evenness). Measures for native and non-native species will be estimated separately to use as indicators of ecological integrity.

Indicator species analysis

In addition to PERMANOVA and BIO-ENV analyses, an indicator species analysis (package indicspecies, De Caceres and Legendre 2009) will be completed to determine which species are most strongly associated with changes in ecological integrity of vegetation communities. This is done to determine if a subset of species provides high predictive value for the presence of community types or community change. Species-site group relationships between the most common species and ecological integrity classes will be evaluated (classes are based on percent cover of non-native grass cutoffs) for CSS and chaparral vegetation communities. The output of this analysis is three-fold: 1) the sample estimate for the probability a plot belongs to ecological integrity class *h*, given species *k* is present; 2) the sample estimate that species *k* is present, given a plot belongs to ecological integrity class *h*; and 3) the significance of the relationship between species *k* and ecological integrity class *h*.

Joint-species distribution models

Finally, joint-species distribution models will be constructed using the R package spOccupancy (Doser et al. 2022) to estimate the distribution, and potential inter-specific interactions, of a subset of species. These models will evaluate the relationship between individual species and environmental covariates, as well as residual species relationships, to determine the strength and direction of inter-specific interactions. This analysis will provide insight into how species are currently distributed across the landscape of San Diego County. In addition, this analysis will quantify the inter-specific co-occurrence patterns, providing exploratory insight into how species interactions may facilitate species distributions. The model will have fixed covariates, year-specific random intercepts, and spatial random effects for each species. For those species selected for this analysis, several types of information will be reported: 1) co-occurrence correlation coefficients, 2) significance of co-occurrence correlation, 3) county-wide distribution maps, and 4) county-wide residual occurrence maps indicating areas where species are observed more or less frequently than predicted.

Rapid assessments and target plant and animal community monitoring (Core++ Monitoring)

Field methods

The monitoring of animal communities will contain two components. First, rapid assessment protocols designed for animal taxonomic groups will provide information on all species detected in the field (Ewing et al. 2023, Mendelsohn et al. 2008; table 2). Second, specific surveys will be completed for a subset of plant and animal species. The species chosen for targeted monitoring were VF species in the MSP (SDMMP and TNC 2017) and include:

- California glossy snake (*Arizona elegans occidentalis*)
- Blainville's horned lizard (*Phrynosoma blainvillii*)
- San Diego black-tailed jackrabbit (*Lepus californicus bennettii*)
- Bell's sparrow (*Artemisiospiza belli belli*)
- Grasshopper sparrow (*Ammodramus savannarum perpallidus*)
- Loggerhead shrike (*Lanius ludovicianus*)
- Lakeside ceanothus (*Ceanothus cyaneus*)
- Del Mar manzanita (*Arctostaphylos glandulosa* ssp. *crassifolia*)
- Cliff spurge (*Euphorbia misera*)
- Nuttall's scrub oak (*Quercus dumosa*)
- Otay manzanita (*Arctostaphylos otayensis*)
- Palmer's goldenbrush (*Ericameria palmeri* var. *palmeri*)
- Rainbow manzanita (*Arctostaphylos rainbowensis*)
- San Diego barrel cactus (*Ferocactus viridescens*)
- Snake cholla (*Cylindropuntia californica* var. *californica*)
- Wart-stemmed ceanothus (*Ceanothus verrucosus*)
- Coulter's saltbush (*Atriplex coulteri*)
- Tecate cypress (*Hesperocyparis forbesii*)

Table 2: Animal monitoring techniques and citations by taxon

Taxa	Survey Type	Citation
Birds	Point Counts	Mendelsohn et al. 2008
Herpetofauna and small and large mammals	HALT and PIR cameras	Ewing et al. 2023
Pollinators	Bee bowls and surveys	Marschalek et al. 2023

Rapid assessment protocols are field methods designed to quickly determine the biodiversity at a plot. Methods were tested by taxonomic group and refined to identify the most-efficient techniques to capture a representative array of species as well as rare species, when present. In 2023, a study of a camera monitoring-station design was shown to detect small mammals including rabbits, rodents, and squirrels and herpetofauna such as lizards and snakes (Ewing et al. 2023). The monitoring station was designed with two cameras: a Hobbs Active Light Trigger (HALT) camera and a Passive Infrared (PIR) trail camera. The HALT camera faces directly down at a light sensor that triggers the camera whenever the beam is broken (an animal moves past it). The PIR camera faces horizontally and is triggered by infrared movement. A drift fence was included in the design to direct animals to the HALT camera sensor (Appendix 4).

The monitoring station with HALT and PIR cameras detected large and small animals, including some birds (e.g., California quail (*Callipepla californica*) and greater roadrunner (*Geococcyx californianus*)) but was the most effective at detecting small mammals, large mammals, and herpetofauna, including one photograph of a rare lizard, Cope's leopard lizard (*Gambelia copeii*). In many cases, individuals could be identified through unique patterns on the dorsum. However, in some cases, species could not be identified past the genus level, specifically deer mice (*Peromyscus* spp.), pocket mice (*Chaetodipus* spp.), kangaroo rats (*Dipodomys* spp.), and woodrats (*Neotoma* spp.). This study demonstrates that the monitoring station with HALT and PIR cameras can be used for taxa-level monitoring.

The State of California is using a similar design to monitor animals across the state (Boynton et al. 2021; Toenies 2024). Details of the project and methods can be found at. This method similarly includes a smaller, downward facing camera with drift fencing and an outward facing camera nearby. Details of the exact camera design are still being evaluated and will be determined when these surveys are prioritized to take advantage of the best camera technology available and be able to leverage data collected around the State.

Although a few bird species were detected using the HALT and PIR camera system, this camera system is not designed to capture the full diversity of bird species at a plot. Bird point counts are required to identify an accurate representation of birds present. Bird point counts will accompany vegetation monitoring at selected plots (Appendix 5). Camera monitoring and bird point counts are not prioritized for surveys in 2024 and will be prioritized at a future date.

Pollinator monitoring will be completed at CSS vegetation plots. A separate pollinator plan is being developed in coordination with this monitoring plan. Pollinator surveys will use bee bowls and walking transects (Marschalek et al. 2024). Pollinator surveys at CSS plots will begin in Spring 2024.

Monitoring for target plant species will be completed using the SDMMP Inspect and Manage (IMG) protocol (Appendix 6). The protocol will be used whenever a target plant species is identified in the plot during UAS imagery collection. The protocol may extend outside of the plot area, especially if the plant's full extent is large. This monitoring will not determine the full distribution of these species in the county. Additional discovery or IMG surveys would need to be completed but are outside the scope of this monitoring plan.

The Rare Plant IMG protocol involves recording information about the target plant species, associated species, photographs, and threat information at multiple scale (fixed 10-m permanent plot and the target species' maximum extent). At a 10-m circular permanent plot, the target species is counted, and phenology information is recorded. A full species list of every plant present within the plot is recorded, and a percent cover is estimated for each. Substrate and litter are recorded as well. At the maximum extent level, a count of the target species is recorded. The current extent for the year is walked and recorded with a GPS. Finally, threat information is recorded on a categorical scale which represents the percent area of the maximum extent that is impacted by each threat. Photographs at set locations and directions are taken each year to record changes to the target species habitat and surrounding areas. Data captured from the IMG surveys are stored centrally on the SDMMP website (SDMMP 2024).

Target animals will be recorded where seen during the rapid assessment. Additional surveys designed to capture the full range of each species habitat would be needed to understand the full distribution of target animal species, especially for rarer species; however, these additional surveys are outside the scope of this monitoring plan.

Animal species data analysis

To evaluate the distribution and status of target animal species over time, several analyses will be conducting depending on the quantity and quality of data we are able to collect. First, an indicator species analysis for plot groups will be conducted (De Caceres and Legendre 2009), as was outlined for plant species community data. These analyses will be conducted for all species, bird community data, pollinator community data, and terrestrial vertebrate community data. The output of this analysis will provide insight into which species are most strongly linked to community or year-specific groups. For a subset of species that are data-rich or score highly as indicators, single-species multi-year species distribution models, with spatial and temporal random effects, will be conducted. Habitat models will provide raster outputs of expected species distributions and how they change over time.

Survey Plot Selection

Power analysis

We conducted a power analysis to inform the number of plots needed in CSS and chaparral habitat classifications. The objective of the power analysis was to determine the number of required sites needed to achieve a minimum of 0.80 power to detect a significant change in mean vegetation cover, using simulated data. To evaluate the power to detect changes in vegetative cover over time, we simulated 1,000 datasets, each consisting of 75 CSS and 75 chaparral study plots (Appendix 7). Each dataset included two years of simulated data for percentage of non-native grass cover and native shrub cover. We simulated the first-year data from a normal distribution truncated with a minimum of 0, and we estimated means and standard deviations of native and non-native grass percent cover from field-measured vegetation data collected during 1995–2020 (Fisher et al. 2008, Kus and Houston 2021). We summarized the data within chaparral and CSS independently, by estimating mean and SD of observed cover (table 3).

Table 3*:* Summary of CSS and chaparral vegetation data collected non-continuously from 1995 to 2020 and used to simulate datasets for power analysis.
The values correspond to the mean (and standard deviation) of the percent cover data present across all years of sampling during the two included studies (Fisher et al. 2008, Kus and Houston 2021). The site visits column

corresponds to the total number of site visits present in the two datasets used for summary. Some sites were visited multiple times. These summaries were used to generate simulated data for the power analysis.

Site Classification	Non-Native Grass PC (SD)	Native Shrub PC (SD)	Site Visits
CSS	23.7 (28.7)	40.1 (31.7)	1072
Chaparral	9.68 (18.6)	42.2 (28.5)	705

We simulated a change in cover in the second years' dataset using a fixed multiplier. In 500 simulated datasets, we simulated increased non-native grass cover (mean = 1.2x, 1.4x, 1.6x, 1.8x, and 2.0x) and decreased native shrub cover (0.9x, 0.8x, 0.7x, 0.6x, and 0.5x), totaling 100 simulations per augmentation. We repeated this process when simulating decreased non-native grass cover (0.9, 0.8, 0.7, 0.6, 0.5) and increased native shrub cover (1.05, 1.10, 1.15, 1.20, 1.25). We chose to use different increments for simulated changes between non-native and native vegetation because we expect non-native annual grasses to exhibit more extreme changes between years. We estimated increases and decreases in native shrubs to be ½ of the change predicted for non-native grass because we estimated simultaneous change in open ground cover (which we chose not to include in further analysis).

We tested our power to detect increasing or decreasing percent-cover of non-native grass using analysis of variance (ANOVA) tests in R (R Core Team 2023). Specifically, we calculated the difference in non-native grass cover and native shrub cover as a function of year. We conducted this test separately for CSS and chaparral vegetation types. For each simulated dataset and vegetation community type, we ran 75 ANOVA tests, each time including an additional sample plot, until all 75 plots were included in the model.

We estimated power as the percentage of simulations that correctly detected a significant difference between years and described the minimum number of plots required to achieve a power of 0.80. We further describe the 95% credible range of power, to characterize uncertainty in our power estimate. Finally, we determined the ratio of plots required to achieve a power ≥ 0.8 for the weakest change scenario and report this as the suggested number of plots to maximize power.

The power to detect changes in vegetative cover increased as sample size increased and in datasets simulated with greater relative changes between years. Power also varied dependent on the vegetation type being considered (non-native grass or native shrub) and the vegetation community (chaparral or coastal sage scrub). The power to detect a reduction in non-native grass cover was slightly weaker than the power to detect an increase in non-native grass cover (fig 4). Mean power to detect changes in non-native grass cover was roughly equal for chaparral vegetation and CSS vegetation communities in the three strongest change scenarios. In the two strongest relative change scenarios for both positive and negative change (40%, and 50% change scenarios), and 30% change scenario for positive change, a power of 1 was achieved for CSS and chaparral given the maximum number of 100 possible plots. In the second weakest relative change scenario (20% change), a power of ~0.80 was achieved for CSS with 34 plots and chaparral with ~42 plots. In the weakest relative change scenario (10% change), we failed to achieve a power of >0.8 when considering up to 75 plots in either CSS or chaparral. On average, 1.24x the number of chaparral plots compared to CSS plots were required to achieve 0.80 power to detect an increase in non-native grass cover.

The power to detect changes in native shrub cover exhibited similar relationships between total percent change and sample size (fig 5). We estimated greater power to detect change in shrub cover within chaparral habitat, compared to coastal sage scrub. We achieved a sufficient power of 1 for the 3 strongest negative change scenarios (30%, 40%, and 50%) given the 100 plot-limit. We failed to achieve sufficient power to detect any of the positive change scenarios (5%, 10%, 15%, 20%, and 25%) given the 100-plot limit. On average, 1.25x the number of CSS plots compared to chaparral plots were required to achieve a power of 0.80 to detect negative change in native shrub cover.

The proposed plot structure outlined below consists of 55 CSS and 45 chaparral plots. The power to detect significant increases in non-native grass cover using this study design is outlined in table 4. For both CSS and chaparral, if relative change is equal to or greater than the

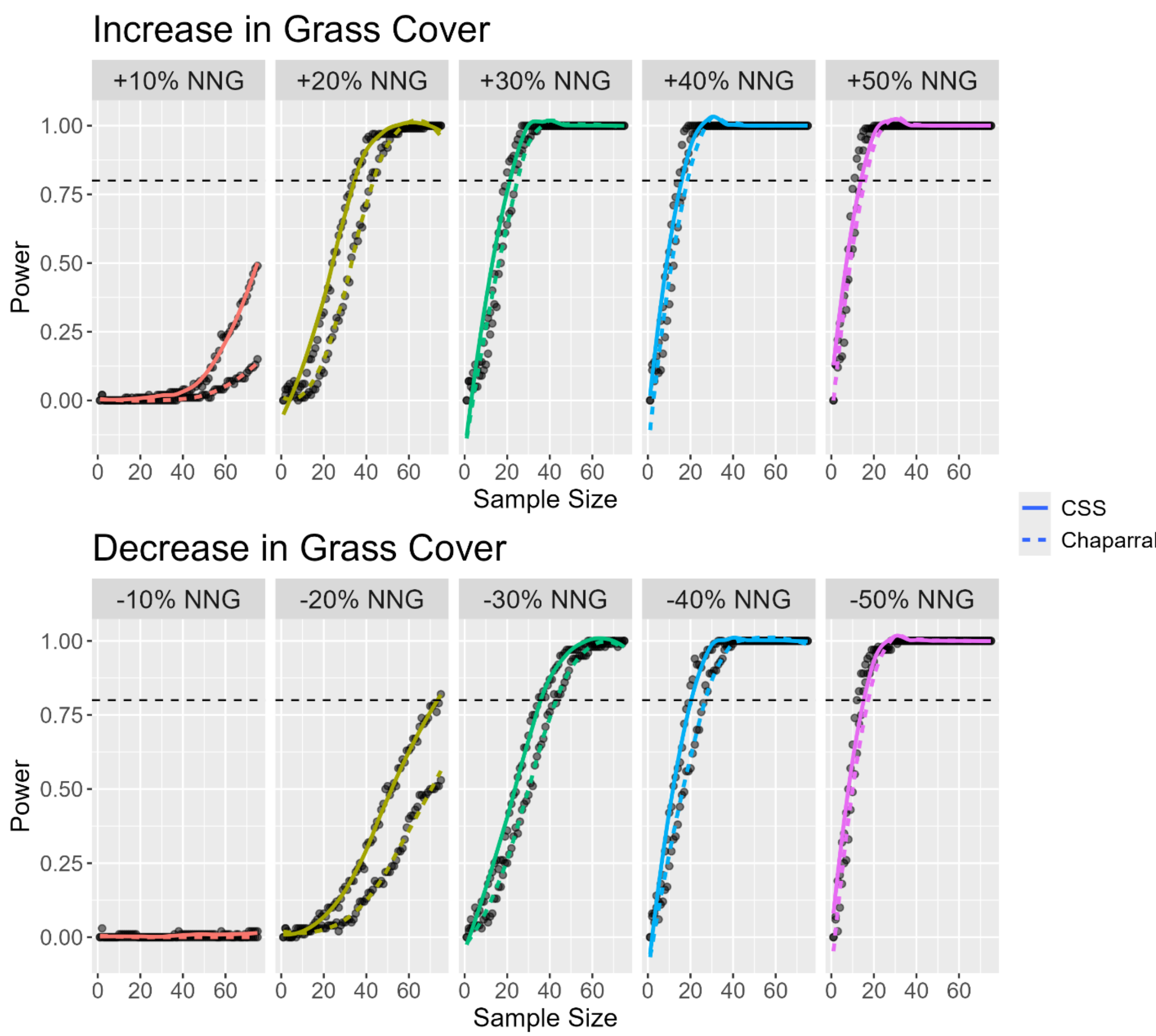

Figure 4: Power analysis for CSS and Chaparral vegetation communities under 5 different percent increasing and decreasing percent cover of non-native grass (NNG) change scenarios.
Power represents the proportion of simulations where the ANOVA p-value was ≤ 0.05. The dashed line represents a power of 0.80, our chosen cutoff for minimum desirable power.

three strongest scenarios, we predict a near perfect ability to detect the change (power = 1, upper 95% highest density interval for ANOVA p-value: <0.05), given the selected sample sizes. More CSS plots were chosen because CSS has a greater diversity in range of conditions and faces larger threats in San Diego County.

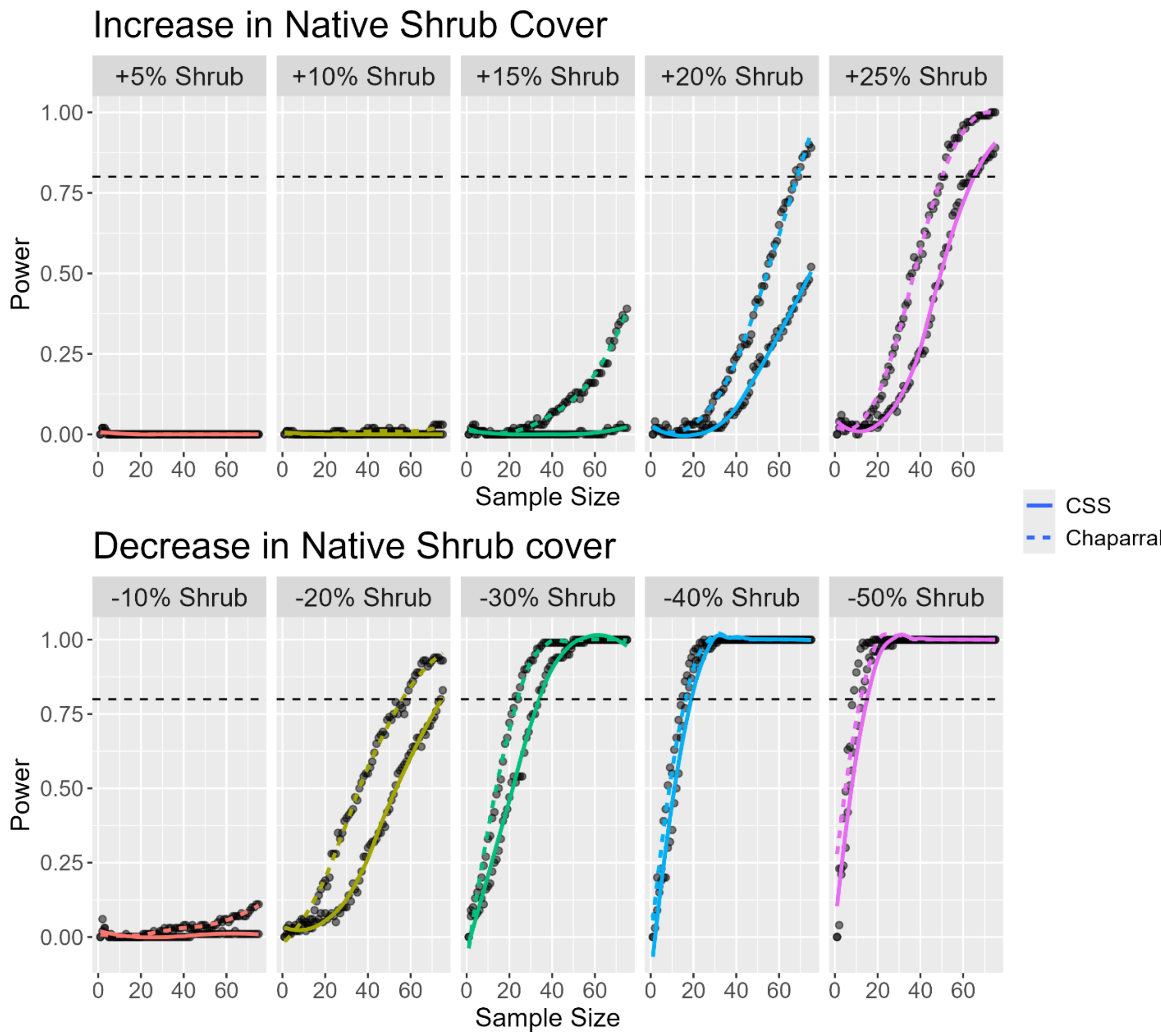

Figure 5: Power analysis for CSS and Chaparral habitat under 5 different increasing and decreasing percent native shrub cover (Shrub) change scenarios.
Power represents the proportion of simulations where the ANOVA p-value was ≤ 0.05. The dashed line represents a power of 0.80, our chosen cutoff for minimum desirable power.

Sampling frame and design

Areas of CSS and chaparral were taken from the 1930s Weislander vegetation map (Kelly et al. 2005, Kelly et al. 2008). This guaranteed that all native shrublands were included, even if they have already type-converted to a non-native grassland. The sampling frame was restricted to CSS and chaparral within the MSPA (western San Diego County) and limited to conserved lands with owners willing to participate in the field collection. Areas that have converted (based on 2021 vegetation map; City of San Diego and County of San Diego 2022) to urban, water, riparian, or forest were excluded.

Due to heavy urbanization along the coast, conserved lands tend to be in the eastern portion of the study area. A stratification of ecological subregions (eco-subregions) was used to ensure that small patches of CSS within the urban areas to the west were selected. There were four eco-subregions used (fig 6; County of San Diego Land Use and Environmental Group 2000). The total number of plots selected in each eco-subregion are listed in table 5. Table 6 shows the total acreage that was available (total in the sampling frame) to be chosen from each subregion in each vegetation type (County of San Diego Land Use and environmental Group 2000, Taylor 2005).

Table 4: Estimated power to detect change in non-native grass (NNG) cover in CSS and chaparral vegetation communities, under 5 different percent change scenarios.

Power is the percentage of simulations that had p-values ≤ 0.05 and correctly detected the difference in cover between years. The P-value columns correspond to the lower and upper 95% highest density interval of ANOVA p-values.

Community Type	Sample Size	Change Scenario	Power	P-value	
				L-95%	U-95%
CSS	55	NNG * 1.10	0.16	0.003	0.281
		NNG * 1.20	0.97	<0.001	0.028
		NNG * 1.30	1	<0.001	<0.001
		NNG * 1.40	1	<0.001	<0.001
		NNG * 1.50	1	<0.001	<0.001
Chaparral	45	NNG * 1.10	0.01	0.06	0.455
		NNG * 1.20	0.83	<0.001	0.071
		NNG * 1.30	1	<0.001	0.012
		NNG * 1.40	1	<0.001	0.001
		NNG * 1.50	1	<0.001	<0.001

Survey plots were aligned with the Landsat grid of pixels (EROS 2020). Landsat pixels are 30 m x 30 m, and a grid representing the center point of each pixel was created. Plots could not be within 1.5 km of each other. Random points were chosen from the entire sampling frame, but the plot center was the chosen as the closest 30-m grid point. The center point of the selected cell and the 8 surrounding cells were chosen as the 90-m^2 plot (fig 3).

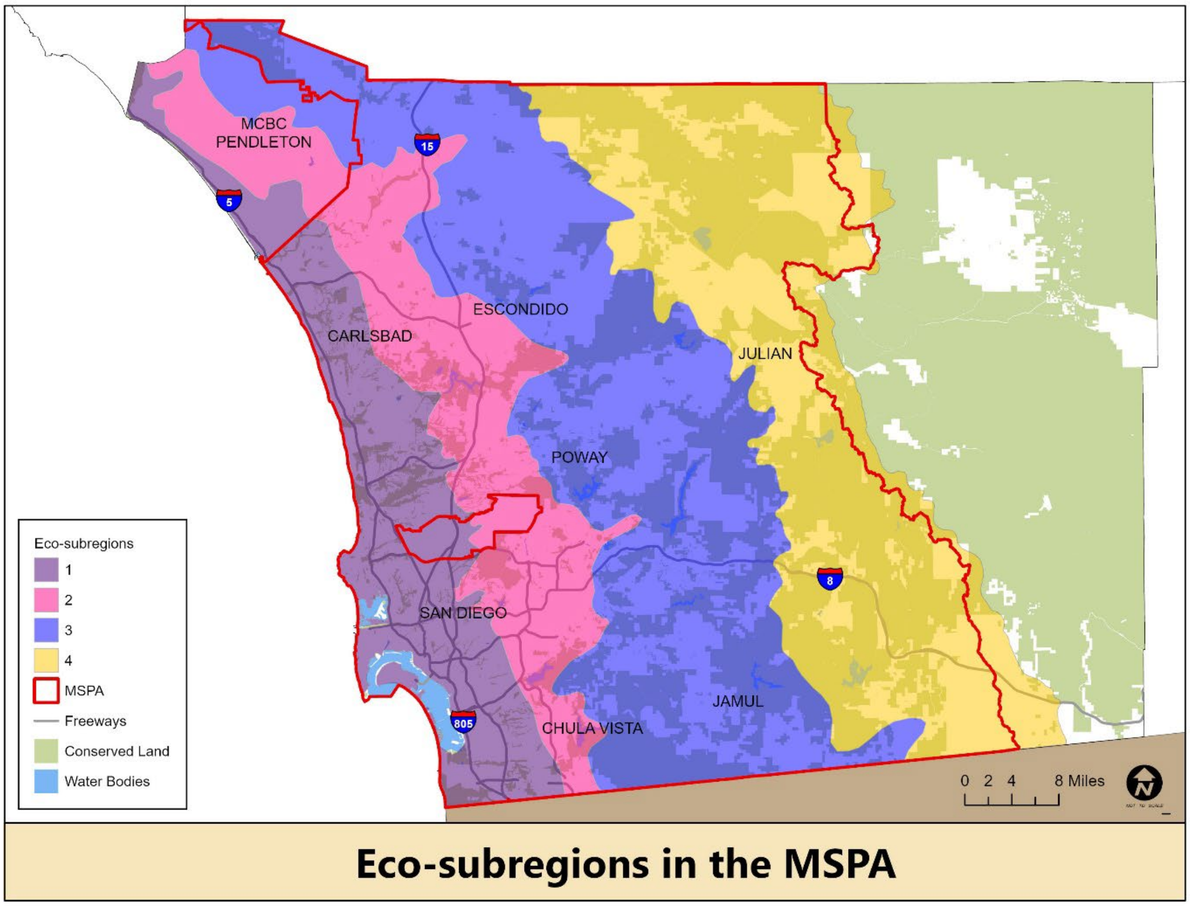

Figure 6: Map of the Eco-subregions that were used in the stratified random sampling (County of San Diego Land Use and Environmental Group 2000).

Plots were first evaluated in the office to verify that they did not include any urban development (including roads or large trails), open water, riparian, or forest vegetation. Plots that fell into one of those categories were moved the shortest distance to a shrubland or grassland

Table 5: The total number of plots selected within each eco-subregion with the percent of the total plots within each vegetation community (County of San Diego Land Use and environmental Group 2000, Taylor 2005).

Vegetation Community	Subregion 1	Subregion 2	Subregion 3	Subregion 4
CSS (55 total)	14 (25.5%)	17 (30.9%)	24 (43.6%)	0 (0%)
Chaparral (45 total)	5 (11.1%)	5 (11.1%)	17 (37.8%)	18 (40%)

Table 6: The total acreage in the sampling frame for each eco-subregion by vegetation community. The percentage indicates the percent of available habitat in each subregion by vegetation type County of San Diego Land Use and environmental Group 2000, Taylor 2005).

Vegetation Community	Subregion 1	Subregion 2	Subregion 3	Subregion 4
CSS	8,445 (8.5%)	22,297 (22.6%)	59,530 (60.4%)	8,269 (8.4%)
Chaparral	5,173 (1.3%)	11,156 (2.8%)	176,798 (45.2%)	197,707 (50.6%)

plot. If a suitable plot was not within 90 m of the existing plot, the plot was dropped, and a new random point was selected from a set of backup plots. Ten backup plots within each subregion and vegetation type were chosen (80 total). Backup plots were given a random number and selected in order of largest random number to smallest.

Four plots were manually moved to align with previous pollinator plots (Hung et al. 2019). Survey locations were moved when there was a pollinator plot within 1.5 km and were in the same historical vegetation community. The plots moved were in Rancho Jamul Ecological Reserve, Rice Canyon Open Space Preserve in City of Chula Vista Preserve, Chollas Radio System Open Space, and the San Diego National Wildlife Refuge. Pollinator plots have multiple years of pollinator data that can be leveraged for more in-depth analysis of change in the biodiversity over time. Pollinator monitoring at all CSS plots will be performed with the first year of vegetation surveys and more will be phased in at more plots over time.

If a plot is inaccessible in the field, the crew should first try to get as close as possible while staying within the same historical vegetation type (crews will need 1930s vegetation maps loaded on a handheld device to verify the historical mapping; crews will also need the grid to line up new plots). If a point has a road or building intersecting the plot, the plot should be moved the shortest distance required to eliminate any human development from the plot. If the plot is on a steep cliff or area that is otherwise not accessible on foot, the plot should be moved the shortest distance to an accessible area while maintaining the same historical vegetation type. If a plot is completely inaccessible and a plot within a close proximity is unavailable, the crews should choose another random plot from the backup list to complete. This point may be somewhere else in the county.

Description of survey plots

The final set of survey plots are shown in fig 7. Each plot contains 9 subplots (fig 3). All subplots were within the same historic mapped vegetation type. The current vegetation classification for each subplot was calculated (City of San Diego & County of San Diego Planning Department 2022). Many of the larger plots changed to multiple vegetation types so subplots were used in these calculations to capture the heterogeneity of the change over time. A total of 29% of the subplots changed vegetation category from the 1930s to present, not accounting for changes to urban, riparian, water, or pine forests (see above). Within historical chaparral, the largest change was to CSS (11.1% of subplots). Almost 2% changed classification to grasslands. Another 1.7% were classified as "Other" or "Torrey Pines Forest." All of these plots were evaluated from aerial imagery and were determined to be on the edge of a transition area where shrubs and grass still dominated.

Within historical CSS, 60.5% remained as CSS. The largest change was to chaparral (25%). Based on viewing of the aerial imagery, many of these classifications may be inaccurate. Field surveys will determine the correct classification, where necessary. More than 13% of the subplots converted to grasslands. And 1.5% were classified as water but are located close to a reservoir where water level fluctuates regularly. If these plots are inaccessible at the time of the survey, surveyors should follow the above instructions for moving the plot.

Percent cover of annual herbaceous, perennial herbaceous, bare ground, litter, shrub, and tree were calculated for each plot based on the RAP data (Allred et al. 2021). Field data will be used to validate this remote sensing model and refine herbaceous categories in the future. A

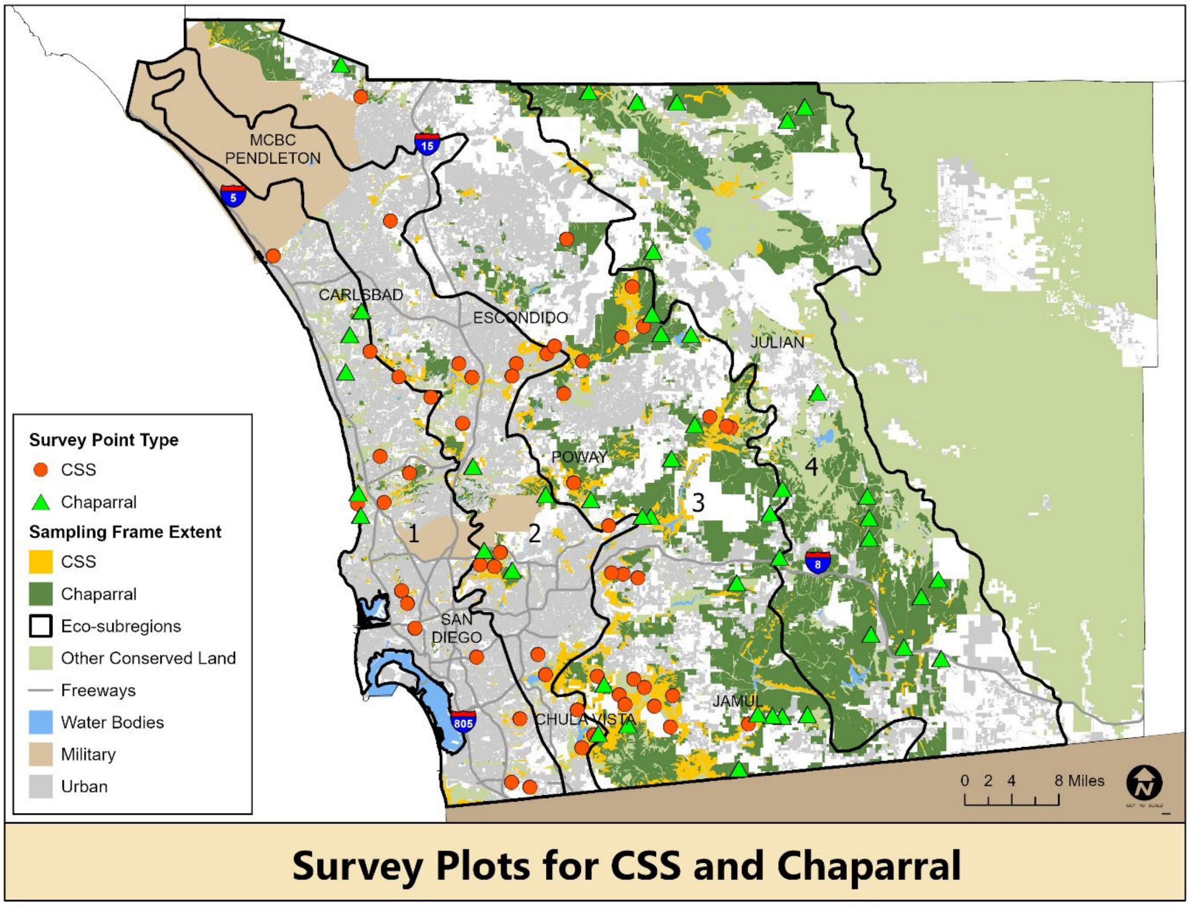

Figure 7: Map of permanent plots chosen with vegetation type (1930s Weislander classification)

summary of all values is presented in table 7. RAP data from 1986 and 2020 are presented to show the general characteristics of the plots chosen and differences between vegetation type and eco-subregion. Rainfall for both 1986 and 2020 were higher than normal. Lindbergh field rainfall was 14.95 inches (144% of normal) for 1986 and 13.6 inches (132% of normal) for 2020 (San Diego County Water Authority 2023).

Overall, in 2020, CSS had a higher percent cover of annual herbaceous (24.1% average cover over all CSS subplots) than chaparral (10.7% average cover over all chaparral subplots).

Table 7: Mean (standard deviation) percent cover of vegetation functional groups in eco-subregion subplots based on 1986 and 2020 RAP models.

	1986 Annual Herb-aceous	1986 Bare ground	1986 Litter	1986 Perennial Herb-aceous	1986 Shrub	1986 Trees	2020 Annual Herb-aceous	2020 Bare ground	2020 Litter	2020 Perennial Herb-aceous	2020 Shrub	2020 Tree
Chaparral	**mean (SD)**											
Eco-subregion 1 (n=45)	9.6 (5.3)	3.5 (2.7)	9.8 (2.5)	13.3 (3.4)	25.5 (6.1)	14.2 (4.9)	10.2 (3.6)	1.3 (1.6)	8 (1.9)	4 (3.2)	43.7 (14.7)	20.2 (13.6)
Eco-subregion 2 (n=45)	16.5 (7)	5.7 (2.5)	9.3 (2.4)	12.6 (3.5)	29 (9.1)	6 (5.6)	17.2 (9)	4.1 (2.4)	7.4 (1.6)	7.4 (2.9)	42.2 (9)	12.5 (8)
Eco-subregion 3 (n=153)	6.1 (4.2)	4.6 (3)	9.9 (3.8)	12.5 (4.4)	28.8 (15)	11.8 (8.1)	11.4 (6.2)	2.9 (2.6)	7.7 (3.3)	8.2 (5)	38.9 (12.9)	11.7 (8.1)
Eco-subregion 4 (n=162)	6.4 (7.4)	5.9 (5.3)	12.4 (3.7)	11.9 (5)	28 (13.6)	16.8 (10.3)	8.4 (6.8)	5 (4.7)	7.8 (3.3)	8.7 (5.5)	33.4 (12.3)	15.4 (6.8)
All Subplots (n=405)	7.7 (7)	5.1 (4.1)	10.8 (3.7)	12.4 (4.5)	28.1 (13.1)	13.4 (9.2)	10.7 (7.1)	3.7 (3.7)	7.7 (3)	7.8 (5)	36.5 (13)	14.2 (8.8)
CSS												
Eco-subregion 1 (n=126)	13 (11.3)	4.4 (3.3)	10.4 (3.2)	11.3 (3.9)	24.9 (12.5)	13.5 (10.6)	14.5 (12.8)	2.9 (2.8)	7.6 (2.6)	5.2 (3.3)	31 (19)	19.8 (20.9)
Eco-subregion 2 (n=153)	28 (10)	6.2 (3.2)	9.8 (2.5)	16 (8.2)	17.6 (9.2)	5.6 (3.8)	32.7 (19.1)	5.1 (2.8)	8.7 (3.3)	5.3 (4.1)	28.7 (16)	7.3 (3.9)
Eco-subregion 3 (n=216)	18 (9.6)	7.2 (2.7)	11.2 (3.4)	15.4 (5.1)	24.4 (11.9)	5.7 (3.9)	23.7 (16.1)	5.8 (3.3)	8.9 (3.4)	7.4 (3.9)	32.6 (13.7)	7 (3.3)
Eco-subregion 4 (n=0)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
All Subplots (n=495)	19.8 (11.7)	6.2 (3.2)	10.6 (3.1)	14.6 (6.3)	22.4 (11.7)	7.6 (7.2)	24.1 (17.7)	4.8 (3.2)	8.5 (3.2)	6.2 (4)	31 (16)	10.3 (12.3)

Chaparral subplots had a higher average percent cover of shrubs (36.5%) and trees (14.2%) than CSS (31.0% for shrub cover and 10.3% for tree cover).

Comparing RAP data for 1986 to 2020, both CSS and chaparral subplots had an increase in average cover for annual herbaceous and shrub cover. CSS subplots increased from 19.8% to 24.1% annual herbaceous cover and from 22.4% to 31.0% in average shrub cover. Similarly, chaparral subplots increased from 7.7% to 10.7% in annual herbaceous cover and from 28.1% to 36.5% average shrub cover. In CSS subplots, litter increased, and perennial herbaceous cover decreased slightly. Other cover categories remained relatively unchanged.

Differences in cover averages were apparent between eco-subregions in both 1986 and 2020. In 1986 in chaparral and CSS subplots, eco-subregion 2 had the highest average annual herbaceous cover with 16.5% in chaparral subplots and 28% in CSS subplots. In 1986, average shrub cover in CSS subplots was highest in eco-subregion 1 (24.9%), but the average shrub cover in chaparral subplots was highest in sub-ecoregion 3 (28.8%). In 1986, the average shrub cover in CSS subplots was lowest in eco-subregion 2, but the average shrub cover in chaparral subplots was lowest in eco-subregion 1 (25.5%). There were not any CSS subplots selected for field surveys in eco-subregion 4 (fig 7).

In 2020, for both chaparral and CSS subplots, eco-subregion 2 had the highest annual herbaceous cover (17.2% for chaparral and 32.6% for CSS subplots). In 2020, eco-subregion 4 had the lowest average annual herbaceous cover in chaparral subplots (8.4%). In 2020, eco-subregion 1 had the lowest average annual herbaceous cover in CSS subplots (14.5%), but CSS plots were not selected in eco-subregion 4. Eco-subregion 3 had the highest average shrub cover in chaparral subplots (38.9%) compared to other eco-subregions in 2020. However, eco-subregion 3 had the highest average shrub cover in CSS subplots in 2020 (32.6).

Fire history among subplots varies across the landscape. Unburned (between 1993-2022) subplots make up 37.4% of the total subplots. Subplots that burned once since 1993 make up 39.8% of subplots. Plots that burned two and three times since 1993 make up 15.8% and 7% of subplots, respectively. A small portion of the county has burned more than three times since

1993 (<2,800 acres of the 492,464 acres in the sampling frame). This is less than 0.5% of the sampling frame and is not represented in the subplots.

Data Collection and Storage Plan

Data fields collected will detail survey efforts and include plant species names, soil properties, plot and collector information, and animal species present with associated information. For herbaceous quadrats, plant species and substrate will be recorded for each of 100 sample plots. Data will be collected in the field electronically and meet standards for each field requirement, as necessary. Field sheets are available in Appendix 3. All data will be stored long-term in the South Coast Multitaxa Database (SC-MTX; Watson et al. 2021) hosted by the U.S. Geological Survey and available through the SDMMP website (sdmmp.com). SC-MTX is the foundational database driving the SDMMP website. The project pages on sdmmp.com contain project metadata and raw data for projects related to conservation in San Diego County and information is housed in SC-MTX (sdmmp.com/projects.php/).

In addition to attribute data, spatial data including polygons and imagery will be collected and stored long-term on the same U.S. Geological Survey servers. Spatial data will be stored in a spatial database engine (SDE) and linked to a SQL server. Connections to locations and previously collected data will be made in SQL and updated automatically based on the survey locations.

Central data storage and standardization of collection will allow for analysis of data across time and space. It will also allow analyses to include field-collected data from other studies in the region. The SC-MTX is designed to store plant and animal data, track name changes, and link data to location and other GIS data (e.g., fire perimeters, climate rasters, etc.).

Finally, all project metadata will be stored with raw data in SC-MTX. This information is available for all projects in the region through the SDMMP website. This project will be tracked on a project page at https://sdmmp.com/view_project.php?sdid=SDMMP_SDID_71_663178c710cba.

Conclusion

Western San Diego County is dominated by native shrublands, classified as either CSS or chaparral. These vegetation communities have been degraded over time, in part due to the introduction of non-native annual grasses. Ecological integrity of a vegetation community is complex and can be difficult to measure. Decades of research in San Diego County led to the development of an index that correlates closely with integrity. The presence and percent cover of non-native grasses in native shrublands can be used to measure ecological integrity and provides an ease and consistency of measurement for land managers (Diffendorfer et al 2007).

An initial conceptual model of the type-conversion process identified fire as the main driver of change. Fires have become more frequent and native shrub communities have not had time to recover while non-native grasses are able to spread very quickly. Higher cover of grasses feeds fire fuel load and creates a positive feedback loop between grasses and fire. This leads to the further decline of shrub cover.

Other factors may also contribute to invasive grass expansions including nitrogen deposition, changing climate with more severe and prolonged droughts, topography, and soil properties. Many of these factors interact with each other to exacerbate the change and potentially reduce shrub cover further. Understanding the relationships between all these factors in San Diego County is an important step forward in developing management practices.

The goal of this monitoring plan project is to capture the complexity of this system through a combination of GIS/remote sensing products, field surveys, and UAS imagery. Data will be collected to enable analyses to identify change and model threats and environmental factors associated with vegetation change. Field-based vegetation surveys will utilize UAS imagery of permanent plots chosen from historical CSS and chaparral on currently conserved lands. Collected imagery can be stored permanently and aid in future projects or identifications. Plant species level information will be collected from the imagery on the SLATS design leading to thousands of plant points across San Diego County.

Combining survey data with existing GIS and remote sensing products will allow us to leverage the data to a landscape scale. Broad-scale variables will not capture species level information but can identify areas with high herbaceous and shrub cover. Point surveys are designed to align with remote sensing imagery to allow for the validation and refinement of landscape-scale products over time.

A power analysis of historical data showed that 100 total plots are enough to show a 25% change in grass cover. Because of a higher level of variability, 55 plots were chosen in CSS and 45 plots in chaparral. To ensure that coastal plots were chosen, stratified random sampling was used with eco-subregions. The plots cover the range of natural variation of vegetation communities, coastal and inland, edge and interior, and existing integrity levels.

The outcomes of this project will result in high-resolution imagery, detailed soil information, plant species information for thousands of points, and a compilation of the best existing GIS and remote sensing data. The data will be stored permanently for use by conservation stakeholders in San Diego. The results of these analyses will provide the stakeholders in the region with maps of change and stability, an understanding of the forces associated with changing vegetation composition and cover, and plant and animal species that are indicators of high and low integrity. These results can be used to inform management of preserves, with data and results of analyses available to stakeholders.

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Appendix 1: The Use of Unmanned Aircraft Systems (UAS) for Vegetation Sampling, Unpublished report

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THE USE OF UNMANNED AIRCRAFT SYSTEMS (UAS) FOR VEGETATION SAMPLING

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THE USE OF UNMANNED AIRCRAFT SYSTEMS (UAS) FOR VEGETATION SAMPLING
WHITE PAPER

1.0 INTRODUCTION

This document describes the methods used and some lessons learned during a pilot study conducted by AECOM for the San Diego Management and Monitoring Program (SDMMP) during the spring of 2020. The pilot study replaced standard field-based biological monitoring methodology with a hybrid monitoring approach that integrated field survey with high-resolution aerial imagery collected from Unmanned Aircraft Systems (UAS). The goal of the study was to provide plant composition and cover data that will be used by SDMMP to develop a model that classifies the ecological integrity of vegetation communities throughout western San Diego County. The model will integrate the results of this study with imagery provided by the U.S. Department of Agriculture's National Agriculture Imagery Program (NAIP), which is produced on a two-year cycle and made available to governmental agencies and the public within a year of acquisition (USDA 2021).

The methodology used in this study was derived from the Statewide Landcover and Trees Study (SLATS) that was developed for use with Landsat imagery (Kuhnell et al. 1998). The initial goal was to sample vegetation within 90 plots across San Diego County that represent the most common native vegetation communities. Each plot was 90 meters by 90 meters in size and was subdivided into nine 30 meter by 30 meter plots, within which vegetation data were recorded at intervals along intersecting transects within each plot. Due to the projected timing of the NAIP flight, it was necessary for all sampling to occur within the month of May. When considering a standard field-based methodology, several concerns were identified:

The required labor effort for data collection was very high due to wide geographic distribution of locations and high number of transects (27) required at each plot. Assuming two biologists can sample two plots per day on average, the field effort for 90 plots would require two to three teams working five days per week for four to five weeks.

The act of sampling causes unintended impact/damage to the target vegetation, especially in intact chaparral and coastal sage scrub vegetation communities.

The difficulties associated with field assessment over rugged terrain and within dense shrublands would restrict the biologists' ability to assess true "straight-line transects" and raised concerns about the spatial accuracy of the resulting point data.

The integration of the UAS imagery was proposed as a solution to mitigate these concerns, and to test a methodology that could provide a cost-efficient, low-impact, spatially accurate database to document the ecological condition of vegetation communities within the study area. This hybrid sampling approach was proposed by AECOM and accepted by SDMMP. The hybrid approach involved the collection of in-situ (in-field) biological data and high-resolution true color aerial imagery, followed by ex-situ scoring each of transect in a desktop Geographic Information System (GIS) environment. The biologist scored the point intersect for each transect using manual photo interpretation.

2.0 Data Acquisition Methodology

Sampling plots were selected by SDMMP to represent the target vegetation communities within the study area and were placed on property where field survey was feasible. (See the Permitting, Access, and Data Agreements section for more information about access permissions.) Each sample plot was 90 meters square. Plots were selected to represent the target native vegetation communities within western San Diego County. Figure 1.1 provides an example of sample plots located northeast of Ramona that were considered for this study.

Figure 1.1. Overview of proposed sample plot locations, San Diego County, north of Ramona. (Image: Google Earth) Green plots were selected and surveyed.

All of the data acquisition for this study was conducted in May and June of 2020, which temporally aligned with the planned NAIP flight for San Diego County. Biological field assessments were conducted concurrently with aerial image acquisition. The survey team consisted of two botanists and a UAS pilot. The survey team was able to complete two to four plots per day, depending on travel time to each site and the distance of the plot from a drivable road (i.e., overland hiking time).

For each sample plot, the survey team did the following:

1. Established four ground control points to assist aerial photo georeferencing.
2. Collected aerial images of the sample plot using UAS and a pre-programmed flight path.
3. Recorded a complete floral inventory for the sample plot.
4. Recorded an estimate of absolute percent cover (ocular) for shrub and herbaceous vegetation types within the sample plot.
5. Recorded an estimate of the relative cover of native versus non-native of herbaceous cover within the sample plot.
6. Recorded per-species cover within six 0.25-meter quadrats within the sample plot.
7. Collected georeferenced photographs of each quadrat.
8. Collected georeferenced photographs of representative taxa.

Aerial imagery was collected using a DJI Phantom 4 Pro UAS. All flight missions were planned and executed using Licthi flight software (https://flylitchi.com/). Two flights were conducted at most plots to maximize spatial resolution (at low altitude) and to support photogrammetry (higher altitude). The range of flight altitude was generally 44 feet for low altitude and up to 150 feet for high altitude.

Ground control targets were printed on letter-sized paper. Four ground control points were set with one near each corner of the plot; ground control point locations were collected using a Trimble R1 Global Positioning System (GPS) unit. In limited cases, the establishment of ground control points was precluded due to dense vegetation with no gaps in cover. In these cases, georeferencing was conducted manually by the photogrammetrist.

The purpose of the complete floral inventory and the representative photographs was to support the biologist to identify taxa during the ex-situ scoring, which was done using the imagery (see the Vegetation Sampling Methodology section). The purpose of cover estimates for the plot (shrub, herb, native, non-native) was to provide semi-quantitative information to support scoring but also be used as ancillary data to describe overall condition of the plot. Quadrat locations were chosen in the field to be representative of the condition of herbaceous cover in each plot.

Photographs were taken of each quadrat to assist in the determination of photo-signatures for native and non-native herbaceous cover. A photo of the quadrat sample area is provided in Figure 1.2.

Figure 1.2. Photograph of a 0.25-meter sample quadrat dominated by the native annual *Zeltnera venusta* and the non-native grass *Festuca myuros* (J. Dunn, May 2020).

3.0 Post-Processing Methodology

Post-processing of the aerial images was conducted using Agisoft Metashape software (https://www.agisoft.com/). Each plot contained 500 to 1000 raw images (4 mm and/or 6 mm spatial resolution) that needed to be orthorectified and mosaicked together to create one georeferenced orthomosaic per plot. The setup time for post-processing averaged one hour per plot, and Agisoft programming scripts were used to maximize efficiency (i.e., to process the plots in batches). Machine time for each orthomosaic was generally two to four hours, but it varied widely depending on the complexity and vegetative content of the imagery and the processing speed of the computer.

For some plots, initial processing was unsuccessful due to pervasiveness of vegetative canopy. The processing software is designed to generate like locations between overlapping images. In those plots that only offer vegetative canopy and not, or little or few, patches of ground, the software was not able to find matching points. This issue was magnified on days when winds were high. The moving canopy from a frame-to-frame perspective prevented potential matching candidate locations from being detected.

Other issues encountered included ground control points that had moved due to wind and plots where ground control points could not be set due to canopy pervasiveness. For these, manual inputs were provided to the software based on visual assessment of the imagery. In some cases, a greater reliance on the onboard drone GPS system was used to spatially locate the imagery.

4.0 Vegetation Sampling Methodology

Once the orthomosaic was complete for each sample plot, biologists overlaid the sample plot boundaries and SLATS transect points using GIS. A 10-centimeter circle was created around each SLATS intersect point to provide an unobstructed view of the sample point. The center-point of each circle was scored to a shrub taxon or ground cover type. An example of the SLATS overlay for a full sample plot is shown in Figure 1.3; an enlarged view is provided in Figure 1.4.

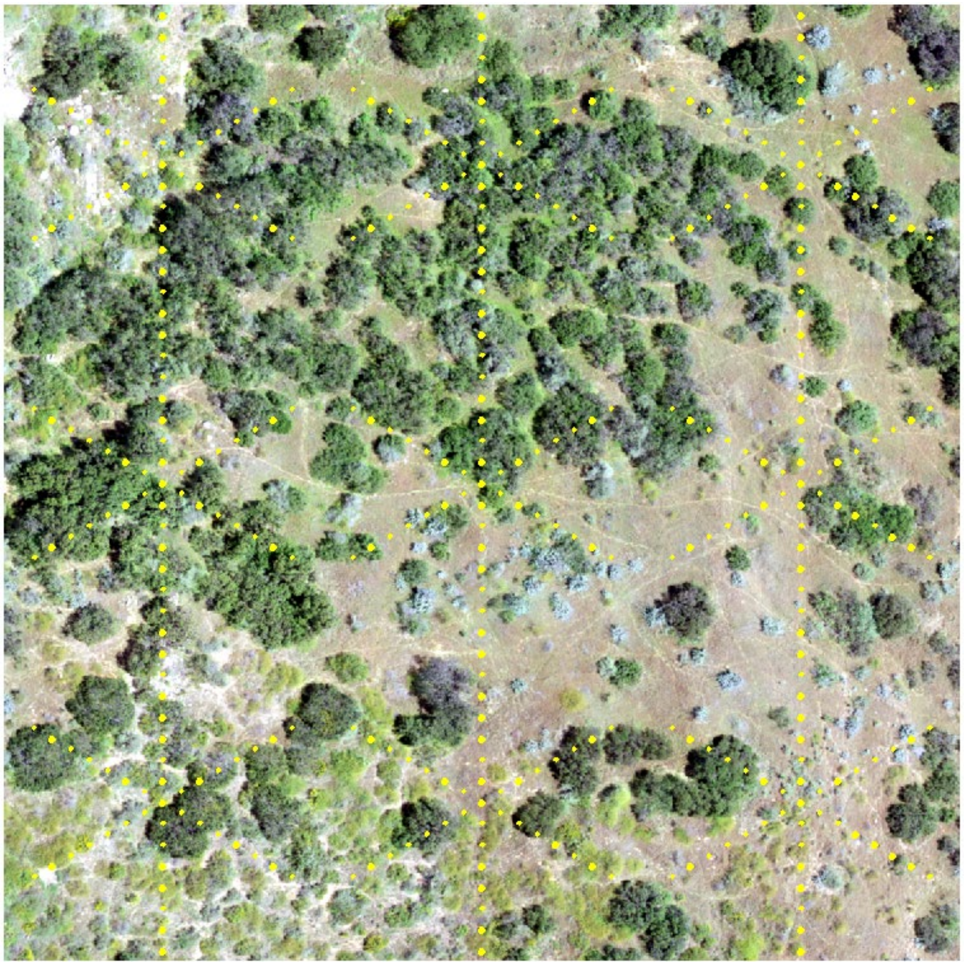

Figure 1.3. Final orthomosaic of one 90-meter square sample plot with SLATS survey points for vegetation sampling (i.e., scoring).

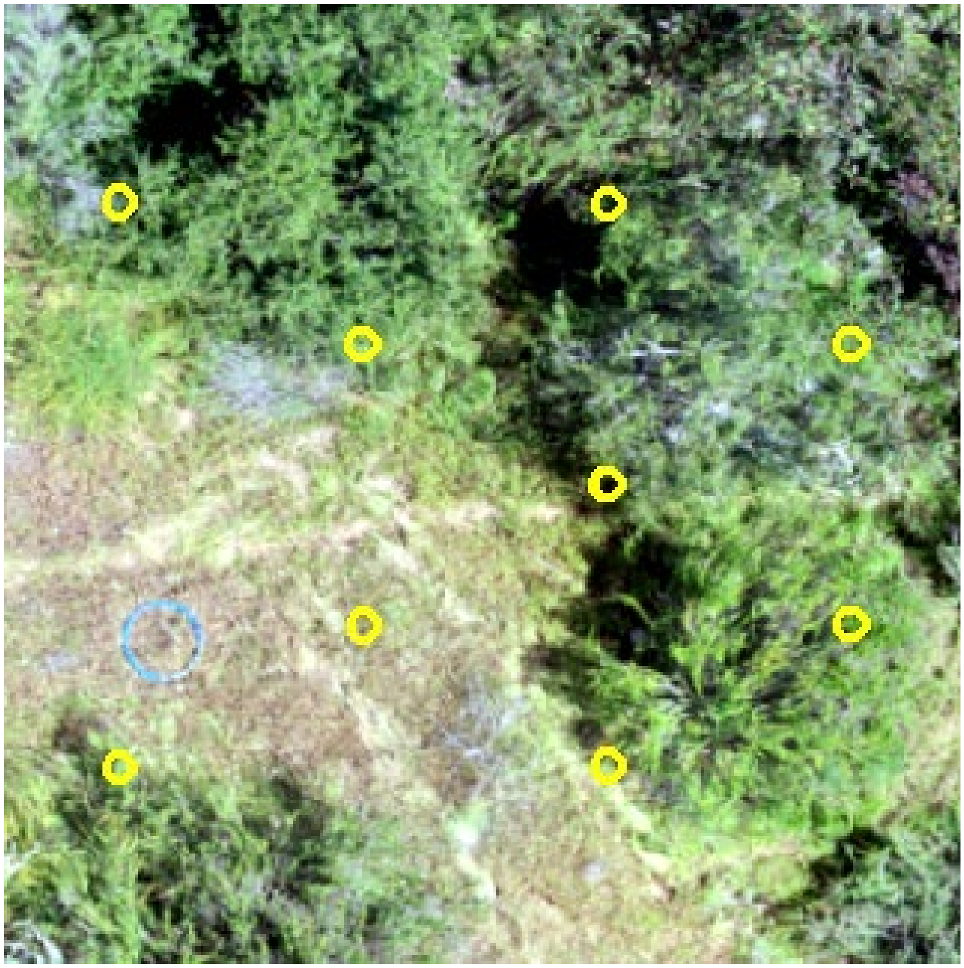

Figure 1.4. Enlarged view of the SLATS points; vegetation sampling was conducted for each 10-centimeter circle.

Shrub scoring assignments were based on the floral inventory list for each plot that was created during field assessment. Herbaceous vegetation was scored as either native or non-native. Where no vegetation was present, the point was scored to either litter, rock, or bare ground. As each plot contained 27 transects, a total of 405 points was scored for each plot. Data were entered directly into the transect point attribute table in GIS.

In nearly all cases, the biologist scoring the sample plot was also present during field survey. As guidance for decision making, they had available to them a complete floral inventory for each plot, representative photographs of key taxa, high-resolution data from the sample quadrats, and visual estimates of cover for the plot (shrub, herb, native, non-native). See the Data Acquisition Methodology section for more information.

Manual scoring the 405 points for each plot averaged three hours. The primary limiting factor for the speed in scoring each plot was image quality. Lower-quality plots imaged required the biologist to spend more time checking plot reference images and floral inventories for confident scoring. Primary limiting factors for image quality were windy conditions during sampling and the quality of the sensor used.

5.0 UAS Licensing Requirements and Flight Restrictions

The Federal Aviation Administration (FAA) regulates all commercial UAS applications. To fly UAS under the FAA's Small UAS Rule (under Title 14, C.F.R. Part 107), the pilot must hold a Remote Pilot Certificate from the FAA. To obtain this certificate, the prospective pilot must demonstrate an understanding of the regulations, operating requirements, and procedures for safe UAS operation. To operate a UAS in any controlled airspace (near airports, military installations, etc.), prior authorization must be obtained.

Individual property owners and managers may have specific restrictions for operating a UAS on their properties. As examples, San Diego Gas and Electric (SDGE) requires all prospective pilots to be vetted by their Aviation Services Department and to be able to demonstrate an understanding of the SDGE Aviation Operations Manual. Additionally, the Department of Defense (DoD) and the Department of the Interior (including the U.S. Fish and Wildlife Refuge system) has banned the use of UAS manufactured outside the United States for all internal and contractor operations. The DoD's Defense Innovation Unit recently finalized its trusted small UAS (sUAS) initiative (Blue sUAS); it approved five companies based in the United States and/or allied nations for immediate use on projects with a federal nexus.

6.0 Permitting, Access, and Data Agreements

Regulatory permits, memorandums, and access agreements must be secured and are required for access to public or private properties prior to UAS deployment. Permits for this project were obtained within a four-week period and included access permission from seven land managing entities. These entities represent utility companies, local government, non-profit, and private organizations. In general, access permit inquiries consisted of four phases: material preparation, initial contact, follow-up, and contract development/execution.

Preparing for initial contact involved gathering all pertinent information about the target survey areas, including maps with proposed access areas and routes. Submitting geospatial data (e.g., kmz, kml, or Shapefile) was particularly useful in streamlining permitting procedures. Acquiring the appropriate contact information can be facilitated through a local land manager-facing organization (e.g., SDMMP); due to the nature of our work, the appropriate contacts existed in AECOM’s network of working relationships. In some cases, contacts can be acquired through an organization’s website contact page. Keep in mind, it may take contacting several organization personnel to find the right person, as was the case for one entity on this project.

Following initial contact, land managers requested clarification and more details on the project and expressed concerns over the use of UAS on their lands. Often, airspace activity may be limited or restricted due to FAA regulations or sensitive resources; refer to the UAS Licensing Requirements and Flight Restrictions section of this paper for more information on airspace limitations. Airspace limitations may or may not be known to land managers and, in any case, it is the UAS pilot's and study practitioner's responsibility to be in full compliance.

Contract formality for access can vary across and is driven by land managers; for this project, access was granted via verbal agreements, signed memorandums, and multi-page contracts. When working with government, non-profit, and private entities, a certificate of insurance is often requested, and required coverage will vary. For this project, three variations of insurance coverage were provided. In addition, agencies and property owners will often request copies of the data acquired from activities on their property.

7.0 Limitations Related to COVID-19

This project was initiated in the early spring of 2020 and coincident with myriad restrictions on travel and association placed on individuals and businesses by local, state, and federal mandates related to the COVID-19 virus. It is both difficult to underestimate and impossible to quantify the impact that these restrictions had on the overall outcomes of this project. We provide two examples of such limitations.

The first limitation was that supply chains were interrupted during a critical planning phase of this project. AECOM had made plans to upgrade the consumer grade UAS (albeit higher-end consumer grade) that it was operating to a more robust commercial UAS platform and sensor with higher photographic resolution and improved flight characteristics. However, aggressive state and federal COVID-19 restrictions during March and April made the timely purchase or rental of this equipment impossible, as manufacturers and vendors were either unresponsive to our inquiries or unable to deliver products within the project timeline. Attempts to procure equipment from within AECOM were unsuccessful due to restrictions that prevented business travel during this time.

The second limitation was that many property owners prohibited access to their lands in response to COVID-19 concerns and restrictions. The loss of these areas from the study reduced the geographic stratification of sampling sites across the study area.

We believe that a superior product could have been achieved if this project would have been undertaken in a less restricted environment, but because the primary goal of the project was a proof of concept for UAS data acquisition; we believe the project was successful despite these restrictions.

8.0 Lessons Learned and Recommendations for Future Applications

Of the 66 sample plots for which imagery was collected, five were deemed unacceptable for confident shrub identification. The quality of orthomosaics varied widely due to challenging field conditions, but the quality improved as the project progressed due to near-daily review of image products, in-field adjustments, and discussions with an extended team of UAS experts within AECOM. The primary quality issues experienced were (1) feature resolution was too low for fully automated georeferencing and photogrammetry, and (2) image clarity was too low for shrub and tree species identification. The sources of these quality issues are summarized in this section, along with solutions that were identified and recommendations for future work.

The compressed timeline for data acquisition (May 1 to June 15) did not allow for much flexibility in flight scheduling. Many flights occurred during less-than-ideal weather conditions, including poor light conditions and moderate to high winds. Wind affected the flight stability of the UAS, but more significantly, the wind moved the relative position of the vegetation from image to image during the capture. This movement made the assignment of “tie points” problematic for photogrammetry software and resulted in a final image that was less clear than it would have been with less movement due to wind. Having more possible flight dates for any planned mission would allow selection for more ideal weather conditions.

The orthomosaics produced from the raw images collected using the DJI Phantom Pro 4 were generally considered adequate for the identification of shrub species but inadequate for high confidence in identifying native and non-native herbs. Higher-quality sensors are recommended for future applications. The current development of UAS technology is rapidly evolving; therefore, any specific recommendations for UAS platforms and sensors would likely be quickly outdated. However, when considering photographic image acquisition equipment, the quality of the sensor and optics should be considered of the highest importance. Increased raw image quality would assist with both primary quality issues identified in this study: feature resolution and image clarity.

Increased raw image quality will make post-processing simpler for the mosaicking software and result in high-quality orthomosaics. The use of higher-quality optics and sensors will require less flight time per area to acquire similar quality images compared to lower-quality sensors and optics. The quality of the airframe is secondary consideration. Pilot preference for airframes should consider the robustness of the platform, flight time, and load capacity.

If in-situ data collection is not required for the confident identification of species, consider other means for aerial image collection. Manned aircraft (such as helicopters) can capture very high-resolution imagery more rapidly over a broader geographical area in a shorter amount of time. When considering labor hours for UAS deployment, manned aircraft may be cost competitive with UAS. Helicopter acquisition was considered for this project but rejected due to timing constraints and COVID-19 restrictions.

If the same plots are resampled over multiple seasons, consider establishing semi-permanent ground control points for each plot. Fixed ground control would reduce costs for resampling and provide higher confidence in the georeferencing process. If sample plots contain physical structures such as pipelines, well heads, foundations, or other solid features identifiable from the air, these features can also be measured with RTK GPS units to serve as ground control points.

9.0 Conclusions

Results of the pilot study show that integrating UAS into vegetation field survey is an affordable option that adds a multitude of benefits as compared to a standard field-based approach. Although it may not be the best option for all situations, its use in this study added value in many ways.

Use of UAS in this study reduced necessary field time, which was extremely beneficial due to the narrow window we had to conduct field surveys (May 1 to June 15). The survey team was able to complete four plots per day on average, whereas a standard field survey approach would have allowed for two plots per day at best.

Application of a flexible botanical survey approach allowed biologists to avoid causing unnecessary damage to the vegetation in the sample plot. Many of the plots sampled for this project were high-quality coastal sage scrub communities, which tend to be fragile. Attempting to walk a traditional transect through these habitats would have required some amount of trampling and caused at least temporary damage.

Integration of the UAS provides opportunity to collect data from rugged, unsafe terrain and impenetrably dense vegetation. Many of the plots sampled for this project contained steep inclines, rocky outcrops, and closed-canopy chaparral that could not have been surveyed if the team were restricted to standard field survey methods (i.e., walking the transects).

Using the hybrid approach, spatial reference for each plot is standardized. Scoring the SLATS points in the GIS environment provides for more spatially consistent sampling compared to what might have been achieved in the field using GPS assisted sampling or traditional methods of pulling tapes. In addition, providing the vegetation data in a geospatial database (rather than Excel or other spatially disconnected format) allows for simple reference of vegetation data to sample location, and it can be easily integrated into a variety of ancillary studies.

This hybrid approach also provides a very significant difference in the final product as compared to the standard approach. At the end of this pilot study, we were able to provide SDMMP with orthomosaic images of each plot. These images serve as a permanent record of the existing site conditions that can be directly compared to conditions in future years. They also provide a qualitative overview of the sample plot that can be used as reference along with the vegetation data.

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Appendix 2: Soil and Herbaceous Plot Cover Protocols

This appendix is part of the following report:

Perkins, E.; P. Gould, J. Kingston, C. Brown, K.L Preston, and R.N Fisher. 2024. Coastal Sage Scrub and Chaparral Vegetation Monitoring Plan for Western San Diego County, U.S. Geological Survey Cooperator Report prepared for San Diego Association of Governments Regional Habitat Conservation Taskforce. Agreement 548642. https://sdmmp.com/view_project.php?sdid=SDMMP_SDID_71_663178c710cba.

Soil and herbaceous plot cover protocols

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Cryptogamic soil

Cryptogamic crust should be listed as a “species” in the herbaceous plot cover and percent cover should be estimated. The type of crust present should be noted- bryophyte, cyanobacteria, or lichen. An anecdotal note can be made if there is other crust observed but a detailed polygon does not need to be created.

Collecting a soil sample

At the center of each of the sub-plots, a soil sample will be collected (9 total). It will cover from the surface (below any top cover) to 10 cm deep. If there is a cryptogamic crust, the sample should be moved just outside of the crust so as not to disrupt the intactness of the crust. The exact location of the soil sample will be recorded. The soil sample should be at least 2000 mL total. The samples from each of the sub-plots will be combined into a single container. The sample will be put into an airtight bag immediately, sealed completely. The bag should be labeled with the site ID and date. The sample should be kept on ice or delivered to SDMMP within 24 hours.

Herbaceous cover

Herbaceous cover should be collected at 4, 1-m diameter circular plots within the 90 m^2 plot, one in each subplot. Starting at the center point of each subplot, put down a PVC circle in the closest location supporting only herbaceous cover that is big enough to accommodate the entire circle. Record GPS coordinates at the center of the circle. Record a list of every grass or forb species that is found. Species scientific names should be identified to subspecies or variety, if possible. Include dead litter or dead standing biomass if present. For each species present, record the percent cover from an ocular estimate as a relative cover value. The total of all species cover values should equal 100%.

Take a photo of the plot from above and include the entire plot area. Record the photo name in the field sheet with the species names and cover. At the center of the 90 m^2 plot, photos of the plot should be also taken facing north, south, east, and west.

Appendix 3: Field Sheets for Data Collection

This appendix is part of the following report:
Perkins, E.; P. Gould, J. Kingston, C. Brown, K.L Preston, and R.N Fisher. 2024. Coastal Sage Scrub and Chaparral Vegetation Monitoring Plan for Western San Diego County, U.S. Geological Survey Cooperator Report prepared for San Diego Association of Governments Regional Habitat Conservation Taskforce. Agreement 548642. https://sdmmp.com/view_project.php?sdid=SDMMP_SDID_71_663178c710cba.

Field Sheets for Data Collection

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Vegetation Monitoring- Permanent Plot Data Field Collection	
Date	
Collector Name	
Collector Organization	
Plot ID	
Name of picture to the north	
Name of picture to the south	
Name of picture to the east	
Name of picture to the west	

Vegetation Monitoring- Permanent Sub-Plot Data Field Collection (one for each sub-plot)	
Plot ID	
Sub-plot #	
Soil collection taken? (Y/N) Include plot ID on bag, keep fully sealed	
UTM E coordinate of soil collection (NAD83)	
UTM N coordinate of soil collection (NAD83)	

Cover type where soil sample was taken (under canopy, under litter, bare ground, etc)	
UTM E coordinate center point of herbaceous plot (NAD83)	
UTM N coordinate center point of herbaceous plot (NAD83)	
Name of picture of herbaceous plot	
List all species present in herbaceous plot and % cover:	*Include type of cryptogamic crust if it is found
Scientific Name	% Cover (total should equal 100%)
**expand to include all species present in circle	

Expected table format of transect information taken from imagery.

Plot ID	SubplotID	Direction	Ground cover	Plant Species	Score	Height (lidar and DSM)
			Options: bare ground, litter, dead shrub, dead tree, rock, developed, image void, native herb, nonnative herb.	Enter plant species for dead plants, if possible. If not, enter "dead shrub" or "dead tree" if known.		
			Litter should be grass or forbs and dead standing biomass should be used for shrubs or trees.			

Appendix 4: Camera Array Protocol

This appendix is part of the following report:
Perkins, E.; P. Gould, J. Kingston, C. Brown, K.L Preston, and R.N Fisher. 2024. Coastal Sage Scrub and Chaparral Vegetation Monitoring Plan for Western San Diego County, U.S. Geological Survey Cooperator Report prepared for San Diego Association of Governments Regional Habitat Conservation Taskforce. Agreement 548642. https://sdmmp.com/view_project.php?sdid=SDMMP_SDID_71_663178c710cba.

Camera Array Protocol –12/13/2023

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Contents

Array Design

Each array consists of two camera types, a Hobbs Active Light Trigger ® (HALT) camera system (modified Bushnell NatureView HD Model #119740) (Hobbs and Brehme 2017), and a Passive Infrared (PIR) trail camera (Bushnell TrophyCam Aggressor Model # 119776), along with approximately 15 m of 30.5-cm tall drift fencing extending outward to funnel animals toward the center of the array (Fisher et al. 2008). Configuration 1 is an unhoused HALT threshold with 3 arms of 5-m drift fencing extending from the center at 120° from each other (Fig 4.1A and 4.1B, Fig 1), and configuration 2 is a housed HALT with 2 arms of 7.5 m drift fencing extending from the center in opposite directions (Fig 4.1C).

Considerations- Housed system likely to exclude larger animals, smaller threshold length, not as much sunlight/shadow interference, unlikely to require focus adjustments in the field, but is heavier, difficult to transport, not as flexible in deployment options (need flat surface), potentially more likely to be tampered with (no lock).

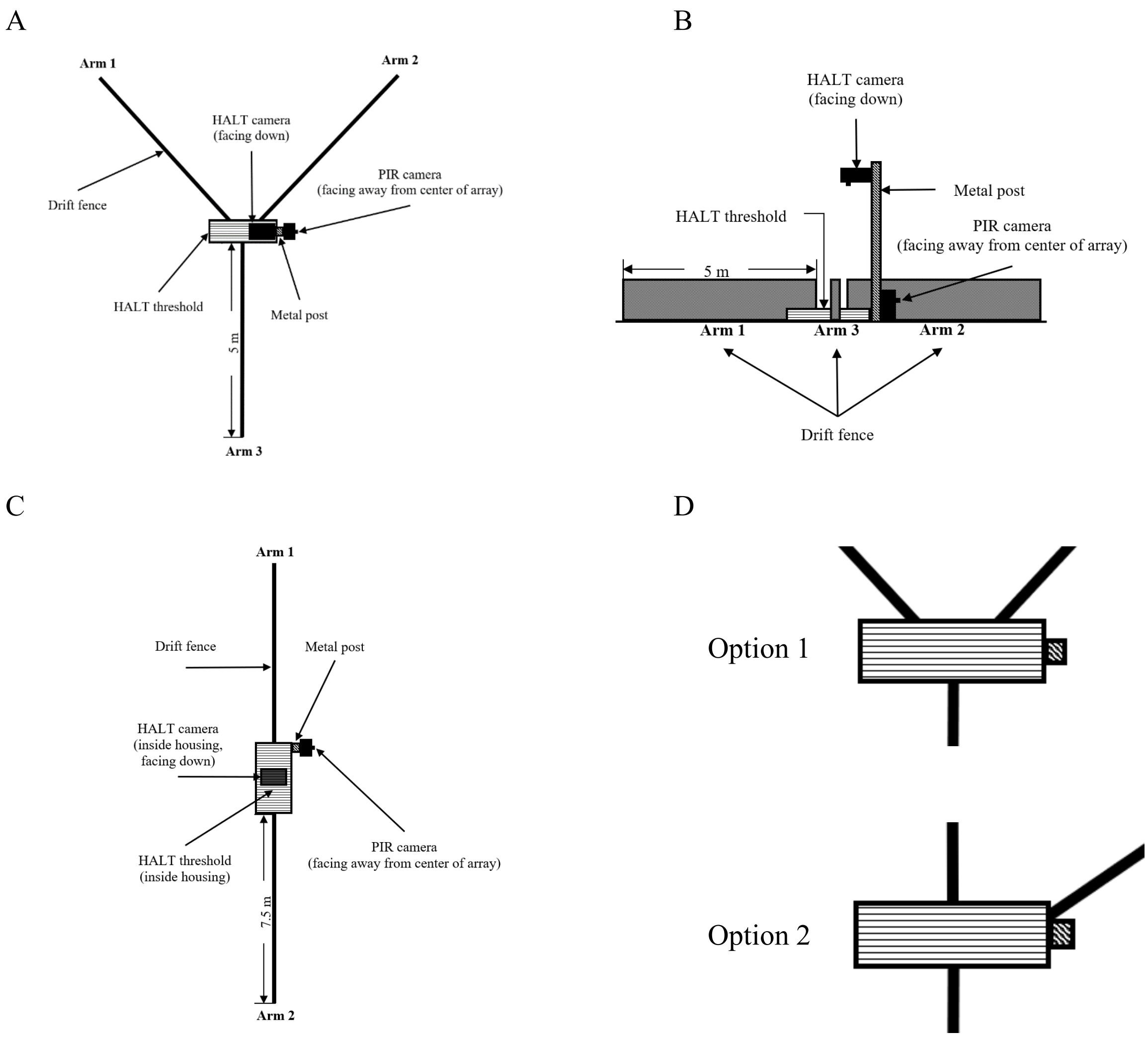

Figure 4.1. Top down (A) and side (B) view of configuration 1, top-down view of configuration 2 (C), and detail top-down view of configuration 1 fence placement options (D).

Figure 4.2. Camera station configuration 1 example. (A) Close up of the camera set-up; (B) Topdown view of threshold; (C) view of the full station with drift fencing.

Materials and Construction

Each array requires a HALT camera, Lenses, HALT threshold, external battery, PIR camera, Bushnell mounting bracket (optional), security boxes, hand saw, wooden stakes, measuring tape, 15 m of 30.5-cm tall drift fencing, staples, 2 locks, 2 python locks, do-not-disturb signs, alarm locks, square metal post, bolts, nuts, washers, zip ties, electrical tape, duct tape, camoflage spray paint, batteries, SD card.

Tools required include Shovel, pickaxe, staple gun, socket wrench, pliers, scissors, post pounder, mallet, lens cloth.

Installation

Fences

Choose a flat location near high-use animal trails where arms can extend out in relatively straight lines at approximately 120° for configuration 1 or 180° for configuration 2. Visualize field of view for PIR camera facing out toward landscape and align flat side of square post in that direction before pounding into the ground. Place HALT at center. For unhoused configurations, place the threshold such that the cable is next to the square post.

For configuration 1, one drift fence arm will begin centered on the long edge of the threshold. The other two arms may begin on the opposite edge of the threshold approximately 1/3 length away from each short edge of the threshold (see Fig 4.1D Option 1). In some cases, it may be preferable to place the second arm centered on the opposite edge, and the third arm immediately next to the metal post (see Figure 4.1D Option 2). For configuration 2, both arms will begin centered on opposite sides of the threshold.

Dig trenches extending out from HALT approximately 10-15 cm deep to length appropriate for chosen configuration.

Cut drift fencing to length required and wrap one end around wooden stake, with drift fence aligned to top flat edge of wooden stake. Staple the fence to the stake, then pound into ground next to HALT threshold (remove threshold before pounding stake in). Lay the remaining fence along trenches and place stakes approximately every 1 m and pound into the ground. Pull fence taut from initial staked end, situate in trench for the bottom edge to be sufficiently buried, and staple to stakes on the same side of the fence. Ensure the top of the fence does not droop and place additional stakes as needed for support.

Fill in the trenches confirming no gaps remain at the bottoms of fences where animals could get through. Pack substrate down and ensure a smooth, clear path to the center of the array.

Cameras

The cameras will be placed at the center of the array, with the PIR facing out into the landscape and the HALT facing toward the ground to capture dorsal images.

The PIR camera will be placed in a metal security box and mounted from the back to the metal post using nuts and bolts. The camera should be mounted approximately 30 cm from the ground.

For configuration 1, the HALT camera will be placed in a metal security box and mounted from the side to the metal post using nuts and bolts. A swivel mount may also be used. The camera should be mounted such that the lens is approximately 70 cm from the ground and centered over the threshold. The HALT threshold cord should be wrapped around the metal post 2-3 times before reaching the camera and secured in place with zip ties. The camera should be secured to the metal post with a Python or alarm lock.

For configuration2, the HALT camera will not need to be adjusted. One leg of the housing should be secured to the metal post using a Python or alarm lock.

Choosing settings on the Bushnell camera

1. Open the camera up and switch power/mode to SETUP.
2. Press MENU and the screen will read "Set Mode" with a parameter listed below it.
3. The first option for the parameter is highlighted black below the parameter name. Pressing the up or down key cycles through the remaining options for this parameter. Once you have selected the setting for a parameter press OK to save the setting. Pressing left or right scrolls to the next parameter.

   Note: If the setup screen does not appear within 10 seconds, you may need to 'massage' the batteries in place as they can get dislodged and interrupt the connection.

Parameter settings on PIR (Bushnell)

Model: Bushnell TrophyCam Aggressor (Model # 119776)

Batteries: Lithium AA x8

SD card: 16 GB

Threshold: 14-in HALT threshold

1. Mode: Camera
2. Image Size: 14M Pixel
3. Image Format: Full Screen
4. Capture Number: 3 Photo
5. LED Control: Low
6. Camera Name: Array # + Camera Type (PIR) (e.g., Array001P)
7. Interval: 30s
8. Sensor Level: Auto
9. NV Shutter: High (may be adjusted later)
10. Camera Mode: 24hrs
11. Format: Press right and skip setting. (This setting deletes photos from card if you select execute)
12. Time Stamp: On
13. Set Clock: Set. Press OK and use up down to change time for selected time field and left/right to move to next time field. Use 24hr format.
14. Field Scan: Off
15. Coordinate Input: Off
16. Video Sound: Off
17. Default Set: Leave on Cancel and press right.
18. Set Mode: Ignore, press menu and exit.

Parameter settings on HALT (Bushnell)

Model: Bushnell NatureView HD (Model #119740)

Lens: 600mm

Batteries: Lithium AA x12

SD card: 16 GB

Threshold: 14-in HALT threshold

1. Mode: Camera
2. Image Size: 14M Pixel
3. Image Format: Full Screen
4. Capture Number: 3 Photo
5. LED Control: Low
6. Camera Name: Array # + Camera Type (HALT) (e.g., Array001H)
7. Interval: 30s
8. Sensor Level: N/A
9. NV Shutter: High
10. Camera Mode: 24hrs
11. Format: Press right and skip setting. (This setting deletes photos from card if you select execute)
12. Time Stamp: On
13. Set Clock: Set. Press OK and use up down to change time for selected time field and left/right to move to next time field. Use 24hr format.
14. Field Scan: Off
15. Coordinate Input: Off
16. Video Sound: Off
17. Default Set: Leave on Cancel and press right.
18. Set Mode: Ignore, press menu and exit.

Field Site Visit

Bring duct tape, zip ties, stapler, scissors, tape measure, extra fencing material, stakes, mallet, and small pickaxe for repairs.

Fences

Check fences for damage and make repairs as necessary. Ensure there is a clear path for animals to travel along fence toward center of array, removing any debris or new vegetation growth.

Cameras

Checking and resetting PIR (Bushnell)

1. Set off the camera with cell phone clock, so that the end time of survey period is captured in the first picture.
2. Unlock security box and remove cover.
3. Remove camera from security box and unlatch, Check and record lithium battery level and # photos.
4. Turn the camera to power/mode OFF, then remove and replace the memory card. Replace all batteries if necessary and secure with electrical tape.
5. Review a few images using SD card reader and adjust flash settings/add tape and correct mount angle/field of view as necessary.

6. Turn the camera back to power/mode SETUP. Review the parameter settings to ensure they are still correct. Check the battery power. If the camera battery were to die between survey periods, parameter settings may be erased. The time stamp is important to check for time drift on the internal clock or any periods of power loss.
7. Change the camera to power/mode ON and gently close and latch camera up, check to see if red light is flashing.
8. Wipe the camera lens with a cloth.
9. Set off the camera with cell phone clock, so that the end time of survey period is captured in the first picture.

Checking and resetting HALT (Bushnell)

1. Set off the HALT trigger with cell phone clock, so that the end time of survey period is captured in the first picture.
2. Disable alarm lock and remove.
3. <u>Configuration 1</u>
    a. Unlock security box and detach threshold cable- ensure cable is not taught or pulling.
    b. Carefully remove security box cover and make sure the mount angle/field of view does not change.
    c. Remove camera from security box and unlatch. Check and record lithium battery level and # photos.

    <u>Configuration 2</u>
    a. Open housing cover and unlatch camera. Check and record lithium battery level and # photos.
4. Turn the camera to power/mode OFF, then remove and replace the memory card. Replace all batteries if necessary and secure with electrical tape.
5. Review a few images using SD card reader and adjust flash settings/add tape and correct mount angle/field of view as necessary.
6. Turn the camera back to power/mode SETUP. Review the parameter settings to ensure they are still correct. Check the battery power. If the camera battery were to die between survey periods, parameter settings may be erased. The time stamp is important to check for time drift on the internal clock or any periods of power loss.
7. Plug in threshold cable and set off HALT trigger to ensure red LED light turns on.
8. If all settings are correct and threshold is functioning properly, unplug the threshold cable. Change the camera in power/mode ON (LED lights will blink for 10 seconds before camera is active). It is important that the camera is not left on SETUP because NO IMAGES WILL BE CAPTURED if the camera is not set to ON. If left on the SETUP power/mode, the camera will power off after a few seconds.
9. Gently close and latch camera, check to see if red light is flashing.
10. Wipe the camera lens with a cloth.
11. Check black cable covers to make sure that all wires are still covered and secure.
12. Clear all debris from threshold and two inches on each side using brush. Ensure the threshold is not buried in substrate.
13. <u>Configuration 1</u>

    a. Place camera back in security box and replace cover, being careful not to change the mount angle/field of view.
    b. Plug the threshold cable back into the camera and lock security box.

    Configuration 2

    c. Close housing cover.
14. Attach alarm lock and arm.
15. Set off the HALT trigger with cell phone clock, so that the start time of the new survey period is captured in the first picture.

Data Management

Data from SD cards should be downloaded and stored on dedicated external hard drive and backed up to a different drive.

Downloading images and naming folders

1. Download all SD Cards upon return to office.
2. On external hard drive create a folder for each check period in format YYYYMMDD.
3. Each folder should be labeled with Array #, Camera type, and date checked (ex. HALT camera checked on June 20, 2023, at Array 001 should be labeled 'Array001H_20Jun2023).
4. Folder structure example:

```
CameraData
    20230620
        Array001H_20Jun2023
        Array001P_20Jun2023
        Etc…
```

5. Transfer photos from SD Card to folder.
6. Delete photos from SD card once they have been transferred by selecting Quick Format.
7. Place empty SD Card into storage book for safe keeping until they get swapped out during the next check.
8. Update data checklist from field datasheet.

Data archive

Once data is in folder structure, back up entire check period to appropriate location on backup drive. The data archive will not be manipulated for further processing.

Image processing

Images on the external hard drive will be processed. Specific image processing steps are dependent on which system is used. Refer to separate instructions for CPWPhotoWarehouse or CR Image Processor.

Pre-review steps

Images may need to be renamed and times may need to be corrected prior to review.

Species identification

Trained observers will identify focal species in images and seek secondary review for any uncertainties.

Literature Cited

Fisher, R.N., D. Stokes, C. Rochester, C. Brehme, S. Hathaway, and T. Case. 2008. Herpetological Monitoring Using a Pitfall trapping design in Southern California. U.S. Geological Survey Western Ecological Research Center. 10.3133/tm2A5.

Hobbs, M.T. and C. S.Brehme. 2017. An improved camera trap for amphibians, reptiles, small mammals, and large invertebrates. PLoS One. 12(10): e0185026. 10.1371/journal.pone.0185026.

Appendix 5: Protocol for Observational Bird Point Count Surveys

This appendix is part of the following report:
Perkins, E.; P. Gould, J. Kingston, C. Brown, K.L Preston, and R.N Fisher. 2024. Coastal Sage Scrub and Chaparral Vegetation Monitoring Plan for Western San Diego County, U.S. Geological Survey Cooperator Report prepared for San Diego Association of Governments Regional Habitat Conservation Taskforce. Agreement 548642. https://sdmmp.com/view_project.php?sdid=SDMMP_SDID_71_663178c710cba.

Protocol for Observational Bird Point Count Surveys

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Introduction

Point counts are used by professional and amateur ornithologists. Point counts are best conducted following standardized protocols as in Ralph et al. (1993 and 1995) for comparison to results of other studies but can still be adapted to suit specific project needs. The U.S. Geological Survey San Diego Field Station (USGS) uses point counts primarily to: 1) assemble a species inventory with habitat associations and 2) enable year-to-year comparisons of species diversity, species richness, relative abundance, and species density.

When performed by trained personnel, point counts are efficient and data-rich, making them well suited for use in multi-taxa studies. Point counts can be performed virtually anywhere – from urban to natural settings – at any time of year (depending on the target species, i.e., breeding/non-breeding/migratory), and require a small time and cost investment per count. There is no equipment to install in the field, and there is little risk to the health of the animal. The biggest potential drawback of point counts is that they rely solely on the skills of the observer and their ability to identify a wide range of species by sight, sound, and behavior. Multiple species can be observed simultaneously through visual observations or auditory detections. Not every field technician can conduct bird point count surveys; a very specific skill set is needed to accurately recognize all potential species in the study area by sight or sound.

Methods

The supplies listed below are recommended to conduct these surveys to the standards and accuracy set out in this protocol (table 5.1).

Count Structure

The methodology of carrying out a bird point-count survey is easiest to understand when referring to the appropriate datasheet (Figure 5.1). The sheet's tabular layout with multiple columns is designed for the temporal and spatial structure of the point count (see Figures 5.2 and 5.3 for blank datasheets). USGS field methods and data forms are based on those recommended by Ralph et al. (1993 and 1995), and these sources should be consulted for issues not covered in this protocol. Point counts are primarily differentiated based on 1) whether birds are observed within a fixed or unlimited radius, and 2) the time intervals during which detections (also referred to as observations; the two terms are used here interchangeably) are recorded. USGS currently uses a 10-min, 100-m, fixed-radius point count, which means that all birds observed visually and/or

Table 5.1. Supplies needed for bird count surveys and rapid habitat assessment.

Supplies for bird point count surveys	
Bird field guide(s) appropriate for the region, a variety of sources may be useful	Digital timing device, preferably with an alarm (e.g., stopwatch, PDA, GPS receiver)
Bird audio guide(s) appropriate for the region, and the equipment needed to play calls in the field	Running species list for the study area
	Point count datasheets, clipboard, field pencils (with erasers)
Global Positioning System (GPS) receiver with waypoints of interest loaded, batteries, and 12V (cigarette lighter) power cord	Laser rangefinder
	Flagging; and 91 cm stakes (may be sold as 36 in.) wood stakes if needed to permanently mark point count stations
Keys and/or combinations to gate locks at study area	
Permits (e.g., to be displayed on vehicle dashboard kept on your person) issued by land manager authorizing access to study area for the season/year AND approval to visit study area on specific day/time	Map of study area with boundaries, roads and point count locations (and possibly vegetation and hydrological features)
	Thermometer and anemometer
	Standard field attire, safety equipment (including cell phone and/or radio), and ample food and water
Binoculars	
Supplies for Rapid Habitat Assessment (additional materials beyond those listed above for bird point count surveys)	
Digital camera with sufficient batteries and memory card	
Compass (may use GPS unit, if equipped with a compass, as last resort)	
Clinometer (aka slope-meter)	
RHA datasheets	
Vegetation species list with USDA PLANTS database codes (USDS, 2016)	

audibly within 100 m of the point count "station" (i.e., the point at which the observer is standing) are counted for 10 consecutive minutes. Each detection is recorded into one of two distance categories (≤ 50 m or >50 m) with exact distances given for distances up to 50 m, and one of three time intervals (0–3 min, 3–5 min, or 5–10 min). The counts are broken into these time intervals so that the data can be compared to other censuses conducted with 3-, 5-, or 10-min time intervals. We also note the vegetation community type used by birds, and record signs of breeding activity. Finally, we separate "flyovers" – observations of birds overhead that are not associated with a specific vegetation community on the ground – from observations of birds associated with the vegetation.

We conduct our point counts so that our data are valid and repeatable and have many applications, such as being used for comparison to point count data collected elsewhere in the world. An important part of this strategy is ensuring that all methods used maximize the probability of detecting all birds present within the count radius (Thompson, 2002). In addition to the skill of the observer and the characteristics of the terrain and vegetation in which the observer is working, the behavior of a bird (i.e., amount of movement, and the volume and quality of vocalizations) and its distance to the observer factor into detection probability (or "detectability") calculations.

In field situations, even a qualified observer typically cannot detect or identify 100% of all birds present. However, when distance categories, such as the two we use, are used during a point count, the data collected can be used to compute the detection probability of each species. Presently, USGS does not use a detectability correction (i.e., we report unadjusted counts), but this is still possible with previously collected data if desired in the future.

Recently, more studies have been incorporating exact distance sampling into their bird point-count methods. Using exact distances in point counts improves density estimates, but distance estimations can be inaccurate depending on the ability of the observers, the openness of the habitat, and the detection method. Most bird point-count detections are aural and are more difficult to accurately estimate a distance (Alldredge et al., 2007, 2008). The variability of the terrain and habitat in our study areas makes accurately estimating exact distances difficult, especially for longer distances; therefore, we only record exact distances for distances up to 50 m. Additionally, a review of the bird point-count guidelines we use (Ralph et al., 1993, 1995) recommends these remain the common standards for bird point counts because they are inexpensive, easy to follow, allow for detection probabilities, and can be modified for study-specific needs, including exact distance sampling (Matsuoka et al., 2014). In the past, USGS supplemented point-count surveys with nocturnal bird surveys to target owls(*Tytonidae* and *Strigidae*), *Caprimulgids*, and other nocturnally active species. However, nocturnal surveys require call-playback and typically are conducted using area search techniques, making the data incompatible to analyze with diurnal bird point data. Consequently, including nocturnal surveys with diurnal point-count surveys only adds nocturnal species to the species inventory list. This can also be accomplished by arriving at the study site prior to dawn and recording nocturnal species as incidentals in the "Notes" field on your datasheet. We recommend nocturnal surveys for focused species-specific studies of owls, Caprimulgids, and other nocturnally active species based on individual project or management needs.

Timing of Counts and Point Selection

Point counts are to be conducted after sunrise, between the hours of 0500 and 1100 (ending earlier if it is warm) during the months of April through August (roughly equivalent to the breeding season) and between 0700 and 1200 during September through March (non-breeding season). These hours are guidelines and should be slightly shifted earlier or later to only include periods of daylight and high bird activity. For example, avoid counts during especially cold temperatures at dawn or particularly warm late mornings. Furthermore, counts should be only completed on mornings with favorable weather conditions, i.e., without rain, winds greater than about 20 km/hr, considerable fog, or abnormally cold temperatures because inclement weather often hinders bird activity and/or detectability.

For most USGS projects, the number and location of point counts in a specified area (e.g., a management unit) are based on statistical sampling guidelines. The goal is to maximize our ability to make comparisons among points, years, and/or treatments (e.g., burned and unburned), by considering in the experimental design the appropriate balance between the number of points on the ground and the number of visits to each point. Most USGS point-count projects involve two to four visits per year to at least 30 points (for the smallest of our study sites). Additionally, each visit to a point needs to be spatially and temporally independent of previous and subsequent visits to that point. These requirements are typically satisfied by spacing points at least 250 m apart from one another and spacing consecutive visits to a point at least a week apart.

Point count stations are typically selected via systematic or stratified random sampling during the study design phase of the project with digital mapping tools rather than selection in the field. Potential locations are computer-generated by overlaying a grid (with cell size ranging from 0.0625 km^2 to 1.0 km^2 so that at least 250 m separates each point) on a GIS map of the study area and then placing a point in the middle of each grid cell (Figure 5.4). This systematic process yields the full pool of potential points from which the points to be surveyed are selected. The total number of points to be sampled depends on the size of the study area, keeping in mind that points must be spaced a minimum of 250 m apart. If the study area is small enough, the number of sampling points is simply the number of points that fit within the boundaries. This was the case for Rancho Jamul Ecological Reserve when the entire grid yielded 68 points (Figure 5.4; Hathaway et al., 2002).

However, when the number of potential points is quite large, the total number of points we intend to survey is based on guidelines discussed here and in the literature, and on available time, funding, and personnel resources. Then, we divide the total number of points we intend to survey by the number of vegetation community types (e.g., chaparral, coastal sage scrub, oak woodland, forest, grassland, and riparian, as determined from an existing vegetation map) to achieve equal point sampling among strata. Alternatively, we can create a proportional allocation of points based on the percentage of the study area covered by each vegetation type. If there are more potential points available within each stratum than we plan to survey, we randomly select the appropriate number. This stratified random sampling strategy results in surveys across the different vegetation community types present in the study area to target as many of the species present as possible. For example, the point count selection for Santa Ysabel Open Space Preserve was pared down to 50 survey points using this selection method (Hathaway et al., 2004).

Additional points can be added by pulling more from the potential pool or selecting in the field, as necessary in areas of specific interest, such as in a vegetation community type (e.g., riparian) that is underrepresented by the computer/random sampling. Likewise, project needs may require the selection of supplemental points to target habitat specialists and/or species of concern. The actual point counts are conducted as close as possible to the selected locations. Most points can be reached exactly with the navigational use of a GPS unit loaded with the coordinates for the station. However, terrain, vegetation, hydrological features, and land ownership sometimes limit accessibility and therefore determine the exact location in which a point count is conducted. In rare cases, we slightly relocate points to allow sustained access. Flagging and/or wood stakes are used to mark all point count stations on the ground, and these locations are always stored as coordinates in GPS units and digital files in the office. Exhaustive species lists of study areas may be unfeasible to create, but surveying birds during breeding and non-breeding times of the year and pre-dawn and post-dawn makes the inventory more complete. Even visits not related to point counts, especially in the winter, nighttime, or before sunrise, often yield previously undetected species.

Step-by-Step Field Methods for Point Counts

1) If an observer does not have much birding experience in the region, he or she should spend a couple days (or longer if needed) becoming familiar with the birds in and around a study area before commencing the point counts. Observers can listen to recorded bird vocalizations in addition to consulting field guides for positive identification. Observers should be able to

identify every potentially occurring species by sight and sound [consult the checklist for the birds of San Diego County in Unitt (2004) and at http://www.sdnhm.org/research/birds/sdbirds.html (Unitt, 2016)].

2) If possible, a reconnaissance survey should be done prior to beginning the actual surveys to avoid spending too much time figuring out access during the first survey. Load all of the point count locations onto a GPS prior to the reconnaissance. Take notes on the best access, via driving and/or walking to each point and save tracks and helpful waypoints in the GPS. This is also a good time to practice the distance estimation technique (preferably with the aid of a laser rangefinder) and note landmarks that will be useful for estimating distance categories during the active survey.
3) Strategize the order in which points will be visited prior to heading out to do the counts. Plan to survey between 6–12 points per morning; the amount that can be visited varies depending on distance between point locations and ease of access. If possible, do all the points in one area before moving on to another. If doing more than one round of visits to points, retain approximately the same overall order for each round so that an approximately constant number of days and or weeks separate each visit to a specific point. Also try to visit points in a subsequent round in the reverse daytime order of the previous round(s), since certain species are more active (and more detectable) at different times of the day.
4) Use maps and a GPS to navigate as close as possible to a point by vehicle before you must walk the rest of the way. Sometimes, for example when points are clustered together but far from a road, it makes sense to survey two or more points in between driving. Also, park the vehicle far enough from the point to avoid influencing the count.
5) When walking up to the point and within seconds of beginning the count, note any birds (and their distance) that are flushed away as a result of your approach. Incidental observations of birds identified en route – walking or driving – to points and after points, should be recorded as well and categorized by activity (Before Count, After Count, Travel Between Counts, or Non-count) on the datasheet. Also record the associated point count location, distance, breeding observations, and vegetation community type when appropriate. Incidental observations are especially useful when observing species not yet detected on the study area during point counts. Any other flora and fauna observations of interest should be recorded in the Notes.
6) Only one observer should be recording birds at a single station at one time. It is recognized that some potentially detectable birds are missed by even the best observers, but it is not necessary (in fact it is discouraged for these methods) to try to increase detections by adding observers. Again, consistency among counts maintains comparability of data. This is different, however, from having one person (maximum) go along with the observer to a point if absolutely necessary (e.g., to help with the vegetation data collection), as long as talking and excessive noise from walking through vegetation is avoided. These types of anomalies should always be recorded in the Notes.
7) After arriving at a point and before starting a count, fill out the Date (day, month, and year), Time (start time, in 24 hr format with no colon), Observer (full name, or at least three initials), Site, Point (point number), Visit #, Data Sheet #, and Page __ of __ fields on the datasheet.
8) Record the three weather variables: Temperature (ambient air temperature in degrees Celsius; use a standard thermometer or other appropriate device), Wind (average wind speed in miles per hour using an anemometer alternatively, use the Beaufort wind scale [Saucier, 1955]),

and Cloud Cover (estimate the cloud cover as a percentage, considering the entire visible sky). If the weather changes significantly during the point, record the changes in the Notes.

9) The point count should begin immediately after recording the weather data, unless significant disturbance was created while accessing the point and the birds need more time to settle and resume normal activity.
10) Every bird observed visually or audibly within the following 10 min is identified to species, counted, and recorded into the appropriate time-and-distance categories on the datasheet. It may be helpful to attach (e.g., with Velcro) a stopwatch with large digits to the clipboard holding the datasheets for easy viewing. Although recording the detections into the correct time interval (0–3 min, 3–5 min, or 5–10 min) is not difficult, the distance classification can be somewhat challenging, especially when detections are made based on audible characteristics. A laser rangefinder should be used for distance verification during the counts and for recording an exact distance for all birds within 50 m.
11) Four-letter alpha codes (species codes reflect current American Ornithological Society, AOS (formerly American Ornithologists' Union, AOU), taxonomy and nomenclature in their check-list (AOU, 1998, AOS, 2017); available at https://www.birdpop.org/pages/birdSpeciesCodes.php) are used for species names. Under "Total Record" record the actual numbers of individuals under the appropriate row and denote the number of each species/sex/detection type detected. Only if an individual can be identified to species should it be recorded on the datasheet. For example, it is common for a bird to enter the point count radius and exit so quickly (often as a fly-over) that identification is difficult. An infrequent exception, where something should be recorded even though a species identification cannot be confirmed, is naming a bird as an unknown/unidentified member of a specific group that commonly creates identification difficulties even for experts, such as the hummingbirds (*Trochilidae*), gulls (*Larus sp*. and *Xema* sp., or *Empidonax* species (recorded as UNHU, UNGU, and UNEM, respectively). Make an educated guess as to which species each unknown was in the Comments section when possible, including notes on plumage, size, vocalizations, or other distinguishing characteristics.
12) The method of detection should be recorded under DET for each bird or group of birds and tabulated under Total. The codes for each detection method can be found on the top of the datasheet: song (S), visual (V), call (C), visual/song (VS), visual/call (VC), flyover (O), Territorial (T), foraging/hummingbird wing sounds (F). Be certain to record if a bird is confirmed by song or sight because these methods have more weight in identifying birds than calls in most cases. Individuals of two or more groups of birds of the same species that are observed separately but in the same time-and-distance category (and vegetation community type, as discussed below) may be tabulated in the Total column (thus grouping their detection codes). For an example of this, see Figure 5.1.
13) Breeding observations should be recorded whenever they are observed on the study area. Observers should be familiar with signs of breeding (e.g., nest types, territorial/distraction displays, appearance of fledglings, etc.) for most of the potentially occurring species. If observations are made during a point count, use the Breed Obs column on the datasheet to record the appropriate code(s). The breeding observation codes can be found on the bottom of the datasheet for reference. If nestlings or fledglings are present in a count and it is feasible, record the number of fledglings separately from the older birds. Similarly, use a separate row for individuals of the same species and vegetation community type if they have nothing to do with the breeding observation listed for another bird or group of birds. Use the

Comments field as well, if necessary, to completely document breeding observations. See Figure 5.1 for examples.

14) Every detection should be associated with a specific vegetation community type and recorded under Veg Comm on the datasheet. The vegetation community codes can be found on the top of the datasheet for reference. Record the most prominent vegetation community type in which the individual/group was first observed. No more than one vegetation community type should be recorded for each row on the datasheet. If detections of different individuals of the same species occur in different vegetation community types, record them in different rows with the corresponding vegetation community type. Depending on the behavior observed, fly-over detections may or may not be associated with a specific vegetation community on the ground. For example, a Northern harrier (*Circus cyaneus*) observed hunting low over grassland should be recorded into the fly-over column but should receive a "G" under Veg Comm because it is clearly using the grassland (rather than just passing over it). If a fly-over is simply flying over the point count station and is not associated with a vegetation community, leave the Veg Comm cell blank. Birds using urban habitat or any non-natural structures on the study area (e.g., telephone/electricity poles, towers and wires, and fences) are recorded as using the "human-modified" type if they are not more associated with another specific vegetation community type.
15) All attempts should be made to avoid counting an individual bird more than once. To help with this, take mental or written notes of the locations of birds already counted. Also, the time-and-distance category should be assigned based on when the individual/group is first detected in the count. This applies to within time intervals, as well as across time intervals and different points.
16) Do not use "pishing" or any other attracting devices or sounds during the 10-min count to increase bird activity or confirm a questionable sighting because this is another example of a non-standardized technique that would limit comparability. Also, avoid spending time consulting field guides during the count because you should have your eyes (except for the brief periods of recording detections on the datasheet) and ears focused solely on the surrounding birds. You may, however, use all these techniques following the count (see next point).
17) Stop counting new birds at exactly 10 min. This is critical for the comparison of data among projects with the same time intervals. Unidentified individual observed during the count the point can be confirmed after the 10-min period; do not spend more than about 10–20 min in the process.
18) Before leaving the point, proof the datasheets for errors and ensure that no cells were unintentionally left blank on the datasheet. For example, a species code is recorded, but no number of birds or vegetation community type is written. This is the time when it is easiest to remember details of the count, rather than hours or days later when entering the data.
19) Use the Notes field for any of the important information mentioned above regarding the points, as well as for the study area in general. For example, include reasoning for relocating a point, previously undetected or rare/sensitive species, predators, etc. If you run out of room, continue on the back of the datasheet or start a new one.
20) Move on to the next point and conduct the count similarly. Whenever starting a new point, fill in the header information (Site, Date, etc.) on the datasheet as before and restart the count in the Page __ of __ field, but continue the count in the Data Sheet # field.

21) At the soonest opportunity, enter the data into the preferred digital format. It is easiest, and thus strongly recommended if time permits, to enter each day's data immediately. It is also better to enter the data while the surveys are still fresh in your memory and mistakes can be more easily identified and corrected.

Rapid Habitat Assessment (RHA)

The value of point-count data (and bird-census data in general) is considerably increased if they are accompanied by vegetation data. The following methodology, called a "Rapid Habitat Assessment (RHA)," is essentially a way to quantitatively and qualitatively characterize the vegetation community (formerly "habitat") and structure around a point, so that the vegetation community type codes that are recorded with each detection can be put into perspective. We record data on the vegetation, substrate, slope aspect and degree, hydrology, and road presence within a 100-m radius "plot" around each point count station. Data are recorded onto paper datasheets in the field and later entered into the preferred digital format. The following steps instruct an observer on using to the paper form (Figure 5.3).

Step-by-Step Field Methods for RHA

1) If alone and conducting an RHA along with a point count during the same visit to a point, conduct the point count first.
2) Start the RHA by entering the standardized name of the Site and Point. Record the Date and the Observer conducting the RHA. The name of the Point may be just the point number (#1, #2), or may include as much as the site's standardized abbreviation plus the year plus the point number (RJER-01-2003). Consult the project lead for directions on this step (and any others where naming is involved) to ensure each record is uniquely identified and standardized in nomenclature.
3) If Plot Radius is blank, enter "100" for the radius length, in meters, of the circular plot (with the point count station as the center) that you are about to characterize/assess. If all the plots to be assessed with this technique have the same radius, this value may be entered into the digital copy of the paper datasheet before printing.
4) For Substrate, use your shoe to scrape away the top layer of leaf litter or loose material so that you can observe the actual soil type. This is perhaps the most non-standardized field in the RHA; do your best to describe the substrate in a dozen words or less. For example, use the soil-texture classes – clay, silt, and sand – or combinations thereof, along with a mention of rocks and their general sizes (e.g., silty-sandy with several scattered boulders). It is not necessary to record leaf litter depth here, but organic matter should be mentioned when significant. Additionally, simply describe the substrate you find below your feet and in the visible vicinity; it is not necessary to walk throughout the entire plot sampling the substrate.
5) Record whether Standing and/or Running Water is present within the entire plot. Use the Notes section to elaborate here if needed, e.g., if the point lies in/near a presently dry, intermittent stream course.
6) For (Slope) Aspect, face either downhill or uphill and use a compass to read the direction that the prominent slope on which the point lies faces. Another way to think about this is "In which general direction would water run if a water tank burst open where you are standing?" Select the nearest cardinal direction (N, E, S, or W) or intermediate direction (NE, SE, SW, or NW) for recording. If the plot is overall flat, leave the field blank. You are measuring the overall slope of the plot, not of individual, smaller ravines or "bumps" in the land. However,

if the point lies at the top of a peak or ridge, or at the bottom of a ravine or narrow valley, it would be helpful to record this information in the Notes section, along with the major slope aspects and angles.

The field Slope (Inclination) refers to the angle of the slope on which the point lies. If the plot is overall flat, record "0". Traditionally, this measurement can be recorded either in degrees or as a percentage, but USGS reports the value in degrees. If the measurement must be recorded as a percentage due to equipment, simply make a note of this, and correctly convert the value to degrees at some point before data entry. Refer to the user's manual of your clinometer for help in taking slope measurements. Read the number from the left-hand scale of this instrument, reporting degrees, not percent. Because the angle of the slope may differ on either side of the point, record the average of the uphill- and downhill-facing measurements.

7) Record whether a Road(s) is present within the plot. If you record a presence, three more fields will be revealed on the digital form. Next, record the Road Width, in meters (if more than one road is present, record the maximum width), % Road (see "cover classes" in #10 below) as the percentage of the plot that is covered by roads, and the Road Type (paved, dirt, or gravel). Use the Notes section to elaborate here if needed, e.g., list the name of the road(s) when applicable.
8) Indicate that a Photograph was taken after snapping two digital photographs from the point count station. It is more important when taking the two photographs to orient the camera so that the plot's vegetation and structures are captured as completely as possible rather than being concerned about always facing the same two compass directions. There is also no rule about taking just two photos if you feel more are necessary. After filling in the Photo field, record the filenames/numbers of the photos in the Photo Name field, which was unhidden.
9) Next, estimate the percentage of the plot's entire area that each General Cover type (e.g., Trees/Shrubs, Herb/Grass, etc.) encompasses, entering one of the cover classes (0%, < 5%, 5-25%, 26-50%, 51-75%, 76-99%, or 100%) into a separate subform for each type present. When recording multiple cover types, ensure that their cover values could total 100%. We recognize that these cover classes are ranges and that the total could actually fall below or above 100% if the end values of the ranges are used in the addition. However, it is assumed that the observer is assigning the cover classes to characterize exactly 100% of the plot (i.e., exact percentages are considered by the observer in the thought process, even though they are not recorded as such). The "0%" cover class is actually rarely used because it is not necessary to enter vegetation community types that do not cover any of the plot. However, if it is necessary to document that the type was verified as being absent in the plot (or if the paper datasheet is being used), use the "0%." "Cover" throughout these methods refers to the position of occupying the uppermost canopy, or what is directly "open to the sky." For example, when trees are completely covering herbs below, only the trees are considered as cover. Note that if you record presence of standing/running water and/or roads, their percent cover should be recorded in the General Cover field as well (unless, of course, they are covered by something above). Also note that trees and shrubs are grouped into the woody type "Trees/Shrubs" and all herbaceous cover (including graminoids but excluding manicured lawn) are grouped into "Herb/Grass" for practicality.
10) The Vegetation Community (formerly "Habitat") Cover types are recorded in the same fashion as types in the General Cover field, but data in addition to the cover class are recorded for each type, as discussed in #12 and 13 below. After visually scanning the plot

from its center (the point-count station), estimate the percent area of the plot that each vegetation community type covers using the familiar cover classes. The observer should be familiar with all dominant and most common plant species in the region and the vegetation community types multiple species compose when each is present at various levels. Walk away from the point if you need to see over/around various obstacles, identify species several meters away, or verify actual vegetation community types. Although there are certainly vegetation communities which are not described exactly by these seven types (chaparral, coastal sage-scrub, grassland, oak woodland, riparian, forest, and human-modified), most if not all potential plots in southern California should be able to be partitioned considerably well among these types. Consider the present condition of the land when selecting a type. For example, even though a plot may have been used for grazing in years past, if it is now a mostly homogeneous, non-inundated area, covered by primarily herbaceous vegetation and largely lacking woody plants, it should be considered a grassland. (In cases of cover types where forbs outnumber grasses and graminoids, "herbland" may be more appropriate than "grassland," but still use "grassland"). However, if the plot is still being used for agricultural purposes, for example, classify the area as "human-modified." The "human-modified" type is the only one that must be further classified. Choose one of the following land use types: low residential, high residential, rural residential, business/shopping district, industrial, agriculture, or other (if "other" is chosen, please elaborate in the Notes).

11) Next, record up to five Dominant (plant) Species within each vegetation community type that was assigned a cover class greater than 0%, filling out a subform for each species. You should usually be listing five species, but there are times when four (or three or fewer in rare cases, such as burned areas) species suffice. Use the USDA PLANTS codes/symbols (USDA, 2016) for a unique species identifier in the field Species. Do not modify the first two fields, which are auto-filled, in the subform. Try to record the Dominant Species under each vegetation community type in their order of dominance within that community type. For example, in a chaparral area, if *Adenostoma fasciculatum* (code/symbol: ADFA) is the most dominant species, record it first, and then follow that with *Salvia mellifera* (the second most dominant; code/symbol: SAME3), etc. "Dominance" has multiple definitions, such that a particular species can be considered "dominant" in a plot for several reasons. For our purposes, a species should be recorded as dominant if it is 1) simply most abundant, and/or 2) largest in size. You may record a particular species under more than one vegetation community type in a single plot.
12) Next, for each vegetation community type assigned, estimate the 1) Native Cover, the percentage (again, select a cover class) of the area encompassed by just that specific community type that is covered by native (this includes bare soil/rocks), versus non-native, vegetation, and 2) Maximum Veg Height (in meters), the height of the tallest plant within that specific community type. So, if you record that the plot is comprised of three vegetation community types (this is not uncommon), you need to record a cover class, up to five dominant species, a native cover percentage, and a maximum vegetation height for each type.
13) For Adjacent Land Use, record any management practices on nearby lands (outside the 100-m radius plot) that differ from that within the plot. For example, if the point lies 150 m from the edge of the reserve, and residential areas lie on the other side of the property fence, record all of this. Estimate distances (of hundreds of meters or more) as best as possible but use maps for help.

14) The Notes field is available for all of the previously mentioned notes and for describing any other items of interest (e.g., fences, water tanks, utility poles/wires, other human-made structures, etc.) usually found within the plot. Use this field liberally, because it is always better to record conditions when they are present and have the data rather than to not have the data and to try and remember what was once present.
15) If using paper datasheets, proof all RHA data at the end of the day, ensuring that there are no errors and that no fields were mistakenly left blank. If using a digital form, QA/QC the data immediately after a HotSync, or within a few days, when the surveys are still fresh in your mind. After downloading the photographs from the plots and naming and storing the photograph files appropriately, update the Photo Name field for each point's RHA in the database.

Post Survey Procedures
Thoroughly clean all equipment and adhere to any post-survey biosecurity measures for your location. All data collected must be double-checked for accuracy. Quality Assurance/Quality Control (QAQC) of data can be accomplished before or after entering paper data or synching digital data to your database. Each datum entered should be looked at again once you have returned from the field, and care should be taken to correct any typographic errors or errors in data entry. This should be done as soon as possible upon returning from the field so the survey will be fresh in your memory. See also chapter four of McDiarmid et al., (2012) for QAQC techniques and procedures.

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Bird Point Count Form

Data Sheet# 1 Page 1 of 1

DATE: 4 / 8 / 2018 TIME: 0759 OBS: MCM SITE: Piru Creek POINT: 128 VISIT# 1

TEMP: 18 %CC: 25 WIND: 1

TIME INT: 1=0-3 min; 2=3-5 min; 3=5-10 min	DET: S=song; C=call; V=visual; VS=visual and song; VC=visual and call; O=flyover; T=territorial; F=foraging/hummingbird wing sounds	SEX: M=male; F=female; I=immature; J=juvenile; U=unknown	DIST (m): Distances up to 50 m are exact using a range finder.
Activity: C=count; B=before count; A=after count; T=travel between counts; N=noncount	Breed Obs: See Below	Veg Comm: C=Chaparral, S=Coastal Sage, O= Oak Woodland, G=Grassland, R=Riparian, F=Forest, H=Human Modified	

TIME INT	Bird Sp.	TOTAL	DET	SEX	DIST	Activity	Breed Obs	Veg Comm	Comments
1	WCSP	1	VC	U	8	C		R	
1	WCSP	1	VC	U	10	C		R	
1	CALT	1	C	U	40	C		R	
1	WREN	1	S	M	>50	C		C	
1	CALT	1	VC	U	18	C	NB	R	saw carrying nesting material several times
1	WCSP	1	V	U	16	C		R	
1	NUWO	1	C	U	30	C		R	
2	HOFI	1	O	M	—	C		R	
2	BEWR	1	C	U	>50	C		R	
2	WCSP	2	VC	U	15	C		R	
3	BUSH	2	C	U	20	C		R	
3	RSFL	1	C	U	24	C		R	
3	CALT	2	C	U	35	C		R	
3	WCSP	3	C	U	27	C		R	possibly more, all calling from same shrub
3	LEGO	2	C	U	>50	C		R	
3	CALT	1	C	U	>50	C		S	
3	LEGO	1	O	M	—	C		—	Singing as he flew over
3	MALL	1	C	U	>50	C		R	
—	WBNU	1	C	U	>50	A		R	

Notes

Breeding Obs. Codes *: JV=JUVENILE bird independent of parents, AB=AGITATED BEHAVIOR or anxiety calls from adult birds, PR=PAIR observed in suitable habitat during breeding season, TB=TERRITORIAL BEHAVIOR such as dispute or chase by two individuals of same species, CB=COURTSHIP BEHAVIOR such as courtship feeding, breeding displays, or copulation, PN=Visiting PROBABLE NEST site (hole nesters), PB=PROBABLE nest BUILDING, by woodpeckers, wrens, or Verdin, NB=NEST BUILDING or carrying nest material by any species except woodpeckers, wrens & Verdin, DD=DISTRACTION DISPLAY or aggressive defense of an unseen nest, UN=USED NEST, if you are certain of the builder's identification, ON=OCCUPIED NEST but contents unknown, FL=FLEDGLINGS still incapable of sustained flight or downy chicks still following parents, FS=Adult carrying FECAL SAC, FY=Adult FEEDING YOUNG or carrying food to them, NE=NEST with EGGS or eggshells on the ground under it, NN=NEST with NESTLINGS seen/heard. *San Diego County Bird Atlas Project (www.sdnhm.org/research/birdatlas/observation-codes.html) has more detailed descriptions.

Figure 5.1. Example of a populated bird point-count datasheet.

Figure 5.2. A blank bird point count data form (next page) for collecting survey information on bird species observed during the indicated time and at the given distance from the point.

Bird Point Count Form

Data Sheet#___ Page_____of_____

DATE: ____/____/____ TIME: _______ OBS: _______ SITE: ____________________ POINT: ________ VISIT# ____

TEMP: _______ %CC: ______ WIND: ______

TIME INT: **1**=0-3 min; **2**=3-5 min; **3**=5-10 min	DET: S=song; C=call; V=visual; VS=visual and song; VC=visual and call; O=flyover; T=territorial; F=foraging/hummingbird wing sounds	SEX: M=male; F=female; I=immature; J=juvenile; U=unknown	DIST (m): Distances up to 50 m are exact using a range finder.
Activity: C=count; B=before count; A=after count; T=travel between counts; N=noncount	Breed Obs: See Below	Veg Comm: C=Chaparral, S=Coastal Sage, O= Oak Woodland, G=Grassland, R=Riparian, F=Forest, H=Human Modified	

TIME INT	Bird Sp.	TOTAL	DET	SEX	DIST	Activity	Breed Obs	Veg Comm	Comments
Notes									

Breeding Obs. Codes *: JV=JUVENILE bird independent of parents, AB=AGITATED BEHAVIOR or anxiety calls from adult birds, PR=PAIR observed in suitable habitat during breeding season, TB=TERRITORIAL BEHAVIOR such as dispute or chase by two individuals of same species, CB=COURTSHIP BEHAVIOR such as courtship feeding, breeding displays, or copulation, PN=Visiting PROBABLE NEST site (hole nesters), PB=PROBABLE nest BUILDING, by woodpeckers, wrens, or Verdin, NB=NEST BUILDING or carrying nest material by any species except woodpeckers, wrens & Verdin, DD=DISTRACTION DISPLAY or aggressive defense of an unseen nest, UN=USED NEST, if you are certain of the builder's identification, ON=OCCUPIED NEST but contents unknown, FL=FLEDGLINGS still incapable of sustained flight or downy chicks still following parents, FS=Adult carrying FECAL SAC, FY=Adult FEEDING YOUNG or carrying food to them, NE=NEST with EGGS or eggshells on the ground under it, NN=NEST with NESTLINGS seen/heard. *San Diego County Bird Atlas Project (www.sdnhm.org/research/birdatlas/observation-codes.html) has more detailed descriptions.

Figure 5.3. A blank data form (next page) for collecting habitat and vegetation variables describing the bird point count station.

BIRD POINT COUNT - RAPID HABITAT ASSESSMENT (*RHA*) FORM

Site: ____________ **Point #:** ____________ **Date:** ________ **Observer:** ________ **Photo #:** _____

Plot Radius: ______ m **Substrate:** ______________________________

Water Presence: standing? Y / N running? Y / N

Slope Aspect: ____________ **Slope Inclination:** ______ °

Road Presence: Y / N **Road Width:** _____ m **Road Cover:** _____ % **Road Type:** paved / dirt / gravel

	Trees/ Shrubs	Herb/ Grass	Lawn	Build.	Pave.	Dirt/ Rock	Water
General Cover (%):							

	Chap	CSS	Grass	Oak	Rip	Forest	Hum*
Veg Community Cover (%):							
Dominant Species:							
(list up to 5)							
Native Cover (%):							
Maximum Veg Height (m):							

***Type of Human-modified:**
Low Resid.
High Resid.
Rural Resid.
Bus./Shop.
Industrial
Agricultural
Other ________

Adjacent Land Use: ______________________________

Notes: ______________________________

BIRD POINT COUNT - RAPID HABITAT ASSESSMENT (*RHA*) FORM

Site: ____________ **Point #:** ____________ **Date:** ________ **Observer:** ________ **Photo #:** _____

Plot Radius: ______ m **Substrate:** ______________________________

Water Presence: standing? Y / N running? Y / N

Slope Aspect: ____________ **Slope Inclination:** ______ °

Road Presence: Y / N **Road Width:** _____ m **Road Cover:** _____ % **Road Type:** paved / dirt / gravel

	Trees/ Shrubs	Herb/ Grass	Lawn	Build.	Pave.	Dirt/ Rock	Water
General Cover (%):							

	Chap	CSS	Grass	Oak	Rip	Forest	Hum*
Veg Community Cover (%):							
Dominant Species:							
(list up to 5)							
Native Cover (%):							
Maximum Veg Height (m):							

***Type of Human-modified:**
Low Resid.
High Resid.
Rural Resid.
Bus./Shop.
Industrial
Agricultural
Other ________

Adjacent Land Use: ______________________________

Notes: ______________________________

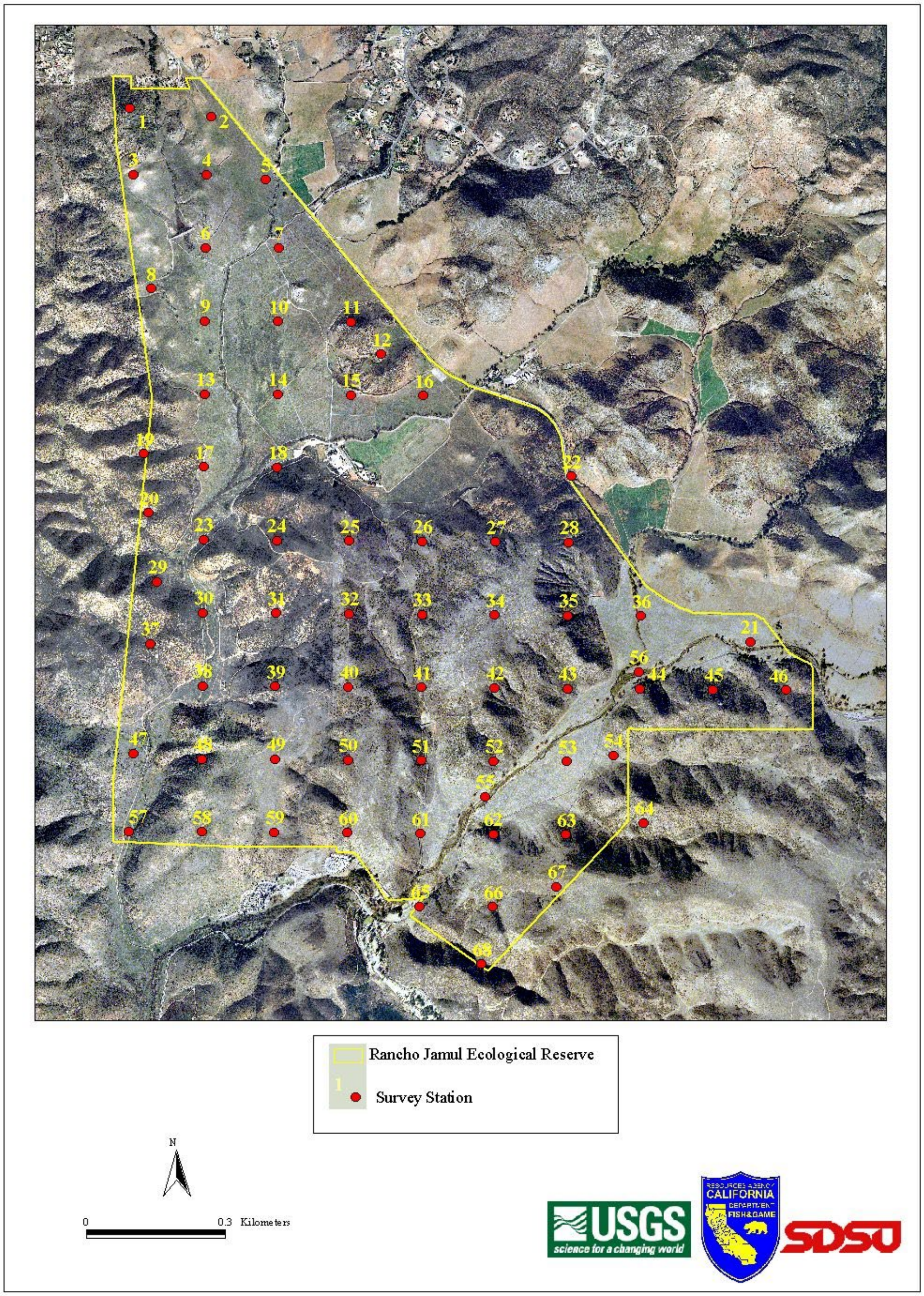


Figure 5.4. Grid of bird point count stations from Baseline Biodiversity Survey for the Rancho Jamul Ecological Reserve (Hathaway et al., 2002).

Appendix 6: Rare Plant Inspect and Manage (IMG) Protocol for Targeted Rare Plants

This appendix is part of the following report:
Perkins, E.; P. Gould, J. Kingston, C. Brown, K.L Preston, and R.N Fisher. 2024. Coastal Sage Scrub and Chaparral Vegetation Monitoring Plan for Western San Diego County, U.S. Geological Survey Cooperator Report prepared for San Diego Association of Governments Regional Habitat Conservation Taskforce. Agreement 548642. https://sdmmp.com/view_project.php?sdid=SDMMP_SDID_71_663178c710cba.

Management and Monitoring Strategic Plan (MSP Roadmap) 2023 Rare Plant Inspect and Manage (IMG) Monitoring Protocol for Occurrences on Conserved Lands in Western San Diego County

Prepared by the San Diego Management and Monitoring Program (SDMMP)
Originally prepared 3-11-14; revised 3-5-15, 3-8-16, 3-16-17, 3-20-18, 3-19-19, 3-16-20, 3-18-21, 11-7-22, **9-16-24**

Introduction

San Diego County is a biodiversity hotspot with many rare, threatened, and endangered plant species conserved under multiple species conservation plans. For successful rare plant conservation, it is important to gather relevant monitoring data to determine management needs and provide prioritized management recommendations for species' populations. The "*Management and Monitoring Strategic Plan for Conserved Lands in Western San Diego County: A Strategic Habitat Conservation Roadmap*" (MSP Roadmap) provides regional monitoring and management goals and objectives for conserved species and vegetation communities (SDMMP 2017, https://sdmmp.com/msp_doc.php).

MSP Rare Plant Inspect and Manage (IMG) Monitoring Objective

The MSP Roadmap includes Inspect and Manage (IMG) objectives for prioritized rare plant species that call for land managers, contracted botanists, and volunteers to inspect occurrences and determine population status, threats, and management needs. Based on this information, land managers can conduct routine management actions or plan and implement more intensive management as funding becomes available. The MSP Roadmap identifies 30 species for IMG monitoring during the 2017-2021 and 2022-2026 planning cycles. Some species are monitored annually and others less often, with the frequency depending on the species status, ecology, and level of threats. The Conservation Biology Institute (CBI) and AECOM, under the guidance of the San Diego Management and Monitoring Program (SDMMP), will coordinate land managers and other participants in monitoring 18 species in 2023 (see page 16). Protocols, data forms, monitoring schedules, rare plant IMG datasets, a map viewer with rare plant occurrences, and other information are available at the MSP Web Portal's "Rare Plant IMG 2014-2026" project page:
https://sdmmp.com/view_project.php?sdid=SDID_sarah.mccutcheon%40aecom.com_57cf0196dff76.
To ensure consistency in data collection, the IMG protocol and associated data forms provide a standardized basis for documenting occurrence status and assessing habitat and threats for the various species. The SDMMP and partners developed the protocol and data forms based on recommendations from a comprehensive review of rare plant monitoring data collected from 1999 to 2009 under the San Diego Multiple Species Conservation Program (McEachern et al. 2007, McEachern and Sutter 2010a, b, Tracey et al. 2011). The MSP rare plant occurrence monitoring component was adapted from methods used by the City of San Diego since 2006 (City of San Diego Plant Survey Form 2013, City of San Diego Plant Field Form Instructions 2013, B. Miller and K. Roeland pers. comm.). The habitat and threat assessment components incorporate covariates used by the Conservation Biology Institute and The Nature Conservancy in some of their projects (South County Grasslands Data Sheet 2011, Crestridge Qualitative Monitoring Data Sheet 2013, Habitat Assessment Form 2013, P. Gordon-Reedy, T. Smith, and J. Vinje pers. comm.). Other partners provided input including the County of San Diego (M. Hamilton, J. Price, and R. Humphrey); Center for Natural Lands Management (M. Spiegelberg and P. McConnell); US Fish and Wildlife Service (J. Martin); AECOM (J. Dunn, T. Oberbauer, F. Sproul, L. Woolley); and the San Diego Association of Governments (K. Greer). Land

managers field tested the protocol in 2014 and provided feedback for revising the protocol for 2015. Further user feedback has resulted in minor changes to the protocol and data forms between 2016 and 2019.

Rare Plant Occurrence Information

A rare plant occurrence is a unit of management and similar to a "population" but without regard as to whether individuals interbreed. Following the California Natural Diversity Database (CNDDB) definitions of an Element Occurrence (CNDDB 2011), two occurrences are unique if the distance between their closest parts is ≥0.25 mile (Figure 6.1). In a few cases related to land manager monitoring and management decisions, we consider occurrences within 0.25 mile of each other as separate. Where a CNDDB polygon encompasses an occurrence, the occurrence has the corresponding CNDDB Element Number. An occurrence can include multiple plant locations extending over different landownerships.

MSP Roadmap rare plant occurrences monitored during 2014-2022 IMG surveys have polygon and sample point data for determining specific monitoring locations. These data are available for download as a geodatabase from the MSP Web Portal's Rare Plant IMG 2014-2026 project page (see link on page 1). The Rare Plant IMG geodatabase also includes population status, and habitat and threat assessment data. **Use the Rare Plant IMG geodatabase to locate rare plant occurrences and sample points that have been previously monitored**. However, for unmonitored occurrences you will need to do one of the following: contact SDMMP to obtain an Occurrence ID for new occurrences or use the MSP Roadmap's Master Occurrence Matrix (MOM) database to find an existing occurrence and then establish the sampling points. This database provides general location information for rare plant occurrences (MSP-MOM-Plants) documented since 2000 on Conserved Lands in the MSP Roadmap area (MSPA). You can find the MSP-MOM-Plants GIS shapefile at the SDMMP Library:

https://sdmmp.com/library.php?Search=mom-plants&Author=&PreparedFor=&PublisherID=&Year=&ArticleType=&submit=Submit.

From the "Article Type" menu select "GIS data" and type in "MSP-MOM Plants" into the search bar and download the MSP-MOM Plants shapefile. The shapefile includes spatial location and other information for MSP rare plant species and occurrences.

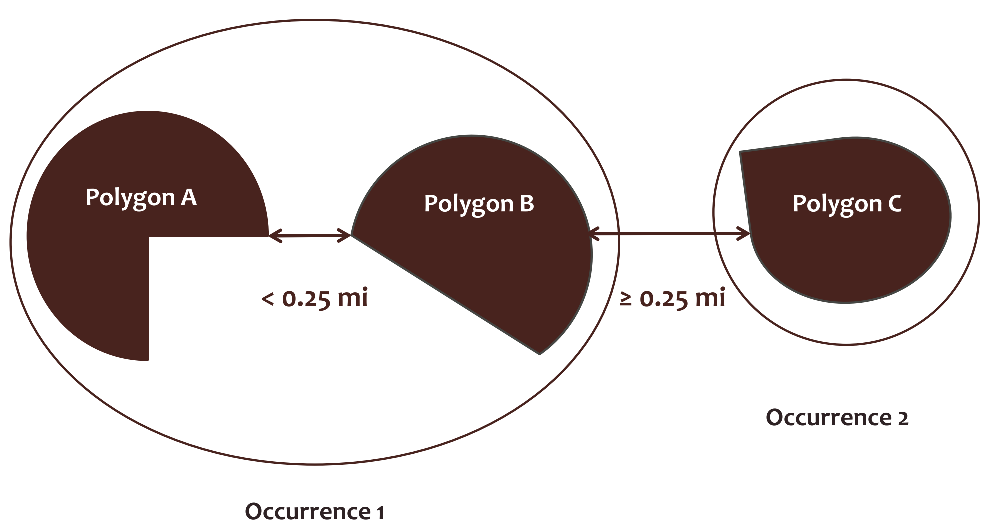


Figure 6.1. Example of how to determine what is an occurrence. An occurrence is a unit of management and similar to a population without regard to interbreeding. The definition follows a CNDDB Element Occurrence with two occurrences considered unique if their closest parts are ≥ 0.25 mile.

A map viewer is also available at the rare plant monitoring web page (see link on page 1) under the "Project Map URL" link. This viewer allows you to view rare plant occurrence sample points and mapped extents and to make maps with the 2014-2022 Rare Plant IMG geodatabase, MSP-MOM-Plants shapefile, and other spatial datasets.

Initial sources of data for MSP-MOM-Plants are the CNDDB, San Diego Natural History Museum's Plant Atlas (SDNHM), Consortium of California Herbaria (CCH), SANBIOS, and rare plant monitoring reports and GIS shapefiles provided by landowners and land managers (e.g., CBI, City of San Diego, County of San Diego, CNLM, USFWS). We update and add new occurrences as they are reported to the SDMMP.

Each occurrence in the Rare Plants IMG geodatabase has an occurrence identification code (Occurrence ID). It is typically comprised of the USDA plant code for the species or subspecies, followed by an underscored space and the Management Unit (MU) number defined in the MSP Roadmap. The next part of the code is a four-digit letter code representing the occurrence site. Typically, this site code designates the geographic area, feature or preserve where the occurrence is located. The site code is followed by a unique three-digit number for that occurrence. If there are multiple occurrences with the same site name, then each occurrence is assigned a unique number. Following are examples of occurrence IDs and the information embedded in the ID:

ACPR_ 1DUTR005	*Acmispon prostratus*, MU1, Dune Triangle, 005
ACPR_7BALA020	*Acmispon prostratus*, MU7, Batiquitos Lagoon, 020
ARGLC4_6MAMI016	*Arctostaphylos glandulosa* ssp. *crassifolia*, MU6, Manchester Mitigation Bank, 016
DUBLB2_6CMPR001	*Dudleya brevifolia*, MU6, Carmel Mountain Preserve, 001
LEGA_3OTMT003	*Lepechinia ganderi,* MU3, Otay Mountain, 003
LEGA_3OTMT004	*Lepechinia ganderi,* MU3, Otay Mountain, 004

The last two examples have the same site code as they both occur on Otay Mountain, but they are different occurrences as they are ≥0.25 miles apart. Unique numbers distinguish these as different occurrences.

IMG Monitoring Approach

The purpose of the IMG objective is to provide current information on the status and management needs of rare plant occurrences on Conserved Lands in the MSPA. IMG monitoring identifies occurrences with management needs that land managers can routinely address. More intensive management actions are also determined, which may require more planning by land managers and implementation as local resources or regional funds become available.

IMG monitoring involves:

1. Establishing permanent circular sample plot(s) and estimating or counting the number of plants.
2. Mapping the perimeter of the current extent of the occurrence and estimating or counting the number of plants.
3. Photo-monitoring.
4. Conducting a habitat assessment within the sample plot(s).

5. Conducting a threats assessment within the cumulative maximum extent of the occurrence over time and including an adjacent 10-m buffer.

In many cases, the maximum extent is larger than the sample plot(s). Figure 6.2 shows the relationship between maximum occurrence extent, current mapped extent, and the sample plot.

Current Mapped Extent and Maximum Extents
The first time a plant occurrence's perimeter is mapped establishes the current extent for that year and represents the initial maximum extent for the occurrence. All suitable habitat near the occurrence should be surveyed. In subsequent survey years, the occurrence may vary in size (depending on environmental conditions and suitable habitat) and the maximum extent expands to include all areas occupied by the plant population across survey years. Thus, the maximum extent is the cumulative area where the plant is mapped over time and is the minimum area searched for the plant during each survey. During each survey, map the current extent of the occurrence so that the distribution of the plant can be tracked over time and areas for management identified. It may not be feasible to survey all suitable habitat and map the entire extent of an occurrence for some widely dispersed species, particularly shrubs and some geophytes, or in situations where a rare plant occurrence population occurs on both conserved and private lands. In these cases, create a survey area shapefile delineating the search area and submit it to the SDMMP with other monitoring data files.

It is important when mapping the current extent to minimize impacts to plants by avoiding trampling or creating trails through the population.

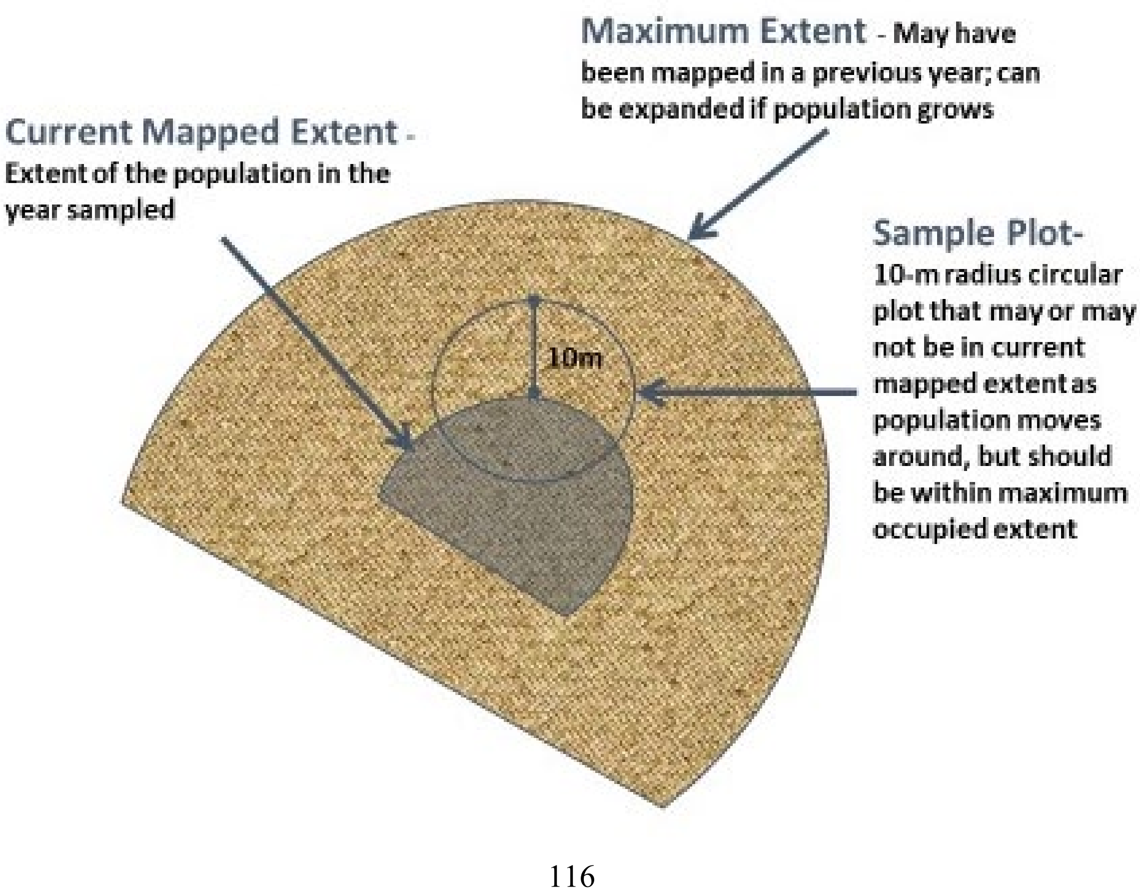


Figure 6.2. Diagram showing the relationship between an occurrence's maximum extent, current mapped extent, and sample plot.

Sample Plots (Sample Points)
Establish at least one **10-m radius circular sample plot** within the maximum occupied extent for each occurrence. In the 2014-2019 protocols, the sample plot is referred to as a sampling area, habitat plot or sample point. We changed the name to sample plot to reduce confusion and to emphasize that the plot samples habitat characteristics within the rare plant occurrence. We continue to use the term sample point to indicate the location of a sample plot.

For annuals and narrowly distributed perennials, the sample plot can include the entire mapped occurrence or only a portion of the occurrence, depending on the size of the occurrence and annual changes in distribution. For occurrences without previous IMG monitoring, establish a minimum of one permanent sample plot per occurrence. Place sample plots in locations where the plants are most likely to occur each year and that encompasses as much of the population as possible. We recommend establishing one to two additional sample plots for large occurrences (greater than one or two acres) to more completely characterize the habitat and increase accuracy of the population estimate. If possible, add more sample plots for very large occurrences (e.g., 5 to 10 acres) taking into account population heterogeneity, environmental characteristics, and land manager staffing and budget constraints. To minimize impacts to plants, the surveyor can set up the photo-monitoring points outside the mapped extent, at the edge of the sample plot and facing into the plant population. We can assist in establishing sample plots and provide GIS or KML files for making maps showing occurrence perimeters and sample plots.

Because some rare plant species populations (i.e., annuals, geophytes) fluctuate temporally and spatially, there may be times when the sample plot is no longer within the current mapped extent of the occurrence. It is important to continue collecting data at the established sample plot instead of moving it to encompass the current location of the plants. If the sample plot is moved, then differences in habitat attributes cannot be compared over time. The current mapped extent, number of plants, and threat assessment still encompass the plant population. You can also choose to establish an additional sample plot in a new location with plants, while continuing to collect data in the previously established sample plot.

Data Collection Options
We prefer IMG data be entered directly into a Survey123 digital form in the field using a smartphone, tablet, or other portable computer. It is quicker for the surveyor to enter data in the field rather than collect data on paper and then enter it into the computer later. Using Survey 123 reduces data collection errors and makes database integration and management more efficient. See instructions for using the Survey123 application at the Rare Plant IMG 2014-2019 webpage (see link on page 1).

Surveyors can also collect data in the field with a tablet or field computer using an Excel data entry form or record data with pen and pencil and enter it into the Excel data form when back in the office. Data entry forms are available at the rare plant IMG monitoring web page. We ask that you submit all rare plant monitoring data to the SDMMP by October 1 of the year in which it is collected. Specific data for submittal includes:

- Completed Survey123 data files or MS Excel files reviewed for errors.
- Clearly labeled photos.

- GIS files with mapped extent polygons and point data (sample plot center and photo monitoring locations).
- Survey area shapefiles if the entire plant extent is not mapped.

Instructions for MSP Rare Plant Monitoring Forms

In preparing for rare plant surveys, surveyors should ensure they have all the required access permits and maps, gate codes, and keys, and training in the data collection protocol. The survey team should include members experienced with identifying the rare plant species being inspected. Ideally, two to three people comprise a monitoring team as this can improve estimates and makes it easier to delineate occurrence perimeters. Time the monitoring events when the target species is flowering and most detectable. Monitor geophytes when they are flowering. There is a calendar on the SDMMP website (rare plant IMG monitoring page) with suggested survey periods for each species. However, it is important to note that inter-annual differences in temperature and precipitation patterns can change species flowering phenology between years. For that reason, we recommend that surveyors visit occurrences early in the season to assess phenology and determine when to conduct surveys.

Specific information for each rare plant occurrence is found in the Rare Plant IMG geodatabases and the rare plant map viewer (see ***Rare Plant Occurrence Information*** section, above). Surveyors should prepare maps that identify access routes to rare plant occurrences. To improve efficiency and reduce data errors, we recommended that the surveyor pre-load information from the rare plant geodatabase that does not change from year to year before going into the field. The Survey123 data entry file already has much of these data pre-populated, whereas you will need to pre-enter data onto paper data forms or into Excel data entry forms for each survey site. This pre-populated information includes scientific and common names, MSP Occurrence ID, preserve, landowner, land manager, and sample plot and photo location coordinates.

<u>Field Equipment Needed for Surveys</u>

☐ Global Positioning System (GPS) submeter unit pre-loaded with occurrence sample plot and photo point location coordinates and polygon perimeters (if available). Alternatively, a smartphone (Android, iphone) is acceptable if no GPS unit is available.
☐ Extra batteries or power rechargers for smartphones, field computers, GPS and cameras
☐ Camera that can attach to monopod or tripod
☐ Tripod or monopod with camera mounting attachment (extendable to 5-6’ and with bubble level, if possible)
☐ Compass (or a smartphone with an app for compass directions, such as Thoedolite)
☐ Survey protocol, field forms (paper or Excel digital entry forms) & pens for entering data or as reference and backup to Survey123 digital data entry
☐ Smartphone, tablet or computer with Excel and/or Survey123 application if plan to enter data digitally
☐ Printed photo point photographs from previous monitoring efforts
☐ Ruler to measure thatch depth
☐ Cover estimate diagram (see page 4 of data form)
☐ Habitat and threat assessment category definitions (see page 4 of data form)
☐ Plant press and/or other plant collecting materials (optional)
☐ Aerial photograph (optional, for mapping population, threats, etc.)
☐ 2 tape measures

Measures to Avoid Impacting Rare Plant Occurrences While Monitoring

It is **very important** to minimize impacts to the plants from monitoring activities. Avoid creating paths or stepping on plants during surveys. Collect as much data as possible from the perimeter of the population and avoid repeated walking through the occurrence.

Undertake biosecurity measures to reduce transmission of invasive plant seed and pathogens, from one occurrence to the next. The California Invasive Plant Council has a manual with biosecurity measures to prevent the spread of invasive plants available for download at:

https://www.cal-ipc.org/resources/library/publications/landmanagers/

Surveyors should review the Best Management Practices in this manual prior to going into the field and implement relevant precautions while monitoring rare plant occurrences. At a minimum, surveyors should use standard precautions such as removing weed seeds from field boots and snake chaps in between occurrence monitoring events.

Field definitions and instructions for the MSP - Rare Plant Occurrence Monitoring Form

If collecting data using Survey 123 on a digital device, please refer also to the Survey 123 data entry instructions posted on the rare plant IMG web page (see above).

After arriving at the site, surveyors should go to the occurrence location, determine the current extent, and install the 10-m radius sample plot. If the occurrence was previously monitored, then the sample plot and photo point monitoring locations already exist in the Rare Plant IMG geodatabase. Locate the sample plot and photo points using the pre-loaded spatial data on the GPS unit or smart phone. You can temporarily flag the boundaries of the sample plot to make it easier to determine the habitat assessment area. Do not install permanent sample plot and photo point markers without permission from the landowner or manager. You will need to establish the sample plot if the occurrence is not previously monitored (see pages 2 - 5).

For previously monitored occurrences, much of the following information already exists in the Rare Plant IMG database and does not need to be re-entered into the monitoring forms and if using Survey123, these fields will not show up at all as the data are attached to the pre-loaded occurrence ID and sample plot number. The existing occurrence ID and sample plot number need to be entered onto paper forms and have been pre-loaded in both the Survey123 survey and the Excel data forms.

Instructions for Completing the MSP - Rare Plant Occurrence Monitoring Form, Page 1

Scientific Name: Record the monitored species' scientific name, including subspecies or variety, if applicable. Current scientific names are provided in the Rare Plants IMG/MSP-MOM-Plants databases in the column "SName".

Common Name: The species common name is the "CName" column in the Rare Plants IMG/MSP-MOM-Plants databases.

MSP Occurrence ID: The occurrence ID is obtained from the "OccID" column in Rare Plants IMG database. Please indicate whether this is an existing occurrence or a new occurrence that needs to be assigned an ID number by the SDMMP. If you are unsure, enter "other/unknown".

For example, MOST_3MAVA002 and MOST_3MAVA003 are two different occurrences of *Monardella stoneana* in Marron Valley and their occurrence names are Marron Valley #2 and Marron Valley #3, respectively.

Sample Plot (Sample Point): There can be multiple sample plots for the same occurrence identified by unique sample point identifiers. These are designated in the occurrence name as "-Obs. #X" (e.g., Carmel Mountain - Obs. #1, Carmel Mountain - Obs. #2) or as unique names (e.g., Crest Canyon North, Crest Canyon South). For the sample point, enter an observation number or name only if there are multiple sample plots for that occurrence. The default is sample point 1 if nothing is entered in this field.

New Sample Point?: Check the appropriate category to indicate whether this is an already assigned sample plot (i.e., sample point) or is a newly established point or unknown.

Occurrence Name: Record the occurrence name from the "OccName" field in Rare Plants IMG database. The occurrence name represents the site where the occurrence is found and is often named after a preserve, geographic area or feature, road, etc. If there are two different occurrences with the same site name, then they are differentiated with a number.

CNDDB EO#: If the occurrence has a CNDDB EO#, it is listed in the "OtherID" column in Rare Plants IMG databse as "EOXX" (e.g., EO4, EO15).

Translocated?: Enter if the occurrence is translocated, natural or if you do not know. Rare Plants IMG/MSP-MOM-Plants databases have a "Transloc" field that can help to complete this field.
Preserve, Landowner, Land Manager: Information on the preserve name, owner and manager can be found in Rare Plants IMG/MSP-MOM-Plants databases.

Surveyors & Affiliation: Record names and agencies of all field personnel participating in the monitoring (use full names).

Date, Time Start, Time Finish: When in the field, record the date (MM/DD/YYYY) and time start of data collection at the beginning of the data entry form. **When the survey is completed, enter time finish at the end of the form in the notes section**. This information allows us to track the time it takes to complete surveys for budgeting purposes.

I. SAMPLE PLOT INFORMATION:

 # Plants/Sample Plot: Directly count or estimate the total number of plants in the sample plot. A surveyor can estimate the number of plants in the sample plot if the plants are too dense, if it's not feasible to count every individual, or if there is a risk of impacting the population or habitat by trampling. A surveyor can estimate the number of plants in the sample plot by counting a portion of the plants in the plot and then extrapolating to a total number of total plants in the sample plot. Describe the **uncertainty** of your count or estimate as very high, high, medium, low, very low. If the occurrence is so large that a numeric estimate is uncertain, give a "ballpark" estimate and indicate in the "Uncertainty?" field that uncertainty is "very high". If every plant has been counted (i.e., census) then the uncertainty is very low.

Enter the radius (m) of the sample plot area, which should always be 10m but is entered to confirm the area sampled. Indicate whether counts/estimates were of individual plants, or clusters of plants. For species that tend to cluster, indicate how a cluster is differentiated from an individual. For geophytes, indicate whether counts/estimates were made when there were flowering individuals or only vegetative individuals.

Phenological Stages and Evidence of Herbivory, Disease, and Stunted Growth: For each phenological stage (vegetative, flowering, fruiting, dead) and for evidence of herbivory, disease, or stunted growth, enter the number of the category representing the range in % of plants in the sample plot that exhibit that trait. Plants that have unopened buds should be included in the flowering phenology category. If individual plants are both flowering and fruiting, then estimate the percentage of the plants in the plot that are in flower and in fruit and fill out both categories respectively.

Disease applies if a species is visually affected (e.g., abnormal spots, fungus, mold, rust, mildew).

Stunted growth applies when a species appears fully grown and is obviously smaller than in previous years or when compared to other occurrences of the same species during the same growing season.

The categories are defined as:

1 (0%) 2 (>0% to <10%) 3 (10% to <25%) 4 (25 to <50%) 5 (50 to <75%) 6 (≥75%)

Record any notes with any additional details on page 3 of the data form.

Is the Sample Plot within Current Mapped Extent? Check yes or no to indicate whether the current distribution of the plant is inside the sample plot.

II. SAMPLE PLOT LOCATION & SITE PHOTOMONITORING

Note: If the location has been previously monitored using the MSP Rare Plant Monitoring Protocol, coordinates for the center or the plot and for the photo point(s) will appear in Survey123 or on the coordinates list provided by SDMMP. Please consult the list to confirm the correct coordinates. If corrections need to be made to the coordinates, record the correct coordinates on the data form.

Sample Plot Location:

GPS /Smartphone Accuracy: Record the accuracy of the GPS unit (or smartphone if GPS unit is unavailable) and specify the units (e.g., meters).

Datum: Record the datum setting for the GPS unit. To standardize data, we ask that surveyors use NAD 83.

Coordinate System: We request that all spatial data be in UTM coordinate systems.

Center of Plot Coordinates: These are the coordinates for the center of the 10m radius sample plot. Indicate "no change" on the form if a surveyor monitored the location previously and the coordinates on the list provided by SDMMP are correct. Indicate "new location" and provide the coordinates for all new monitoring locations. Indicate "correction" and provide the new coordinates if you have reason to believe that the coordinates on the list provided by SDMMP are incorrect. Record the easting and northing coordinates at the center of the sample plot and at the photo point using coordinates from your GPS or Smartphone.

Photo Monitoring:

Take photos from the exact same viewing location during each monitoring visit. The surveyor should place the photo monitoring point in the location that maximizes the rare plant assessment and/or population extent view. Photo point establishment could be on the outside of the sample plot looking in toward the population, from the center of the sample plot looking in one or two different directions or from another appropriate location. Use a tripod or monopod with an elevation/bubble feature if possible and avoid using camera zoom features unless the exact zoom level can be recorded. Ensure that your photograph view lines up to the extent possible with previous monitoring photograph views so that visual changes can be tracked over time. Bring copies of previous monitoring photographs into the field to ensure annual photo monitoring accuracy.

Camera Type: Record the type of camera used for photo monitoring, including make, model, and lens type (if known).

Photo 1 Location: The coordinates for this location are recorded where the photo is taken. If photos are taken from a secondary location, then the coordinates should be entered under "***Photo 2 Location***". Survey123 will provide coordinates if the sample plot has been previously monitored. Indicate "no change" on the form if photos were taken at this location previously and the coordinates on Survey123 or the list provided by SDMMP are correct. For new monitoring locations, indicate "new location" and provide the photo coordinates. Indicate "correction" and provide new coordinates if you have reason to believe the photo coordinates on the list provided by SDMMP are incorrect.

Direction: Using a compass (or smartphone app), note the direction that photo(s) are taken using either cardinal directions and/or degrees. Be certain that the compass is reading true north and record the declination in the notes.

Height: Measure the height of the camera *in meters* (from ground to bottom of camera body, unless otherwise noted).

***Camera Angle**:* Record the angle that the photo(s) are taken, whether level or at an upward or downward facing angle. Include degree of angle, if possible.

Photo Number: Label photographs using the following protocol: occurrence ID_plot # (numeral only)_photo number (use the word 'photo' along with photo #)_monitoring date (MMDDYYYY) (Example: ACPR_ 1DUTR005_1_photo 1_03292019).

III. HABITAT ASSESSMENT IN SAMPLE PLOT

Conduct the habitat assessment within the 10m radius sample plot.

SANDAG 2012 Vegetation Alliance/Association: Determine the vegetation alliance and association of the sample plot based upon data collected in "Associated Species" and using the key in the *Vegetation Classification Manual for Western San Diego County* posted on the SDMMP Rare Plant Monitoring web page. This is typically done in the office after fieldwork is completed.

***Cryptogamic Crust Cover, Thatch Cover*:** Record the number of the % cover class for cryptogamic crust and thatch (i.e., non-native grass) cover within the sample plot. Cover classes are defined as:

1 (0%) 2 (>0 to <10%) 3 (10% to <25%) 4 (25% to <50%) 5 (50 to <75%) 6 (≥75%)

Thatch Depth: Thatch is defined here as dry, dead, nonnative grasses (lying on the ground or attached and standing up) within a site that are from the previous year. Any dry, dead grass from the current year should be included in the associated species section and not included as thatch. Estimate average thatch depth using the following categories: 1 (no thatch); 2 (<1 cm); 3 (1 to <5 cm); 4 (5 to <10 cm); 5 (10 to <15 cm); 6 (15 to < 20 cm); 7 (≥ 20 cm). Estimate maximum thatch depth in cm within the sample plot.

Dead Standing Biomass: Standing dead biomass is typically larger dead nonnative forbs, such as fennel, mustard, curly dock and star thistle, that are attached to the ground. Standing dead biomass <u>does not include dead, native shrubs</u>. Record whether there is dead standing biomass and if it is present, record the dominant species and cover class (above) and average height in cm.

Mammal Species Activity Categories: Assign the number of the appropriate activity category for feral pigs, ground squirrels, and pocket gophers. Activity categories numbered from 1-4 are defined as:

Feral pig activity within sampling area:

1 = No feral pig activity (rooting, wallowing, vegetation destruction, tracks, scat, pig) detected.

2 = Signs of pig activity (rooting, wallowing, vegetation destruction) in sample plot appear months old.

3 = Signs of recent pig activity (rooting, wallowing, vegetation destruction, tracks, scat, pig) in adjacent areas but not within sample plot.

4 = Recent signs of pig activity (rooting, wallowing, vegetation destruction, tracks, scat, pigs) within sample plot.

Ground squirrel activity within sampling area:

1 = No ground squirrel burrows detected.
2 = Burrows and/or ground squirrels observed in adjacent areas but not within sample plot.
3 = Single squirrel or burrow seen within sample plot.
4 = Multiple burrows and/or squirrels seen within sample plot.

Gopher activity within sampling area:
1 = No pocket gopher mounds detected.
2 = Mounds or gophers observed in adjacent areas but not within sample plot.
3 = <10 mounds observed within sample plot.
4 = ≥10 mounds or one or more gophers seen within sample plot.

Sample Plot Representative of Maximum Extent? Indicate whether the sample plot appears representative of the maximum extent. If the sample plot encompasses the entire maximum extent of the occurrence, then enter yes. If the sample plot appears to differ substantially from the maximum extent, then enter no and note the differences in the notes section on page 3 of the data form. Be sure to specify which covariates differ and how they differ.

IV. VEGETATION COVER/ASSOCIATED SPECIES IN SAMPLE PLOT

List all *native* and *nonnative* plant species, bare ground, litter, rock, water, dead shrubs, and cryptogamic soil crusts with estimates of percent cover within the sample plot. **Cover is estimated as a specific value** and should be equal to or slightly greater than 100%. Avoid recording plant overlap to the extent possible since we use the 'bird's eye' or vertical view to record cover. Record *all* non-native plant species in order to identify if management actions are needed. The preferred reference for species names is "*Checklist of the Vascular Plants of San Diego County*, *5th Edition*" (2014) by Jon P. Rebman and Michael G. Simpson. It can be downloaded from the San Diego Natural History Museum's website (http://www.sdnhm.org/science/botany/projects/checklist/).

Total cover in the sample plot is defined as total surface cover + total vegetation cover. Total cover must equal at least 100% of the plot. To collect total cover, visually (bird's eye view) estimate and record the percent of the plot occupied by the associated species, bare ground, litter, rock, water, dead shrubs and cryptogamic soil crusts and then add up all values. Do not record occupied area as a cover class (e.g., 1-5%, 10-25%). If total cover is less than 100%, adjust cover for the various substrates or vegetation to reach at least 100%. Always use the diagram of Percent Cover Categories from the California Native Plant Society (CNPS) (see below) for this analysis; estimates without such guidance tend to be inflated. It is recommended you copy the diagram onto a clear plastic sheet (like an overhead) for field use. Additionally, it helps to have two surveyors make individual estimates, then compare estimates and come to agreement on a final cover estimate.

To estimate total cover within the sample plot:

1. Walk around the entire sample plot and look down at the surface and vegetation cover (i.e., bird's eye view). View the plot from a higher vantage point if possible.
2. Estimate and record percent of the sample plot occupied by each surface cover category. Litter includes any non-living material on the ground surface, such as dead leaves, grass thatch (from the previous year), sticks, logs and even scat that can decompose and disappear from the surface. Rock includes all pebbles, cobbles and boulders and also includes sea shells, which are more permanent. Bare ground includes pebbles smaller than 2mm in size. Water may or may not be present. Lump together and record the combined cover of all dead, native shrubs that are upright, still attached to the

ground, and not lying on the ground surface. Lump and record the cover of all non-vascular cover (lichens, mosses, cryptobiotic crusts) in the cryptogamic soil crusts location.

3. To calculate vegetation cover:
   - Create a comprehensive species list for the sample plot. Record species' scientific name. If plants cannot be identified in the field with certainty, collect the species for later identification and/or verification. If you submit a specimen to an herbarium, note the collector, collection number and the herbarium name at the bottom of page 2 of the data form.
   - Estimate percent cover for each species on the list using the CNPS cover categories figure as a guide. Enter cover values using whole numbers (i.e., 2%, 6%, 12%, 22%) except for any species with cover less than 1%. Enter the numeric value of 0.2% for species with cover less than 1%, which is equivalent to 'trace cover'.
   - Add all species percentages together to obtain a single vegetation cover estimate value (e.g. 27.2%). Collect plant species cover as absolute cover values (**do not record overlap**) and include cover estimates for target rare plant species.
4. Calculate total percent cover for the sample plot by adding up percent cover estimates from all cover categories (Total cover = % bare ground + % litter + % rock + % water + % vegetation + % dead shrubs + % cryptogamic soil crusts).
5. Verify that total cover equals at least 100%. If total cover is less than 100%, adjust surface and/or vegetation cover values to reach at least 100% so that the entire area of the sample plot is accounted for.

Nonnative: Check this column for known nonnative species if using paper forms (this option is not included in Excel or Survey123 data forms where it is automatically entered).

V. CURRENT MAPPED EXTENT INFORMATION

This section involves collecting information on the status of the occurrence within the current mapped extent.

 # Plants/Current Mapped Extent: **If the mapped occurrence perimeter falls entirely within the sample plot, then this number is the same as that entered for "# Plants/Sample Plot"**. If this is the case, enter the number in both places. If the occurrence perimeter is larger than the sample plot, then count or estimate the number of plants within the entire mapped perimeter of the occurrence. **If there are multiple sample plots per occurrence, the # Plants/Current Mapped Extent should be the total number of plants in the entire occurrence and the same number should be entered for each sample plot.**

Counting individuals is preferred, with estimation used only when occurrences are too large to reasonably count. Provide only numeric values and do not add modifiers like < or > or use non-numeric descriptors such as 1000s, instead estimate a specific number of plants (e.g., 1,000 or 2,500). Round off estimates to the order of magnitude that you are most comfortable estimating. Describe the **uncertainty** of your count or estimate as very high, high, medium, low, very low. If the occurrence is so large that a numeric estimate is uncertain, give a "ball park" estimate and indicate in the "Uncertainty?" field that uncertainty is "very high". If every plant has been counted (i.e., census) then uncertainty is very low. Indicate whether the counts/estimates were of individual plants, or clusters of plants. For geophytes, designate whether the counts/estimates were of flowering individuals or of vegetative individuals.

Area of Current Mapped Extent: Map the perimeter of the occurrence using a GPS and enter the size of the area and specify units (e.g., square meters). The size of the area is usually calculated in the office using GIS. If you do not have access to GIS, the SDMMP can calculate this variable once the GPS points are received. If the occurrence perimeter is not delineated with GPS, then record an estimate of the occurrence size. This can be done by mapping onto an aerial photo and then calculating the area in GIS or Google Earth in the office. Indicate whether the area was GPS mapped or estimated based on methods such as mapping onto an aerial photo. Specify whether the perimeter of the current extent was determined by walking it and recording with a GPS unit, or determined by other means.

Species Found in Maximum Extent? Check off whether or not the species was located within the cumulative mapped extent for this occurrence. If the species is not found, note if there are potential or obvious explanations for why the species wasn't detected.

Is the Current Mapped Extent different from previous years due to variation in survey efforts from previous years? In some cases, the current maximum extent changes significantly from one year to the next due to a change in the survey effort not a change in the actual species fluctuations. This may be because an occurrence is split between multiple owners and access to one or more properties varies from year to year. This could also occur when a new location of the species is found in an area that was not previously monitoring (i.e. there is no negative data associated with the new location). This would mean that the extent appears to grow or shrink between years but it is not reflective of the actual conditions. If this is the case, indicate "yes". In the follow up questions, specify the reason for this change. A note field is available to explain further.

VI. THREATS ASSESSMENT IN MAXIMUM EXTENT

The threats assessment includes the maximum extent of the occurrence plus a 10-m buffer. The maximum extent is the **cumulative area over which the species has been mapped over time**. This area may be substantially larger than the current mapped extent or the sample plot, depending on the size of the occurrence.

Surrounding Land Use/Activity: Record the land use or human activities adjacent or surrounding the preserve (e.g., residential, road, open space, etc.) and indicate the distance to the sample plot.

Disturbances: There are a number of disturbances that may threaten rare plant populations, such as invasive plants, soil disturbance from a number of activities, altered hydrology, etc. For all disturbances detected within the occurrence's maximum extent and adjacent 10-m buffer, rank the level of disturbance and enter the numeric category code (1- 7) using the following criteria:

Disturbance categories within maximum extent:

1 = No sign of disturbance within maximum extent or in adjacent 10 m buffer.

2 = Disturbance does not occur within maximum extent but is detected within the surrounding 10 m buffer area.

3 = Disturbance present in >0% to <10% of area within maximum extent.

4 = Disturbance occurs in 10% to <25% of area within maximum extent.

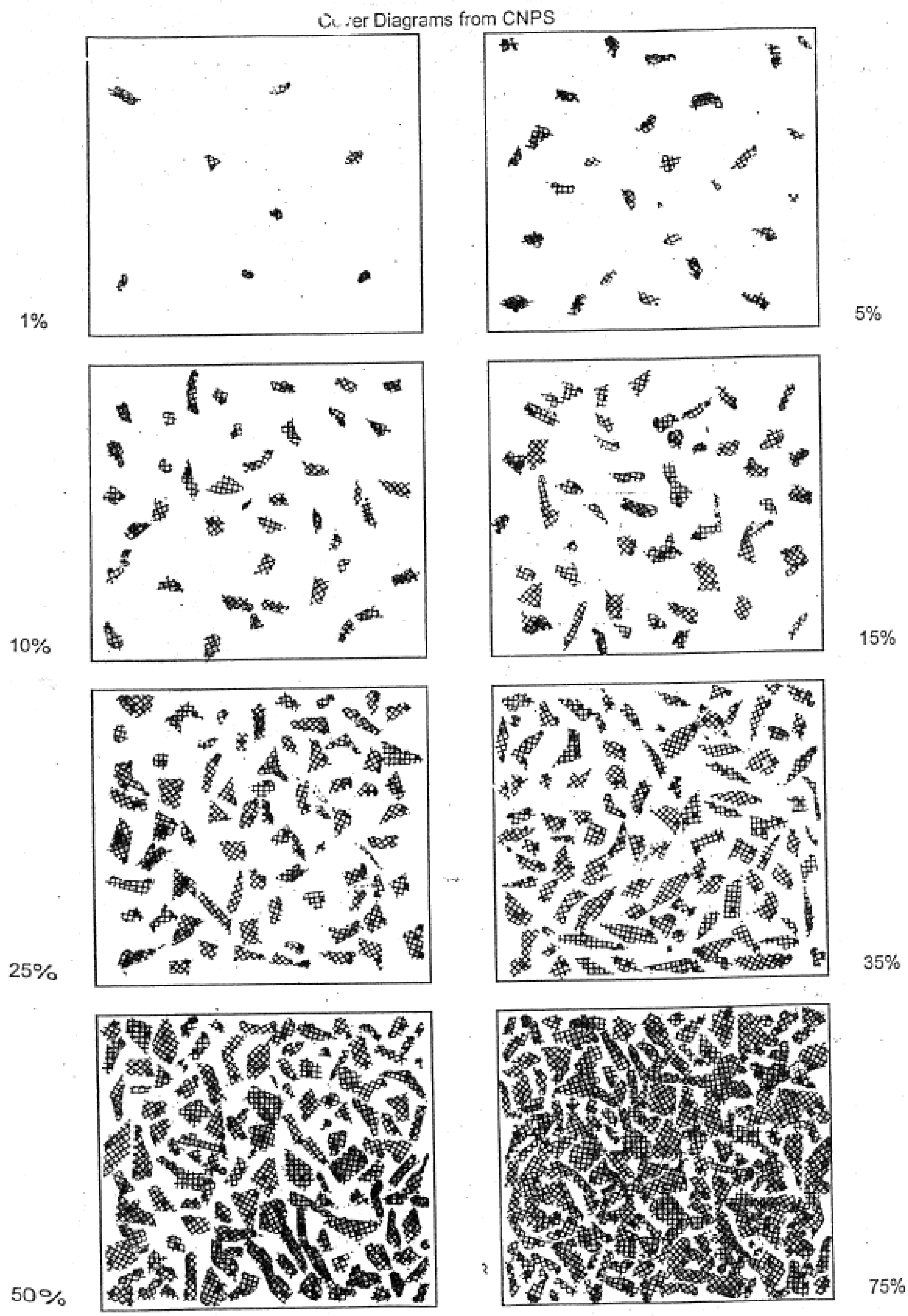
5 = Disturbance occurs in 25% to <50% of area within maximum extent.

6 = Disturbance occurs 50% to <75% of area within maximum extent.

7 = Disturbance occurs ≥75% of area within maximum extent.

Provide additional information into the designated fields on the data form if trails or recent fire are detected in the occurrence or buffer area. Record and rank if there are other potential threats that are not listed on the form. Please note that the restoration field refers to management actions to improve habitat but that adversely impact rare plants. Other vegetation management activities that are not for habitat restoration or enhancement are covered by fuel modification zone, brush management and vegetation clearing categories. For notes sections, please **avoid the use of special characters** as these symbols cause formatting issues when importing data into the relational database.

Percent Cover Categories from the California Native Plant Society



VI. MANAGEMENT RECOMMENDATIONS

Based on disturbances and threats noted previously, provide management recommendations for the site.

VII. MANAGEMENT ACTIONS IN LAST YEAR

Record any known management actions that have been implemented at the rare plant occurrence over the last year.

VII. CNDDB SPECIES DETECTED & NOTES

Record detailed notes and any other useful field comments **not previously addressed in other sections of the form**. If sensitive or rare species (e.g., MSP Roadmap Species, species in CNDDB database including CDFW Species of Special Concern, state and federally listed species) are detected incidentally, record the observation with coordinates, number of individuals, etc. in this section. Do not record the target rare plant species in this section.

VIII. COLLECTIONS

Collection? Indicate whether a collection of plants within the sampling area was taken during the monitoring event. If there is a collection, complete the section on collector, collection number, and museum/herbarium where the collection was submitted.

Don't forget to record Time Finish in the bottom of Page 3 of the data form or at the end of the Survey123 form.

References

CNDDB. 2011. *California Natural Diversity Database (CNDDB) Data Use Guidelines*. http://www.dfg.ca.gov/biogeodata/cnddb/

McEachern, B. Pavlik, J. Rebman, and R. Sutter. 2007. *San Diego Multiple Species Conservation Program (MSCP) Rare Plant Monitoring Review and Revision*. U.S. Geological Survey Scientific Investigations Report 2007-5016, 68 p..

McEachern, K. and R. Sutter. 2010a. *Assessment of Eleven Years of Rare Plant Monitoring Data from the San Diego Multiple Species Conservation Plan*. USGS-WERC-Channel Islands Field Station. Administrative Report 2010-01. Ventura, California, 146 p.

McEachern, K. and R. Sutter. 2010b. *San Diego MSCP Rare Plant Monitoring Data Review*. Presentation, February 10, 2010, San Diego, CA.

SDMMP. 2017. *Management and Monitoring Strategic Plan for Conserved Lands in Western San Diego County: A Strategic Habitat Conservation Roadmap. Vol. 1-3*. Prepared by the San Diego Management and Monitoring Program and The Nature Conservancy for the San Diego Association of Governments, San Diego. https://portal.sdmmp.com/msp_doc.php

Tracey, J., K. McEachern, and K. Greer. 2011. *San Diego Rare Plant Monitoring Plan: Fiscal Year 2011*.

Appendix 7: Power Analysis R Code

This appendix is part of the following report:

Perkins, E.; P. Gould, J. Kingston, C. Brown, K.L Preston, and R.N Fisher. 2024. Coastal Sage Scrub and Chaparral Vegetation Monitoring Plan for Western San Diego County, U.S. Geological Survey Cooperator Report prepared for San Diego Association of Governments Regional Habitat Conservation Taskforce. Agreement 548642. https://sdmmp.com/view_project.php?sdid=SDMMP_SDID_71_663178c710cba.

Power Analysis R Code

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The code used to the power analysis run analysis in this report is available to download. This code is intended to run using the R programming language. For inquiries regarding this code or analysis, please contact Philip Gould (pgould@usgs.gov).

The code is available to download as an R file at:
https://sdmmp.com/view_project.php?sdid=SDMMP_SDID_71_663178c710cba