FINAL CAMP PENDLETON Coastal Sage Scrub and CHAPARRAL MONITORING PROTOCOL

MARINE CORPS INSTALLATIONS WEST
MARINE CORPS BASE CAMP PENDLETON

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Cover Photo

Coastal sage scrub on Marine Corps Base Camp Pendleton. Photo taken March 1, 2019. Photo by D.M. Lawson

Acknowledgments

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LIST OF ACRONYMS

Base	Marine Corps Installations West – Marine Corps Base Camp Pendleton
Camp Pendleton	Marine Corps Installations West – Marine Corps Base Camp Pendleton
CAGN	California gnatcatcher
CLC	Coastal low cloudiness
CM	centimeters
CNLM	Center for Natural Lands Management
CSS	Coastal Sage Scrub
ESA	Endangered Species Act
FDR	Fire Danger Rating
FDRS	Fire Danger Rating System
G3	Base Operations and Training
GPS	Global Positioning System
km	kilometers
LMS	Land Management Section – Marine Corps Base Camp Pendleton
LTETM	Long Term Ecological Trend Monitoring
m	meters
MMU	Minimum Mapping Unit
MCBCP	Marine Corps Base Camp Pendleton
MCI-West	Marine Corps Installations West
NDVI	Normalized Difference Vegetation Index
NPS	National Park Service
NCCP	Natural Community Conservation Plan
SDMMP	San Diego Management and Monitoring Program
SPAWAR	Space and Naval Warfare Systems Command
SSC Pacific	Space and Naval Warfare Systems Center, Pacific
SD	Standard Deviation
USFWS	U.S. Fish and Wildlife Service
USFS	U.S. Forest Service
USGS	U.S. Geological Survey

EXECUTIVE SUMMARY

Shrubland habitats comprise over half the land area of Marine Corps Base Camp Pendleton, supporting both the military mission and threatened species in a complex working landscape. Wildfire, a common effect of military training operations, poses the single greatest threat to shrubland habitats. The vast majority of Camp Pendleton's 125,000 acres have burned repeatedly since its origin in 1942, including the Basilone Complex Firestorm of 2014 which burned approximately 22,000 acres (Base GIS data). The frequency of fires on Base is uncharacteristically high for its native plant communities which can drive accelerated shrubland degradation on the landscape level (Keeley and Brennan 2012). In this context, Marine Corps land managers strive to cost-effectively manage natural resources, balancing compliance with federal environmental legislation, and while meeting the needs of Camp Pendleton's military training mission. Current data on shrubland condition, resilience, and vulnerabilities is needed to support strategic decisions to manage these trade-offs while sustaining the military training mission.

The overarching goal of this protocol is to deliver a simplified but accurate tool to determine integrity classes of shrublands to allow land managers to identify when a management action needs to take place to prevent shrublands from shifting past a tipping point to a degraded state where recovery requires costly management interventions. This document present lays out a shrubland monitoring protocol (figure ES-1) with sufficient statistical power to provide timely, reliable yearly assessments (snapshot maps) of ecosystem integrity and forecast future trends and vulnerabilities. The information developed will be used to develop an improved understanding of ecosystem shifts, and better anticipate vulnerabilities in coastal sage scrub and chaparral vegetation systems on a spectrum of degraded to non-degraded states.

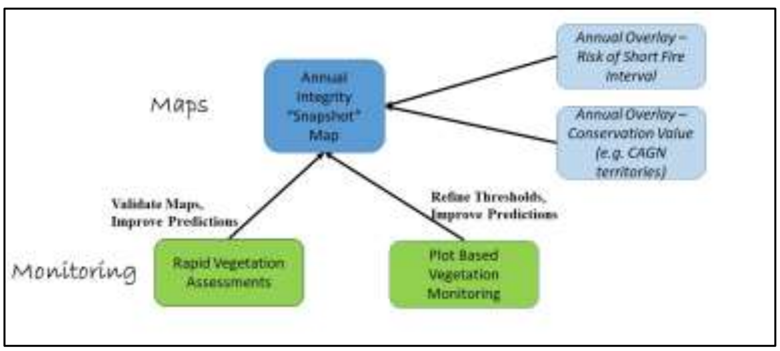

Figure ES-1. Protocol elements include annual integrity maps, overlays and vegetation monitoring.

To be sustainable monitoring must be easy to repeat, cost effective, and produce timely results. This protocol uses tiered sampling that employs rapid vegetation assessment for the bulk of the integrity assessments coupled with judicious use of more intensive plot-based protocols to validate integrity data and address specific questions. Better understanding of the ecosystem as annual data is collected and analyzed is anticipated to reduce the amount of field work needed to validate maps generated by annual fire data. Community integrity, defined by the degree to which shrublands are invaded with invasive annual grasses, is used to characterize condition. The classification system is based on ecosystem components (shrub and grass composition) readily understood by non-specialists (figure ES-2), and expected to enhance communication among land managers. The break points between the classes are intended to be tipping points between resiliency and degradation (Suding and Hobbs 2009) are based on the literature and expert opinion and will be refined over time. Over time, as shifts in integrity are better understood, the annual map updates should take less field time to create and validate.

Figure ES-2. Community integrity classes defined by degree of non-native grass dominance are readily identifiable by non-specialists.

Primary protocol products include: 1) annual integrity maps and 2) map overlays depicting integrity threats, (e.g. habitat patches at-risk of short fire interval), and conservation values and special status species. Projection of trends in integrity will be developed from threat overlays. While at this stage projection of trends in integrity centers on wildland fire return interval but protocol implementation and refinement should allow other disturbance factors and site and weather factors related to aridity into our model of integrity class transition (figure 9) to more accurately project trends in integrity.

While the objective is to implement the protocol on Camp Pendleton, the protocol is applicable to coastal sage scrub and chaparral across the portion of California’s southwest ecoregion (Hickman 1993) in San Diego, Orange, and western Riverside Counties. Broad utilization of the protocol would improve statistical power, which would help land managers develop information needed to inform management of coastal sage scrub and chaparral communities sooner.

DOCUMENT ORGANIZATION

This protocol is organized in two sections and two appendices. Section 1 is the introduction provides a general overview addressing the purpose, goals and objectives of the protocol and defines key terms. Section II is the protocol (see table 2) and includes 5 main elements:

1) the **integrity classification system** (section II.A) with a summary of the scientific basis of ecosystem integrity and proposes initial thresholds values.

2) the **methods** section lays out procedures for data collection and map generation (section II.B),

3) the **data management guidelines** address quality assurance, data documentation and database maintenance (section II.C),

4) the **analysis, reporting** (section II.D) **and revision guidelines** (sections II.E), lays out the analytical framework and calls for regular methods review to determine and subsequent revision is determined necessary

5) the **protocol implementation** (section II.F) outlines the procedures for baseline map generation, overlay development and supporting Tier 1 and Tier 2 vegetation sampling.

The appendices contain data sheets and field equipment lists.

I. INTRODUCTION

Camp Pendleton is one of the Marine Corps' most important training facilities. Ecological communities provide the natural infrastructure that supports military training. Developing information on relating to sustainment of these resources is vital to mission support. The vast majority of Camp Pendleton's 125,000 acres have burned repeatedly since its establishment in 1942. This has resulted in a much shorter fire interval than the regional 20th century average of approximately 35 to 40 years for shrublands in San Diego County (Keeley et al. 1999). Recent (2005 to 2015) shrubland fire return intervals for the Base were 10 years for coastal sage scrub and 23 years for chaparral (Tetra Tech Inc 2016). The high fire frequency is also reflected in the total number of fires on Base. Between 1970 and 1997 there were more than twice as many brush fires on Camp Pendleton than in the rest of San Diego County, an area more than 20 times larger (Keeley et al. 1999; Base Fire History Data).

The Base's fire regime lends itself to accelerated vegetation change on the landscape level, whereby dense shrub communities are converted to sparse shrublands dominated by invasive annual grasses (Keeley and Brennan 2012). While there are a number of threats (figure 3) to coastal sage scrub (CSS) and chaparral, shortened fire intervals in combination with invasive annual grasses, are the most significant. Once shrublands are invaded with these grasses, positive feedbacks, where fire fosters grasses which in turn foster short fire intervals, can result in further increases in grasses and decreases in native shrubs. Of the two main shrubland types CSS is more widespread on the Base (an estimated 57,500 acres) and dominates in lower elevations and more coastal locations, while chaparral (an estimated 15,000 acres) dominates at higher elevation inland sites (figure 4; AMEC 2006). Figure 5 shows Camp Pendleton's shrublands in the context of regional shrublands.

The goal of the Department of Defense's conservation program is to support the military's combat readiness mission while maintaining the long-term sustainability of its natural resources (Sikes Act 16 U.S.C. 670a et seq. as amended). To maximize military training flexibility while complying with laws that protect endangered species (ESA) or require natural resource management programs (Sikes Act), Base natural resource and military land managers must have clear, concise information on status and trends, of shrubland systems for decision support. The data developed under this protocol will be integrated into the Base's annual fire prevention planning to identify high value resource assets. Although wider implementation is not a formal program objective, adoption of the program by other land managers of shrubland habitats in San Diego, Riverside and Orange California's southwest ecoregion (Figure 5) (Hickman et al. 1993) could improve the statistical power of collected data to reveal key aspects of ecosystem function useful for land managers.

The overarching goal of this protocol is to support a simplified but accurate tool to determine integrity of shrublands to allow land managers to identify when a management action needs to take place to shrublands from shifting to a degraded state past a tipping point where recovery requires costly interventions. The objectives are to develop a cost-effective shrubland monitoring protocol with sufficient statistical power to provide timely, reliable yearly assessments (snapshot map) of ecosystem integrity and forecast future trends and vulnerabilities. The initial phase will be a pilot study where the data collected is used to evaluate statistical power and ensure that sample size is sufficient but not excessive to achieve objectives. Over time data collected under this protocol will be used to develop an improved understanding of drivers of change, and develop capabilities to better anticipate vulnerabilities in coastal sage scrub and chaparral vegetation systems on a spectrum of degraded to non-degraded states. The detailed scientific basis for the protocol can be found in Lawson and Keeley (2019).

The approach employed in this protocol combines mapping to develop information on the integrity status of shrubland stands and plot-based vegetation monitoring to develop a more nuanced understanding of the impact of threats and drivers on integrity status. Together these elements will support improved identification of integrity status, and projections of vulnerabilities and future trends.

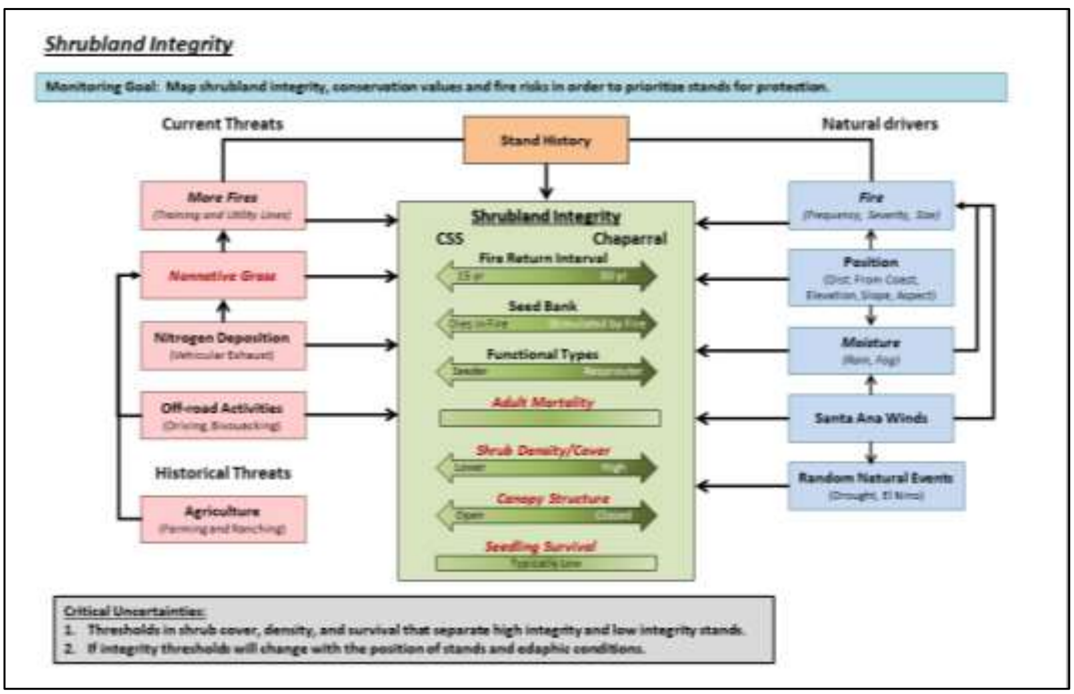

Figure 3. Relationships between threats and natural drivers and shrubland integrity. Arrows between boxes show interactions. Red text identifies parameters to be monitored.

The most effective biological monitoring programs have a sharp focus on specific resource management problems and objectives while providing timely information to land managers (Margoluis et al. 1998). A number of increasingly sophisticated monitoring plans (Deutschman and Strahm 2011, CNLM 2013, National Park Service 2005), monitoring guides (Atkinson et al. 2004), monitoring reviews (McEachern 2001, Jones and Kunze 2008) and an Index of Biological Integrity (Diffendorfer et al. 2004, Diffendorfer et al. 2007) that include shrubland elements have been developed for coastal southern California. These documents address long-standing weaknesses of monitoring efforts, including cost effectiveness and statistical power. This monitoring protocol has been developed to build on and advance these efforts with input from managers and scientists (table 1) who met as a working group in 2015 and 2016.

Table 1. Working group members and roles.

Role	Name and Affiliation
co-lead	Deborah Bieber, Head MCI-West MCBCP Land Management Section (LMS)
co-lead	Dawn Lawson, Project Lead, SPAWAR SSC Pacific
assistant lead	Lisa Ordonez, SDSU
participant	Jim Asmus, Ecologist, MCBCP LMS
participant	Pete Beck, Fish and Wildlife Biologist, USFWS
participant	Gabe Goodman, Fire Ecologist, MCBCP LMS
participant	Jon Keeley, Ecologist, USGS
participant	Gwen Kenney, Ecologist, MCBCP LMS
participant	Patrick McConnell, Natural Resources Specialist, MCBCP LMS
participant	Yvonne Moore, Coordinator, San Diego Management & Monitoring Program (SDMMP)
participant	Kris Preston, Science Support, SDMMP, USGS
participant	Trish Smith, Ecologist, TNC

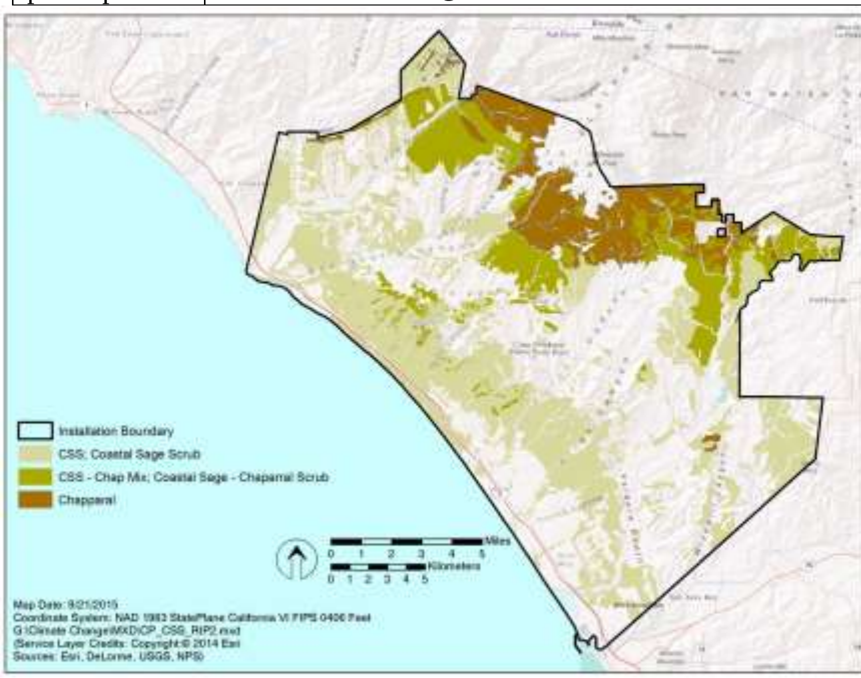

Figure 4. Camp Pendleton shrubland communities.

Figure 5. Coastal sage scrub and chaparral habitats in San Diego, Riverside and Orange County. Southwest ecoregion boundary in blue. Camp Pendleton boundary in black. Data from SDMMP, USFS and MCB Camp Pendleton

Key Definitions

Ecosystem integrity best thought of on a scale of low to high is the degree to which the structure, composition and function of an ecosystem operates within the bounds of historical variation (Karr & Chu 1999). Disturbance outside the range of historical variation drives changes in integrity. High integrity is close to natural structure, composition, and function; low means is substantially degraded relative to high integrity. This classification system specifically relates to plants.

A practical way to define this gradient for southern California shrublands is based on the proportion of vegetative cover composed of exotic annual grasses (Diffendorfer et al. 2007). Exotic annual grasses are more influential than other exotics on stand integrity because of their influence on:

a. structure (replace shrub cover and reduce bare ground and biological soil crusts in canopy gaps, increase continuity and quantity of fine wildland fire fuels).
b. composition (increases in grasses are accompanied by decreases in native plant abundance)
c. function (annual grasses can promote short fire intervals through their effect on wildland fire fuel loading, moisture, continuity, and increased probability of ignition when grasses are dry)

Vulnerability in the context of ecosystem integrity refers to the ease and likelihood of a stressor resulting in a decline in ecosystem integrity. Shrublands have a key post-fire period where sites of high to moderate ecosystem integrity are highly vulnerable to degradation from short fire intervals. The vulnerability to short fire interval is increased by other stressors including long term drought, nitrogen deposition, and invasive species.

Resilience, or the ability to rebound to a pre-existing condition after change, is a positive quality at the high end of the integrity spectrum, but negative (resisting an increase in integrity) or neutral (resist further degradation) at the low end. In the context of shrubland monitoring and management this term should be used with reference to a site-specific stressor (e.g. fire and invasive species). The definition includes resilience to stressors such as anthropogenic disturbance (vehicular and foot traffic, agriculture, land clearing), drought, altered fire regimes, invasives, and climate change. Over the long-term climate change is anticipated to slowly degrade resilience (Scheffer and Carpenter 2003).

Thresholds are tipping points at which the relationships between drivers and ecological properties change from linear to non-linear so that a small change in the driver (e.g., a short fire interval) results in a much larger change in the ecological response (e.g. low or no shrub recruitment) than at other places along the response curve. Thresholds can be difficult to detect due to multiple interacting drivers and natural stochasticity (Scheffer et al. 2001). This protocol uses structural thresholds (Briske et al. 2005) related to floristic composition of shrub stands.

In addition to non-linear changes, thresholds are also characterized by whether ecosystem changes are reversible (Sasaki et al 2015, Suding and Hobbs 2009). Irreversible thresholds are often associated with the loss of non-renewable resources (e.g. soils). Invasive species can create difficult to reverse thresholds by changing competitive relationships so that resources such as water and space are essentially lost. When competitive relationships are altered, environmental stochasticity may create periodic conditions where previous species assemblages are competitive and can regain space.

Thresholds are often a characterized by a time lag (referred to as hysteresis) after an ecosystem driver reverts to historical ranges of variation where the community is slow to recover. Resilience often declines as thresholds are approached. In post-fire coastal sage scrub resilience is low until seed and budbanks are replenished. Threshold drivers may need to be defined separately for degradation and recovery processes. A short fire interval may rapidly degrade a stand while several generations of seed production, dispersal, and recruitment may be required to fill gaps in shrub cover.

II. PROTOCOL

This monitoring protocol (table 2) lays out an integrity classification system and methods for protocol implementation and revision. Implementation consists of four main elements: baseline integrity mapping, annual integrity mapping updates, vegetation monitoring and data management and reporting. Baseline integrity will be based on recent vegetation mapping. Updates will utilize annual fire maps and relationships between fire, environmental conditions and integrity. The vegetation monitoring is designed to: 1) validate the integrity maps and updates 2) validate and refine the integrity classification system and 3) improve the ability to project integrity changes based on fire and environmental conditions (e.g. rainfall, aspect, soil texture, presence of fog and low clouds and nitrogen deposition). Map and integrity classification system validation and refinement utilizes a two-tiered vegetation sampling system with tier one consisting of rapid visual estimation techniques and tier two consisting of plot-based vegetation measurements. The basis for the protocol is detailed in section II.A and Lawson and Keeley (2019). Its elements and methods including analysis and reporting are found in sections II.B – II.D. The process for the process for revision is covered in section II.E and initial implementation including the pilot phase in section II.F. Table 2 contains the main program elements.

Table 2. Protocol Elements

Protocol Element	Document Section
Integrity Classification System (figure 6)	**II.A**
Metrics	II.A.1
Overlays	II.A.3 & II.B.3
Methods (figure 7)	**II.B**
Baseline Integrity Map Generation	II.B.1
Annual Updates of Integrity Maps	II.B.2
Overlays (vulnerabilities and conservation value)	II.B.3
Vegetation Sampling	**II.B.4**
Tier One—Rapid Visual Estimation	II.B.4.a
Tier Two—Plot-Based Measurements	II.B.4.b
Data Management	**II.C**
Data Analysis and Reporting	**II.D**
Protocol Review and Revision	**II.E**
Planned Protocol Implementation	**II.F**

The basis of this protocol is that a simple set of metrics derived from native shrub and exotic annual grass composition are sufficient to characterize ecosystem integrity (section II.A). The classification scheme consisting of 3 integrity classes with risk and value subcategories is depicted in figure 6. Based on preliminary evidence, this protocol identifies initial threshold values for coastal sage scrub and chaparral (section II.A.1) subject to validation during the pilot phase (section II.F). The breakpoints or thresholds between classes are intended to identify tipping points beyond which resilience and natural recovery declines abruptly so that it is more cost effective to implement management to maintain stand integrity than it is to try to try to improve it after the threshold is crossed.

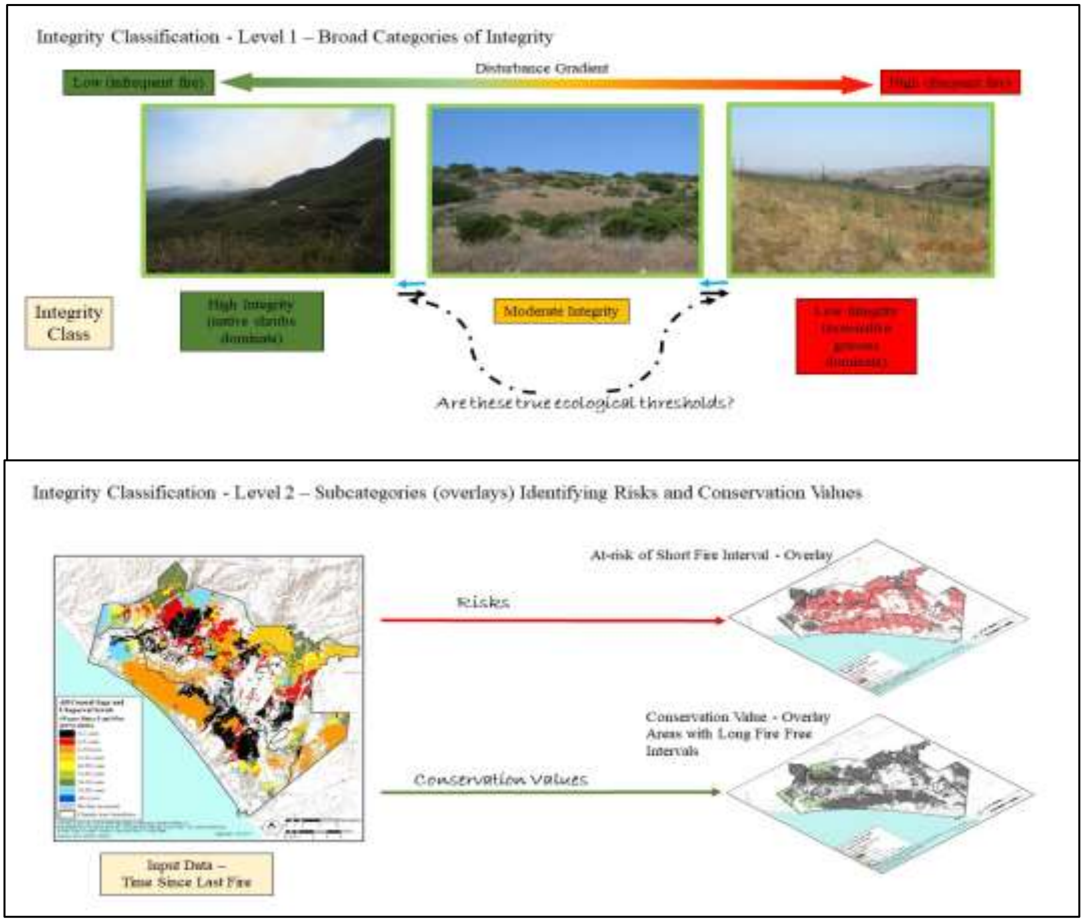

Figure 6. Integrity Classification System. Level 1 identifies broad categories of disturbance along a disturbance gradient. Level 2 are subcategories identifying risks and conservation values.

The primary protocol products include a baseline integrity map (section II.B.1), annual integrity map updates (section II.B.2), map overlays (section II.B.3) that depict integrity threats (short fire intervals (section II.B.3.a), and potentially drought (section II.B.3.b) and specific conservation values (old growth stands (section II.B.3.c) and special status species (section II.B.3.d) and finally projection of trends in integrity (section II.D.2).

Figure 7 shows the process for integrating the protocol elements to develop and update the annual integrity maps. The baseline integrity map will be created using the new vegetation map being developed and a crosswalk table between that map and the integrity classes (section II.A.1). Annual updates "integrity snapshots" will be created using the baseline map, the annual wildland fire map and the integrity transitions (figure 9) that links fire return interval and integrity class. The map will be corrected and validated using tier 1 vegetation sampling (section II.B.4.a) and iterating as needed. The integrity transitions (figure 9) will be updated using results from both tier 1 and tier 2 vegetation sampling (section II.B.4) as a more nuanced understanding of drivers that cause integrity shifts including fire, weather and other site-specific factors is developed.

This protocol includes specifications for data management (section II.C) to support accurate timely reporting and also includes an approach to data analysis and reporting (section II.D). The protocol is intended to be reviewed annually as part of the analysis and report generation, and incremental modifications will be made to better meet objectives and emergent requirements (section II.E). Finally, initial implementation is addressed in section II.F.

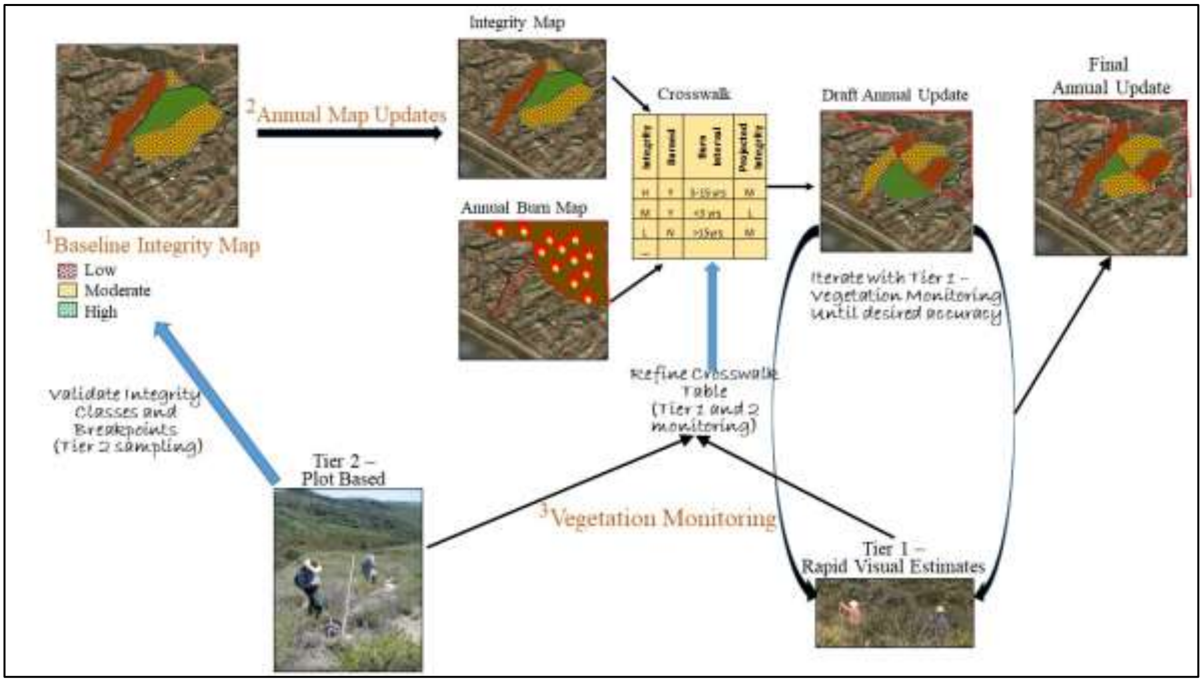

Figure 7. Diagram of protocol methods. This process uses the baseline integrity map, with the annual fire map and a cross walk table capturing what is known about the effect of fire on integrity. This produces a draft annual update which is then refined by Tier 1 and 2 vegetation sampling to produce the final annual update.

II.A. Integrity Classification System

An integrity classification system needs both a measure of integrity and breakpoints to establish classes. The breakpoints for this protocol divide classes called out as Low, Medium and High integrity. The protocol has two levels (broad categories and subcategories) (figure 6). In the first level condition is ranked as high, medium, or low (sections II.A.1). The second level involves risk overlays (e.g. short fire intervals, section II.A.3) and conservation values (section II.A.4).

For this protocol, relative cover of woody vegetation, invasive annual grass cover, and shrub density (number of shrubs per unit area) were chosen. Vegetation cover is the amount of the ground surface covered by plants (this can be measured by species or groups of species). It typically consists of multiple layers of plant material and depending on methods can sum to 100% (relative cover) or be reported as the total number of intercepts which will not necessarily sum to 100% (absolute cover). For more details on cover estimation and reporting under this protocol see section II.D.3.

to over 100% and is measured by recording taxa that intercept a vertical projection at a point or plot. Estimating cover from a distance (e.g. tier 1 sampling, section II.B.4.a) over larger area typically only captures the top layer and does not allow for detection of multiple layers of cover. On the other hand, recording at points along a transect (e.g. tier 2 sampling, section II.B.4.a) or from a close position on a small plot allows for detection of all the layers. Under this protocol we measure cover in two different ways (section II.B.4) but report it as relative cover. Unlike some calculations of relative cover portions of the community not covered by plants (e.g. bareground, rock, lichens) are included in the relative cover calculations. Conversion of tier 2 sampling results to relative cover essentially converts a multidimensional description of the community into a one-dimensional description. This is done by for each point if there is a shrub hit record as shrub, if it is grass or forb record the tallest individual, other land covers (e.g. bare ground, rock, lichen) recorded as those land cover types. Because non-native grasses can fluctuate widely year to year point intercept data may result in a sites' integrity class changing due to annual grass flushes even though shrub cover does not change. Calculating and reporting cover in this way is intended to moderate swings in integrity class due to weather drive fluctuations in annual grass cover.

Because the Base has accurate fire history maps there was no need to use a surrogate for disturbance. The integrity classes include both young and old stands. Even though young shrub stands have very different cover characteristics than mature stands, shrub seedling and resprout density in young stands can be used to project shrub cover in mature stands and thus used to classify integrity (Hanes 1971). The density thresholds in recently burned stands are based on field studies that link stand age and seedling density (Cario and Zedler 1995).

The data collected by Diffendorfer (Diffendorfer et al. 2004, Diffendorfer unpublished data), Cario and Zedler (1995), Hanes (1971), Hedrick (1951) and Sampson (1944) served as a basis for the preliminary thresholds chosen for this protocol. These breakpoints will need to be validated in the first two to three years of data collection. While this protocol will focus on vegetation, studies could be initiated for other taxa to characterize the biological response of those taxa to the disturbance gradient and vegetation metrics to be used for this protocol. Then the condition of those taxa could be inferred based on the results of this protocol.

II.A.1. THRESHOLDS IN COASTAL SAGE SCRUB AND CHAPARRAL INTEGRITY

Figure 8 shows the ecosystem integrity states (or classes) and the primary drivers thought to be responsible for shifts between the states. Tables 3 and 4 contain preliminary threshold values that differentiate the integrity classes for coastal sage scrub and chaparral. Values for stands recovering from fire are distinguished from stands in long fire-free periods. The data collected by Diffendorfer (Diffendorfer et al. 2004, Diffendorfer unpublished data), Hanes 1971, Hedrick 1951 and Sampson 1944 was used to identify thresholds in long fire-free periods and Cario and Zedler 1995 and Sampson 1944 was used to identify thresholds in stands recovering from fire. A cluster analysis was used with the Diffendorfer data under the assumption that the clusters would represent basins of attraction for the alternate stable states. Regression analysis was used with the data from Cario and Zedler 1995 to characterize cover and density in high integrity stands as a function of time since fire.

II.A.2. INDICATOR SPECIES

Formerly cultivated or physically disturbed sites with only *Artemisia californica* and *Baccharis pilularis* will be classified as moderate if they have more than 41% total shrub cover or low integrity if the sites have less than 41% cover. In addition, the presence of *Malosma laurina* in very high densities may also represent disturbance. *M. laurina*, a strong resprouter, is favored 1) by short fire intervals that can eliminate shrubs which typically regenerate from seed and 2) extreme drought which disproportionally harm shallower rooting mature shrubs (Dario 2014). Stands of 80% or more *M. laurina* will be classified as moderate integrity.

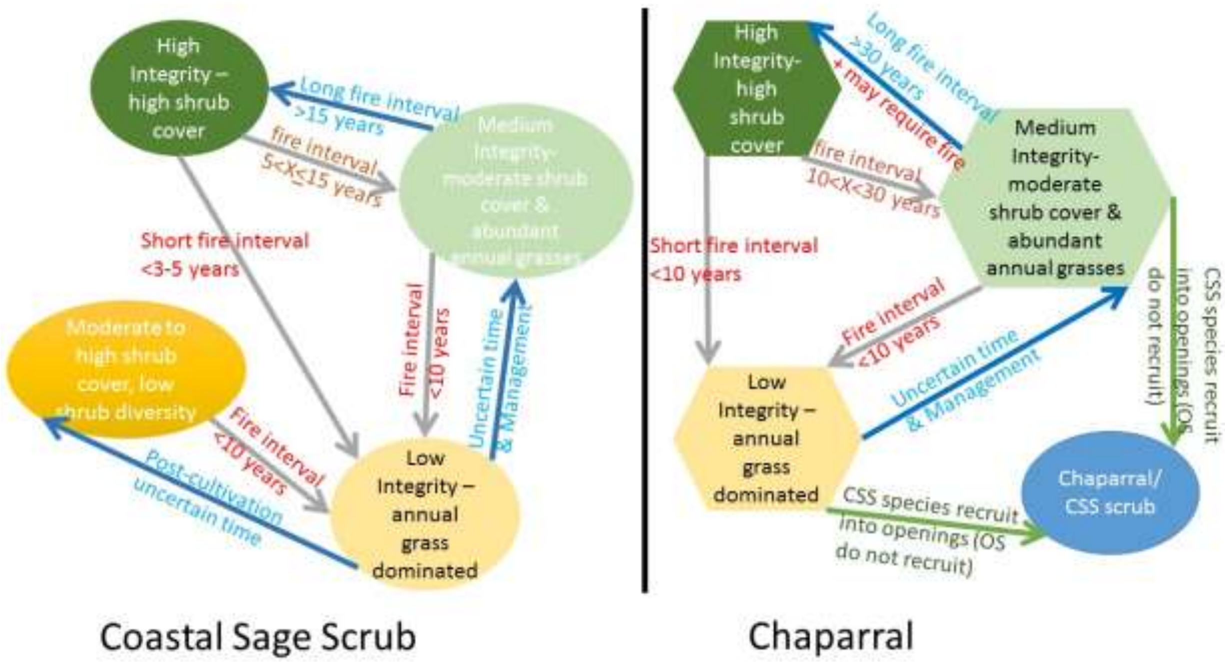

Figure 8. Ecosystem integrity states and drivers. The primary drivers of transitions between states for coastal sage scrub and chaparral are shown. OS=obligate seeder shrub.

II.A.3. RISK OVERLAYS

II.A.3.a At-risk of short fire interval.

A "risk overlay" will be developed to identify otherwise high integrity sites that are at risk of a short fire-return interval. The overlay will simply be those sites that have burned in less than 15 years for coastal sage scrub and 30 years for chaparral. Having a repeat fire under these thresholds is projected (figure 9) to result in insufficient seedlings to support a fully stocked stand. Over time as information accrues and figure 9 is modified these time-since-fire thresholds may be changed (section II.B.1).

II.A.3.b Risk of Drought Effects on Recovery

This overlay is envisioned to be a future annual designation, the data to support this will have to be developed through this program or other published research.

Table 3. Preliminary Integrity class thresholds for CSS in long fire-free periods and recovering from fire.

Integrity Class	Attribute	Stands in Long Fire Free Periods (>13 years post fire)	Stands Recovering from Fire (<13 years post fire)
High Integrity		(Cario and Zedler 1995)	(Cario and Zedler 1995)
	Live native shrub cover (relative)	68-100%, avg=97%	≥68% or shrub cover = $-0.2261*t^2 + 8.4273*t + 22.682$ (t=years since fire)
		(ARTCAL = 7-71%, avg =38%)	
	Native shrub density		0.07/m2 increasing to 1.8 plants/m2,
			ARTCAL = 0.00-2.77, avg=0.77
			BACPIL 0.00-0.03, avg=0.01
	Native shrub seedling density		19/m2 decreasing to 1/m2;
			seedling density = 0.053x2 - 1.5756x + 10.972
	Annual grass cover	<20%	range=0-77%
Intermediate Integrity		(Diffendorfer et al. 2007; Diffendorfer et al. 2004; expert opinion)	(Diffendorfer et al. 2007; Diffendorfer et al. 2004; expert opinion)
	Live native shrub cover (relative)	< 31-65%	< 31-65%
	Native shrub density		
	Native shrub seedling density		0.1-0.5/m2
	Annual grass cover	20%-69%	20%-69%
Low Integrity		(Diffendorfer et al. 2007; Diffendorfer et al. 2004; expert opinion)	(Diffendorfer et al. 2007; Diffendorfer et al. 2004; expert opinion)
	Live native shrub cover (relative)	< 30%	< 30%
	Native shrub density		<0.1m2
	Native shrub seedling density		<0.1m2
	Annual grass cover	>69%	>69%

Table 4. Preliminary Integrity class thresholds for coastal chaparral in long fire-free periods and recovering from fire.

Integrity Class	Attribute	Stands in Long Fire Free Periods (>15 years post fire)	Stands Recovering from Fire (<15 years post fire)
High Integrity			
	Live native shrub cover (relative)	> 80-100% (Hanes 1971)	1% increasing to 80%;
		$y = 0.7926\ln(x) - 0.2277$, $R^2 = 0.9482$ (Sampson 1944)	
	Native shrub density		0.1-1.5
	Native shrub seedling density		21/m2 decreasing to 2/m2;
			$y = 12.913e^{-0.072x}$ $R^2 = 0.9477$ (Sampson 1944)
	Annual grass cover	<5%	5-15%
Intermediate Integrity			
	Live native shrub cover (relative)	< 31-80%	< 31-80%
	Native Shrub density		
	Native Shrub seedling density		10 - 1/m2
	Annual grass cover	15-20%	20-30%
Low Integrity			
	Live native shrub cover (relative)	< 30%	< 30%
	Native shrub density		<0.1m2
	Native shrub seedling density		5 - 1/m2
	Annual grass cover	30+%	30+%

II.A.4. CONSERVATION VALUE OVERLAYS

II.A.4.a General conservation value.

The conservation value overlay will identify long-unburned habitat. Table 5 shows the acreage by habitat for stands over 30, 35 and 40 years respectively. Because fire mapping prior to 2005 has significant errors, the habitat age for the stands identified on the conservation value overlay will be verified with growth ring counts (Keeley 1992).

Table 5. Estimated acreage of old shrubland stands. These were calculated using the Base's fire history GIS layers to represent year of last burn.

Habitat	>30 years old	>35 years old	>40 years old
Coastal Sage Scrub	10,423	8,640	6,507
Chaparral	2,419	1,153	1,079
Coastal Sage-Chaparral Scrub	1,181	458	353

II.A.4.b Species-specific conservation value.

This will include species such as the California gnatcatcher and will be created as needed.

II.A.5. MINIMUM MAPPING UNIT (MMU)

In determining the minimum mapping unit, the scale of disturbance, related mapping efforts, management, and California gnatcatcher territory size were considered. Vegetation mapping with fine-scale data on shrub and grass cover will serve as the basis for the integrity maps and has a 1 acre MMU for upland habitats, including shrublands. Wildland fire frequency is anticipated to be the primary cause of degradation on the Base and annual fire maps with a MMU of less than 1 acre for fires over 5 acres will provide the basis for annual integrity map updates. Land management efforts often occur on a similar scale. While the maximum project sizes can be much larger, the minimum project size is less than 1 acre for land management activities, including invasive species control and seeding or planting for plant community restoration. Finally, the primary target of conservation focus in shrubland habitats on the Base, the California gnatcatcher, has a territory size ranging from less than 5 acres on the coast to over 20 acres inland (Preston et al. 1998).

Thus, a 2 acre minimum mapping unit was chosen based on the minimum mapping units of fire and vegetation mapping, the scale of land management on the Base, and California gnatcatcher territory size. Mapping will be a two-step process with integrity maps first produced and validated at the 2 acres MMU and then the mapping units aggregated to a 100-acre MMU (section II.B.1.4)). This approach, with a minimum mapping unit for data generation and subsequent aggregation, allows within-polygon variation to be minimized while still providing mapping useful to upper management (100 acre MMU). The finer scale map with a 2-acre MMU unit is anticipated to provide useful detail for natural resource program managers planning and executing land management activities.

II.B. Methods

II.B.1. BASELINE INTEGRITY MAPPING METHODS

Baseline integrity map development and major map updates will be linked to the vegetation mapping program, which is projected to be redone every five years. The vegetation mapping program uses the National Vegetation Classification System, which maps vegetation in hierarchical levels. The process on the Base uses aerial imagery to identify polygons. The classification scheme for vegetation includes percent cover of shrubs and invasive annual grasses. When sites are repeatedly burned with short fire intervals, shrub cover and density can be maintained at such a low level that distinguishing with certainty between grassland and shrubland can be problematic. For purposes of the integrity mapping protocol, the decisions made with the Base-wide vegetation map about whether a site is grassland or highly disturbed shrubland will in general be used. It is likely that over the years the data collected under the integrity protocol and the vegetation map updating process will refine the understanding of this problem.

The baseline integrity map will be developed using both the final vegetation map and the plant community composition data used to develop it. The map will be developed in three steps and then a 4^{th} step can be used to aggregate the mapping units (minimum 2 acres, section II.A.5) to a minimum 100 acre minimum mapping unit for communication with upper management.

1) A crosswalk table between the categories used in the vegetation map and integrity classes using the thresholds in tables 3 and 4 will be developed.
2) The crosswalk table will then be used to assign vegetation polygons to integrity classes and create the map.
3) Map validation will be done using tier one vegetation sampling (section II.B.4.a). The validation process will evaluate the map's accuracy as follows:

a. An initial sample of 10 plots per integrity classes projected to shift and projected not to shift will be sampled using tier one methods. The objective will be to classify integrity correctly more than 80% of the time.
b. Complete table 6, which shows polygon counts for the actual integrity class as determined by tier one sampling compared to the predicted integrity class using predicted integrity class transitions (figure 9).
c. If the map's accuracy is determined to be less than 80%, the possible cause of the error will be evaluated. If a category of vegetation polygons has been systematically assigned to the wrong integrity class the integrity class transitions predicted in figure 9 will be revised and reapplied. If it is not a crosswalk error, other environmental variables (e.g. slope, aspect) will be evaluated to determine whether another variable could be used together with the vegetation classification to correctly assign the integrity class.

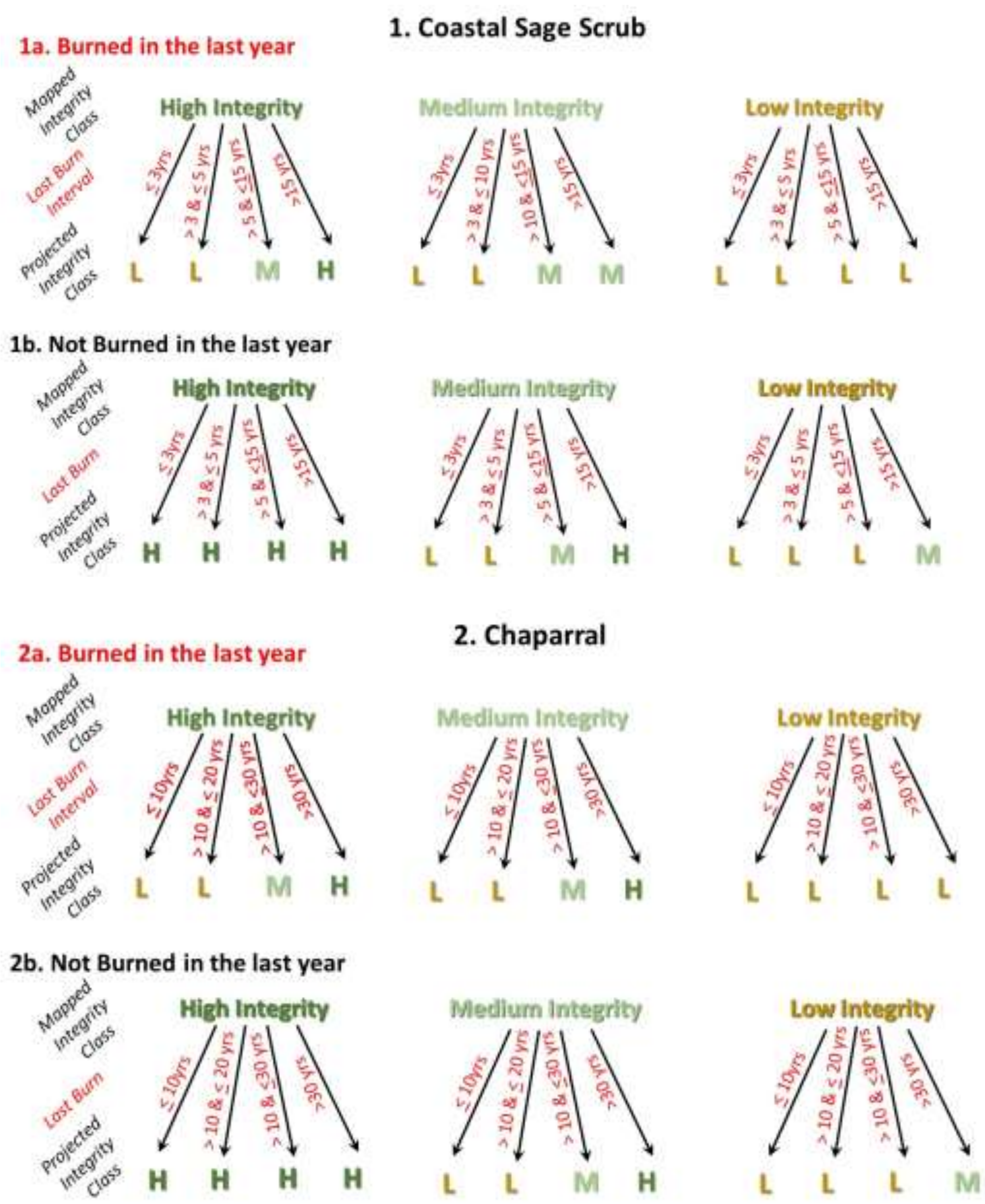

Figure 9. Integrity class transitions for annual integrity updates based on fire history for coastal sage scrub, and chaparral. Based on whether there was a fire in the last year and the previous fire interval the last line in each section of the figure shows the projected integrity class; L=low integrity, M=medium integrity and H=high integrity. These assignments will be used to make the initial integrity class assignments for individual polygons (section II.B.2) that will be refined and validated through tier one field sampling (section II.B.3). This transition chart will be updated based on knowledge developed through that validation process.

Table 6. Integrity class contingency table with example of 8 of 10 low integrity sites properly classified using the vegetation map and predicted integrity class transitions (figure 9) as low integrity and validated by the tier one sampling and 2 sites improperly classified as medium integrity. Diagonal cells (shaded) represent properly classified polygons where the predicted and observed classification match.

Observed (Tier 1 Sampling)	Predicted (using vegetation map & crosswalk table)			Percent Correct
	Low Integrity	Medium Integrity	High Integrity	
Low Integrity	8	2	0	80%
Medium Integrity				
High Integrity				
Overall Percentage				

4) The baseline integrity map will be upscaled from a 2-acre MMU to a 100-acre MMU using the following methods in ARCGIS.
   a. Run the “dissolve” tool to ensure that all adjacent polygons of the same integrity class are merged. Recalculate acreage.
   b. Select all polygons less than 20 acres and use the “eliminate” tool to merge these polygons with the neighboring polygons of the largest area (figure 10). These are done in batches starting with the smallest polygons in order to minimize the amount of aggregation while still ensuring the resulting polygons are over 100 acres. Recalculate acreage.
   c. Select all polygons between 20 and 50 acres and use the “eliminate” tool to merge these polygons with the neighboring polygons of the largest area or longest shared border. Recalculate acreage.
   d. Select all polygons greater than 50 and less than 100 acres and use the “eliminate” tool to merge these polygons with the neighboring polygons of the largest area or longest shared border. Recalculate acreage.
   e. Union the resulting 100 acre mmu coverage with the 2 acre mmu coverage and calculate the percentage of each integrity type within the 100 acre mmu polygons.
      i. Verify the label of the final polygon is the dominant integrity type.
      ii. Verify that the dominant integrity type is >50% of the land area.
         1. For any polygons where the dominant type is <50% of the land area visually inspect and manually edit the coverage so that resultant polygons have greater than 50% coverage of the dominant integrity type. This may involve splitting polygons.
   f. Union the revised 100 acre mmu coverage and with the 2 acre mmu coverage and report the percentage of each integrity type within each polygon in the 100 acre mmu coverage.

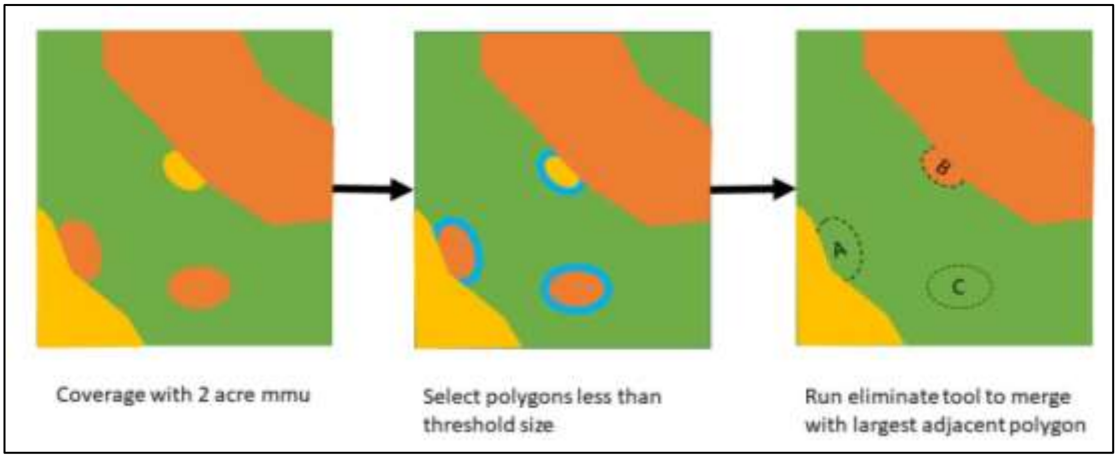

Figure 10. Use of ARGCIS "eliminate" tool to aggregate polygons into a map with a larger mmu. Note that feature "A" is added to the green polygon because it is larger than the yellow one in this example.

II.B.2. ANNUAL UPDATES OF INTEGRITY MAPS

The annual integrity map update process will utilize the wildland fire spatial database to identify polygon-level integrity category changes (figure 11). The first year of the protocol will be focused on refining the following steps for integrity class assignment based on fire return interval:

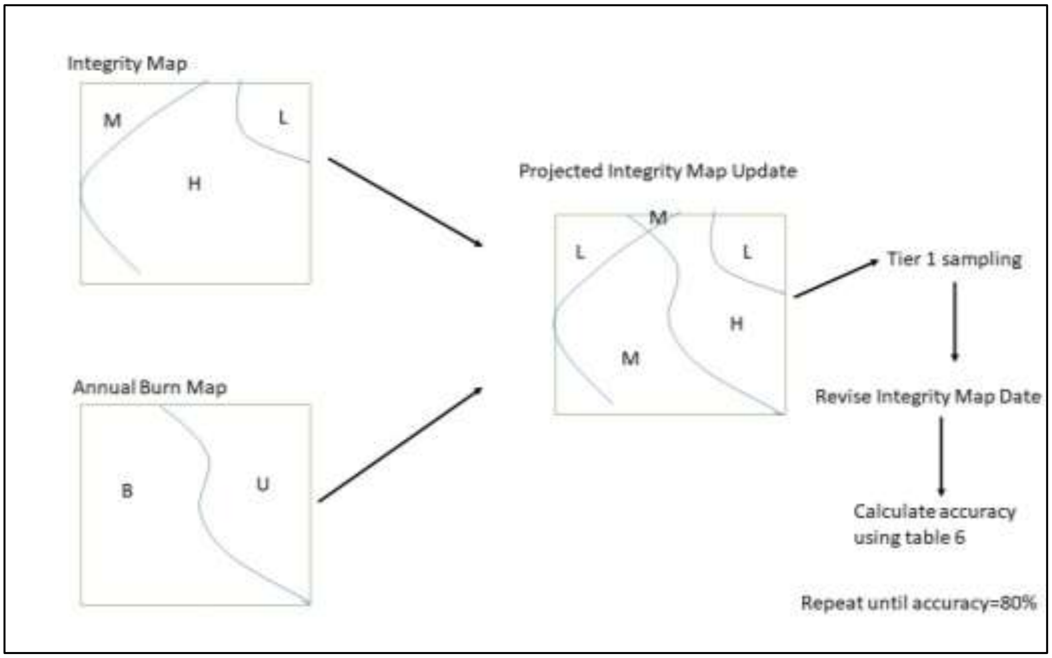

Figure 11 Annual integrity map update process. Use annual burn map and the transitions in figure 9 to develop a map of projected change. Use Tier 1 sampling to validate.

1) Annual updates will be initiated in January of each year after the previous year's fire map is complete.

2) The current fire interval for all shrubland polygons will be calculated and preliminary polygon status will be assigned using the integrity class transitions in figure 9. The scorched fire severity category (table 7) will be counted as unburned. The transitions will be validated using tier one and tier two vegetation data (section II.B.4).

Table 7. Fire severity classes used in Base fire mapping. These follow National Park Service (2003) definitions.

Fire Severity	Description
Heavily Burned	Foliage consumed; only larger branches/stubs (>1.0 cm) remain
Moderately Burned	Foliage consumed; branches >0.6 and $\leq$ 1.0 cm remain
Lightly Burned	Less than 60% of foliage consumed
Scorched	Foliage scorched, still attached to branches

3) Map refinement and validation will be done using tier one vegetation sampling (section II.B.4.a). In the first years of protocol implementation it is anticipated that two iterative rounds of refinement and validation will be required. As more specific information through vegetation sampling is developed on the influence of drivers of recovery and degradation (i.e. fire, year to year variation in precipitation, aspect, distance from the coast) it is anticipated that fewer iterations will be required to achieve the specified accuracy threshold.
    a. An initial sample of up to 10 plots per integrity class will be sampled using tier one methodology (section II.B.4.a). The initial objective will be to classify integrity correctly more than 80% of the time; the feasibility of this will be validated in the pilot phase and the value changed if necessary.
        i. Complete table 6 using predicted integrity classes and the actual values from the tier one sampling to evaluate the accuracy of the integrity map.

    b. The accuracy of the map will be evaluated. If the accuracy is less than 80% an evaluation of the possible cause of the error will be made. If environmental variables can be correlated, table 6 will be recreated and the predicted integrity classification (figure 9) redone. Redoing figure 9 could involve restructuring the predicted transitions to change the fire intervals, for example instead of <3 years in coastal sage scrub it might be <4 years, and it could be revised to show that habitat on different aspects or at different distances from the coast recovers at different rates and so has different transitions between integrity classes.
    c. Use the revised figure 9 to update the integrity map.
    d. Validate integrity map using tier one sampling
    e. Repeat steps 4-6 until accuracy equals or exceeds 80% or further improvements aren't possible.
    f. The polygons on the validated map will be aggregated to an approximate 100 acre MMU map. This larger-scale is needed for the map to be relevant to the scale of military land management decisions and impacts.

II.B.3. OVERLAYS

II.B.3.a At-Risk of Short Fire Interval

Sites will be identified as at-risk of a short fire interval using the wildland fire map for the most recent calendar year and the fire intervals specified for transitions to lower integrity classes in figure 9.

II.B.3.b Risk of Drought Effects on Recovery

Methods will be developed in the future at the time this overlay is determined to be needed.

II.B.3.c Old Growth Conservation Value

This overlay will identify shrubland stands where the last recorded fire was prior to 1977 (greater than 30 years of age). Because fire mapping prior to 2005 has significant errors, the habitat age for the stands identified on the conservation value overlay will be verified with growth ring counts. To do this, three stem cross-sections taken at ground level will be collected and rings counted to validate actual stand age in these old stands (Keeley 1993).

II.B.3.d Suitable for Special Status Species (CAGN, Cactus Wren)

This overlay will be created as needed using data provided by the Wildlife Management Branch.

II.B.4. VEGETATION SAMPLING

While fire is the dominant disturbance in these systems, simply developing ecosystem integrity maps based on time since last fire is likely to lead to inaccuracies, because site factors related to fire severity, aridity, anthropogenic nitrogen deposition and other disturbances influence time to recovery and trajectory (Cox et al. 2014, Diffendorfer et al. 2007, Deutschman and Strahm 2011, Keeley et al. 2006, Vasey et al. 2012). To identify errors, improve map accuracy and improve projections of integrity changes, map and integrity classification system validation and refinement will utilize a two-tiered vegetation sampling system. In this system tier one will utilize rapid visual estimation techniques and tier two utilizing plot-based measurements of vegetation attributes.

Experiments in addition to monitoring may be employed periodically when that approach is determined to be more cost-effective in answering specific questions than observational monitoring. Field sampling will occur in spring from January to April 30 to assure greatest cover is apparent.

II.B.4.a Tier One—Rapid Visual Estimation

Tier one sampling consists of visual estimates of shrub and grass cover, integrity class and polygon boundaries to validate the baseline map, refine the annual updates, and in addition it includes visual estimates of dominant species, seedling density and disturbance which together with the first set of variables will be used to refine and update the rules (figure 9) used to update the integrity map with wildland fire data. While designed to address these primary purposes, the data are also anticipated to be useful in understanding ecosystem function. Tier one sampling consists of the following steps:

1) Polygon selection—In the first year, data will be collected for polygons selected from the draft annual update (section II.B.2) in a stratified random manner within each integrity class and used to validate the annual update map. The polygons will vary in size above a

2 acre minimum mapping unit. In the second year and beyond, polygons will be selected in a stratified random manner within each integrity class transition type (figure 9) to validate the map and refine figure 9. This will likely need to be done iteratively using the following steps 1) plots are selected, 2) figure 9 is updated, 3) the integrity map update is recreated, and 4) then new plots are selected to validate the second map. It is anticipated that not all possible transitions included in figure 9 will be represented in the field in a given year and that data on these transitions will be developed over time. While density and cover are not anticipated to undergo rapid or large changes in high integrity habitat, these areas will be included to ensure that other drivers like drought aren't resulting in undetected changes in shrub and annual grass populations.

2) Sample size—In the pilot phase of the protocol up to 10 polygons in each integrity category will be selected for evaluation using the methods laid out in section II.B.4.c below. Based on this data sample size will be calculated (section II.B.4.c) and additional data collected if necessary. If there are obvious corrections to make to figure 9, they will be made and the integrity update map recreated using the iterative process described under II1) Polygon Selection" above.

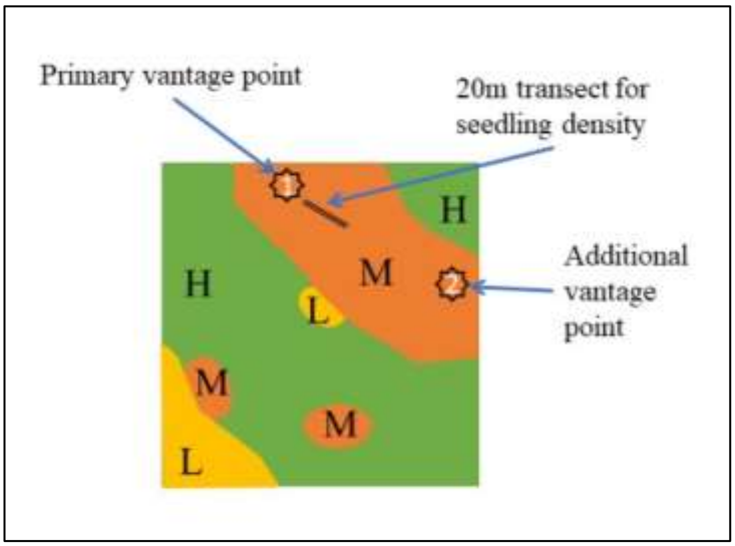

Figure 12 Tier 1 sampling, rapid visual estimation. Primary vantage point to be used for data collection unless entire polygon not visible. Additional vantage points will be used where needed. An approximately 20 m long transect will be walked (section II.B.4.a.3.vi) to estimate seedling abundance.

3) Field data collection
   a. Preparation
      i. Equipment – data entry forms (electronic data collection e.g. ArcGIS collector, is recommended to speed data processing but data sheets are provided in the appendices (tables 13-17) to spell out what data needs to be collected), aerial imagery of each site with polygon boundary, GPS, field computer, camera, small white board.
      ii. Train field crew in cover estimation and methods to reduce bias prior to field work (Gallegos-Torell and Glimskär 2009; Morrison 2016).

   iii. Data sheets are included in Appendix A (tables 13-17)

b. Data collection Tier 1, rapid visual estimates
   - i. Select a vantage point where the entire polygon is visible or record the data below from more than one vantage and summarize the data for the polygon as a whole (figure 12).
   - ii. Photos will be taken with plot number on a white board.
   - iii. Polygon boundaries and integrity classification will be validated.
     1. Is the polygon homogenous with respect to integrity class?
     2. Are boundaries correct within 10m, (yes/no)?
     3. If the boundaries are not correct, they will be drawn onto the aerial imagery then the estimated percentage of the mapped polygon mapped that is correct will be recorded.
     4. What is the integrity class (H, M, L) and is the classification correctly identified, yes/no)?
     5. If a portion of the polygon is not correct the correct integrity class(es) will be recorded and notes will be collected on environmental parameters that may have contributed to the misclassification (e.g. the correct classification was made on a certain aspect and incorrect classification on another).
   - iv. A visual estimate of shrub, annual grass cover and bareground or rock will be made. This is a 1-dimensional estimate of relative cover (section II.D.3).
   - v. Dominant shrub species will be recorded. Dominant shrub species are species with >30% relative cover (rc). This includes the codominant (≥30% rc and <50% rc), dominant (≥50 and <75% rc), and strongly dominant (≥75% rc) categories in the Vegetation Classification Manual for Western San Diego County (Sproul et al. 2011).
   - vi. Shrub seedling density will be estimated. Seedlings are defined as ≤20 cm in height. This will be done by walking an approximately 20 m transect towards the center of the polygon and ranking the number of seedlings seen using the following categories: 0, 1-10, 10-50, 50-100 and >100). The proportion in the cotyledon stage will be estimated as they are anticipated to have a higher mortality rate than seedlings in later stages.
   - vii. Disturbances in the following categories will be recorded and the proportion of polygon affected will be estimated. For fire, small scale patchiness that might have allowed shrub seedlings to survive fire will be described.
     1. Burn within the last year,
     2. Burn patchiness (100% burn, <80% burn with unburned patches <1 m^2)
     3. Vehicle tracks (wheeled and tracked)
     4. Bivouac, grading, or excavation
     5. Erosion (gully, sheet, rill)
     6. Other disturbance, natural or human caused, with a description of such disturbance to be described.

II.B.4.b Tier Two—Plot-Based Measurements

The purpose of tier two monitoring is to validate the integrity classification system, including the specific thresholds chosen, and to improve the ability to predict site specific changes in integrity based on disturbance and environmental factors. A better understanding of integrity changes related to fire will be used to increase the reliability of the "at-risk of short fire interval" overlay in predicting sites that will be degraded by additional fires. A robust dataset will be developed to answer specific questions related to the recovery and degradation of shrublands from disturbance. The goal is not long-term monitoring per se, although long term monitoring may take place to answer specific questions, such as how extreme drought affects adult mortality and longevity; or how site (e.g. soil texture, aspect etc.) and weather (e.g. precipitation, fog etc.) factors affect seedling establishment, survival and recruitment. There are approximately 110 permanently marked LTETM shrub plots (73 in coastal sage scrub, 27 in coastal sage scrub/chaparral scrub, and 10 in chaparral) with data collected one or more times in the 1990s. These are a combination of "core" (Seiger et al. 2001) and "special use" (Cario and Zedler 1995) plots. These plots will be used in tier two sampling when the historical data will contribute to answering specific questions.

In tier two, point intercept sampling will be used unless specific questions require accurate estimates of cover in stands with very low shrub cover (<15%). Line intercept is much more time consuming than point intercept (Heady et al. 1959) it but gives more accurate estimates when cover is low (Bonham 1989). If cover values <15% are particularly important in answering a specific question, line intercept sampling may be warranted. If this is done sampling using both methods could be conducted in the mid-level numbers (e.g. 10-20%) to determine cover threshold for use of line intercept, evaluate bias and allow results using both methods to be linked. One transect per polygon will be used and variance will be assessed at the integrity class level. This will allow more extensive plot sampling at the expense of characterizing within polygon variation. Because unlimited time and funding will not be available for sampling, there is a trade-off between repeat sampling within polygons and more independent samples across the landscape. The within-polygon variance could be used to better define polygons, but having more independent samples across the landscape will improve the understanding of degradation and recovery processes that is needed to improve the efficiency and accuracy of the annual mapping. In addition, the minimum mapping unit of two acres is consistent with broad landscape drivers of variation in shrub and invasive annual grass cover and density, including factors that influence the aridity gradient (slope, aspect, CLC, soil) and fire, and thus should control within polygon variation to a degree. In addition, tier one sampling can be used to get a sense of within polygon uniformity.

Both annual grass cover and, density and cover of native shrubs are sensitive to fire, the primary disturbance in these communities (Keeley and Brennan 2012) and other environmental drivers (e.g. anthropogenic nitrogen deposition (Cox et al. 2014), weather patterns (Williams et al. 1987) site aridity (Poole & Miller, 1975)). The vegetation survey will fill knowledge gaps to allow changes in integrity class to be better predicted using annual fire maps and potentially other factors as spatial data on them is developed. In sites that haven't burned since the mid-2000s shrub growth ring counts will be made to verify date of last burn.

1) Initial questions and plot selection – Initially plot selection for tier 2 monitoring be done to validate our understanding of integrity recovery from fire and validate thresholds (section II.A.1).
    a. Monitoring plots will be stratified to capture a range of factors that contribute to aridity and thus could result in different sites recovering at different rates including: precipitation, solar insolation (aspect), nitrogen deposition and CLCF.
    b. In addition to determine how many shrubs may escape fire in a burned area the 1) range of small scale (e.g. <10 m^2) fire patchiness not captured in the wildland fire mapping minimum mapping unit will be evaluated in burns of different fire intensity and different integrity classes and 2) influence of fire patchiness on shrub mortality and seedling establishment will be evaluated.
    c. The initial hypotheses will be: 1) For coastal sage scrub if a site has burned within in the last 15 years then it will have an elevated exotic grass component that decreases with time since fire and a suppressed native shrub component that increases with time since fire. When the site is burned again in the first year after the fire in long unburned stands there will be sufficient density and distribution of native shrub seedlings and resprout to

restock the stand to more than 80% shrub cover through autosuccessional processes. In stands that burned less than 15 years prior the density and distribution of seedlings and resprouting shrubs will be insufficient to restock the stand.

2) Sample size – see section II.B.4.c

3) Field Data Collection
   d. Preparation
      i. Equipment – data sheets, airphotos of each site with polygon boundary, GPS, field computer, camera, small white board
      ii. Data sheets are included in Appendix A (tables 13-17).
   e. Transect establishment
      i. One transect, 50 m long per LTETM plot
      ii. Transect location selected randomly within polygon
      iii. permanently marked with rebar every 25 m
      iv. location recorded with GPS
      v. photograph down transect from start point and perpendicular to start point.
      vi. Draw map of transect local features
   f. Data to be collected
      i. aerial plant cover will be recorded using point intercept with data collected every half meter starting at 0.5 m. During the pilot study (section II.F.1) sampling using both methods will be conducted in the mid-level numbers (e.g. 10-20%) to determine cover threshold for use of line intercept, evaluate bias and allow results using both methods to be linked. This results in a multidimensional estimate of absolute cover that will need to be converted to relative cover to identify integrity class (section II.D.3)
      ii. ground cover and disturbance will be collected along the point intercept as well
      iii. Belt transect (1m wide along the 50m transect). The belt transects runs along the right side of the transect tape. Adult shrub density will be estimated by counting shrubs (plants >20 cm) in a 1m wide belt along the transect. Because shrub seedling density can be high enough to make counts impractical it will be estimated on an ordinal scale. To characterize patchiness of seedling establishment these estimates will be made for each 10m segment of the transect.
         1. Adult shrub density will be measured by counting shrubs in 1m segments along the entire transects. Plants will be recorded using the following status categories: live, dead, killed by fire, and resprout. For multi-stemmed individuals the center of the plant must be in the plot for the plant to count in the density counts.
         2. For the entire transect, estimates of seedlings ($\leq$20 cm) will be divided into two categories: 1st year seedlings and seedlings 1 or more year old. The distinction between the two will be made based on height, stem diameter and stem woodiness. This will support modeling of seedling establishment and quantification of recruitment potential. Total number of seedlings will be estimated for each 10 m segment of the entire transect in the following categories: 0, 1-10, 10-50, 50-100, >100.
      iv. In order to avoid over or undersampling, transect widths will be changed in sparse or dense stands. The criteria will be developed during the pilot phase (section II.F.1).
      v. A complete species list of all plants at least partially rooted in the 50 X 1 m belt.
      vi. Any species that cannot be identified in the field will be collected.
      vii. Soil textural and field water holding capacity.

viii. Recently burned plots
    1. Pre-fire woody-plant density will be recorded. They will be identified to species by stem and bark characteristics (Keeley et al. 2006).
    2. Diameter of smallest twigs remaining (Moreno and Oechel 1989)

ix. Time frame for sampling. Because most post fire seedling establishment occurs within the first three years post fire (Keeley et al. 2006), sampling to confirm post-fire integrity will be done for three years. Additional sampling years will be done to evaluate the stability of the three integrity classes (alternate stable states) and better understand degradation and recovery processes. Additionally, follow-on sampling will be done on at least a subset of plots that reburn to validate integrity class changes.

x. Plots not burned since 2005
    1. Collect 3 stem cross sections from the base of woody plants near transect to establish stand age (Keeley 1993).
        a. Cut stem section at ground level. If the plant has more than a single stem select the largest.
        b. Polish stem sections with 200-300 grit sandpaper.
        c. If needed apply one of the following to accentuate growth rings: water, linseed oil or paraffin oil.
        d. Count growth rings at 7-10x power with two independent observers and average counts.

II.B.4.c Sample Size

Sample sizes will be based on power calculations to ensure that the results have sufficient statistical power to meet objectives while minimizing sampling effort to achieve cost effectiveness (Deutschman and Strahm 2011). The required sample size will depend on the following parameters (table 8) type 1 error rate (false positives), type 2 error rate (false negative) and the minimum magnitude of change to be detected. An effect size (minimum magnitude of change to be detected) of 20% is recommended for the calculations as it is considered large enough to represent a meaningful shift in cover and small enough to identify the shift relatively early. In addition to these three variables that are specified by the investigator, an estimate of the variability of the data is required. The estimates of variability can come from existing data sets (e.g. Camp Pendleton LTETM data, Jones and Kunze 2008) or pilot data (e.g. section II.B.4.a.2).

If the sample size calculated given the above parameters, exceeds the project budget, land managers may need to reconsider the questions being addressed and potentially restrict them to address a smaller set of factors or to potentially extend the sampling period to multiple years. One obvious place to cut costs would be to only conduct Tier one—Rapid Visual Estimation sampling to allow map validation but not address additional questions under Tier two sampling. Another alternative would be to conduct sampling that may address limited questions in a single year but which over time could support an expanded analysis, to do this the same algorithm for site selection should be used each year.

In terms of cost effectiveness other mapping and monitoring that generate similar data should be evaluated and leveraged if possible, to develop the information needed. California gnatcatcher monitoring described in section II.B.5 below is one such program. Another program the Base has done in the past that could be leveraged if done again is fuel type mapping (Technosylva 2014). Fuel types are vegetation assemblages defined specifically by shrub and grass composition. These data, with some modification of collection methods, translate directly to the ecosystem integrity metrics proposed and could be used to generate baseline maps and map updates.

Power estimation webpage

http://sphweb.bumc.bu.edu/otlt/MPH-Modules/BS/BS704_Power/BS704_Power_print.html

Table 8. Power analyses parameters.

Parameter	Description	Value
α	**alpha or type I error** is defined as the probably of rejecting the null hypothesis when it is true	0.1
β	**beta or type II error** is defined as the probability of accepting a null hypothesis as true when it is false. Power=1- β. Power is the probability of properly rejecting a false hypothesis.	0.2
Effect Size	The minimum magnitude of change to be detected. This value should reflect meaningful change. Here it refers to proportion of the mean but it can also be expressed as an absolute value.	20% of the mean

II.B.5. LINK TO CAGN MONITORING

The USGS, SDMMP and USFWS have been developing and refining monitoring protocols and sampling design for the California gnatcatcher over the last several years. USGS conducted the initial years of a post-fire recovery study in 2015 and 2016 in San Diego County. In 2016 the first long-term regional survey of the U.S. portion of the gnatcatchers' range was completed in collaboration with partners across the region. Both the fire study and the regional monitoring were implemented in cooperation with the Wildlife Section at Marine Corps Base, Camp Pendleton. The objectives of this work include developing a better understanding of post-fire recovery of California gnatcatcher populations and long-term California gnatcatcher population dynamics (extinction and colonization). Vegetation data are collected as explanatory variables in conjunction with California gnatcatcher population surveys to improve understanding of habitat relationships and management response.

Initial vegetation sampling in the 2015 fire study involved visual estimates of cover but in 2016 this was changed for the fire study and regional monitoring to collection of plant data along line point transects (https://sdmmp.com/view_project.php?sdid=SDID_201612021615.35 (California gnatcatcher post fire study);

https://sdmmp.com/view_project.php?sdid=SDID_201612021615.5 (monitoring program website)). The current methodology calls for establishing four subplots at each California gnatcatcher 150m x 150m survey plot and collecting vegetation data in the center of these sub-plots using point-intercept sampling. Within the region there are 780 California gnatcatcher plots. Of these, 152 plots were established on Camp Pendleton, with many plots included in both the fire study and the regional monitoring to total 84 plots in the regional monitoring and 130 in the fire study. These are permanent plots that will be resampled every 4 or 5 years after 2016.

The California gnatcatcher vegetation monitoring protocol calls for recording hits if the pole passes through the plant even if it doesn't hit plant material. This is because the developers of this protocol wanted to ensure that the presence of shrub canopies were documented as shrub presence is more important to the California gnatcatchers than simply cover. This methodology was used for the 1994 and 1998 Camp Pendleton LTETM data collection (referred to as "polygon of minimum perimeter" method) although not for the 1991 data (Jones and Kunze 2008). The advantage is that it provides stable measures of canopy in systems with drought deciduous plants. This is otherwise difficult because the timing of the onset of summer drought is highly variable from year to year and it is very difficult to plan to collect data at the same phenological stage every year. However, the disadvantage is that many plant studies do not collect data in this way (Deutschman and Strahm 2011) but rather only record a hit if the pole touches plant tissue. A further problem is that cover estimates between the two methods can differ significantly particularly during drought.

Only a subset of plants are recorded to species (table 9). The remainder are recorded as other shrub or other herbaceous. Dead shrubs are not identified by taxon. Substrate is only recorded where there is no vegetation at a given point.

This data will be evaluated during the pilot phase (section II.F.1) to determine if it can be used to substitute for or augment both Tier -1 and Tier – 2 vegetation monitoring.

Table 9. Plant species recorded in California gnatcatcher plots.

Taxa
Shrubs
Oak (*Quercus* sp.)
Laurel sumac (*Malosma laurina*)
Elderberry (*Sambucus mexicana*)
Lemonadeberry (*Rhus integrifolia*)
Lilac (*Ceanothus* spp.)
California sagebrush (*Artemisia californica*)
California buckwheat (*Eriogonum fasciculatum*)
Bush sunflower (*Encelia californica*)
Brittlebush (*Encelia farinosa*)
San Diego sunflower (*Bahiopsis lanciniata*)
White sage (*Saliva apiana*)
Black sage (*Salvia mellifera*)
Coyote bush (*Baccharis pilularis*)
Deerweed (*Acmispon glaber*)
Yucca (*Hesperoyucca whipplei* or *Yucca* spp.)
Dead shrub / DEAD – entire shrub is dead
Other Shrubs – not listed or unknown
Herbs
Black mustard (*Brassica nigra*)
Tocalote (*Centaurea melitensis*)
Artichoke thistle (*Cynara cardunculus)*
Fennel (*Foeniculum vulgare*)
Invasive annual grasses
Other Herbs – not listed or unknown

II.B.6. Link to Fuel Model Mapping

Fire behavior fuel models are a land cover classification system that groups vegetation assemblages including both live and dead plant material into categories with similar fuelbed characteristics (i.e. the fuel models). The resulting fuel model maps are used as input in fire behavior models. Baseline wildland fire fuels mapping was completed in 2014 on Camp Pendleton (Technosylva 2014). This mapping effort used established fuel behavior models (Scott et al. 2005). Ten different fuel models were mapped on the Base (table 10).

The overlap between integrity mapping and fuel model mapping is substantial. For the shrubland fuel models (GS1, GS2, SH4, SH5, and SH7, table 10) the fuel model mapping project uses the same vegetation characteristics (percent shrub and grass cover) as this project to classify polygons. In addition, procedures under this CSS protocol to create the annual updates of the integrity maps should be suitable to support updates of the fuel model maps if desired. In the future it may be possible to leverage air photo acquisition and associated field work needed for shrubland monitoring, fuel model mapping and vegetation mapping program to meet multiple objectives. To date, the process for fuel model mapping does not involve providing more granular estimates of shrub and grass cover than just the broad fuel model categories and the cutoffs do not match with the proposed cutoffs for the integrity classes. If more granular estimates could be made the process could potentially support both fuel model and integrity category classification.

Fuel model mapping has also been initiated more broadly on other lands in the region and so it is possible that this work could be leveraged more broadly.

Table 10. Fire behavior fuel models found on Camp Pendleton (Technosylva 2014).

1. Nearly pure grass and/or forb type (Grass)	
	a. GR1 (short sparse grass)
	b. GR2 (moderate grasslands)
2. Mixture of grass and shrub, up to about 50 % shrub coverage (Grass-Shrub)	
	a. GS1 (sparse sage)
	b. GS2 (California Sagebrush)
3. Shrubs cover at least 50 % of the site; grass sparse to nonexistent (Shrub)	
	a. SH4 (coastal sage scrub with some large shrubs)
	b. SH5 (mature chaparral)
	c. SH7 (north slope coast sage scrub)
4. Dead and down woody fuel (litter) beneath a forest canopy (Timber Litter)	
	a. TL6 (riparian areas)
	b. TL9 (oak woodland understory)
5. Insufficient wildland fuel to carry a fire under any condition (Non-burnable)	
	a. NB1 (urban or suburban area – insufficient wildland fuel to carry a fire)
	b. NB8 (open water)
	c. NB9 (bare ground)

The approach employed by Technosylva (2014) used high resolution imagery (2012 NAIP CIR Orthoimagery (National Agriculture Imagery Program – Color Infra-Red)) to define map polygons (figure 13), Landsat 8 satellite imagery to assign aradiometric signature to each polygon and rapid visual assessment of approximately 1,500 field plots to calibrate the fuel model assignment algorithms and validate the maps. In addition, they used NDVI (normalized difference vegetation index) to analyze model fuel succession on 15 fires that burned between 2003 and 2011. NDVI is an indicator used to differentiate land cover types (e.g. water, bare ground, different categories of vegetation etc.) in remotely sensed data. The purpose of this was to provide a basis for updating the fuel model maps after fire. They identified three successional patterns that can be roughly mapped onto integrity transitions that are the focus of this protocol. Two of these patterns rapidly moved through the grass (GR1, GR2) and sparse shrub (SH4) (these would be low to intermediate integrity stands) in about 7 years to either coastal sage scrub with greater than 50% shrub cover (SH5) or chaparral with greater than 50% shrub cover (SH7) models (these would be intermediate to high integrity stands). The third identified was maintained longer in GR1 (2 to 3 years) and did not progress past GS1 (sparse shrub cover) in 7 years (this would be stands that began as low integrity and either remained low or transitioned to intermediate integrity).

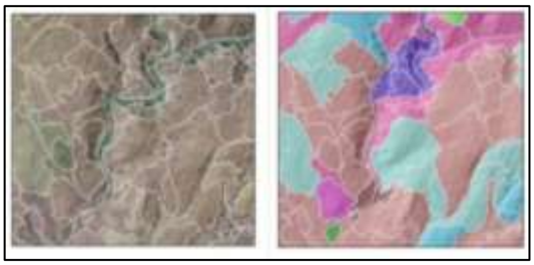

Figure 13. Fire behavior fuel model polygon delineation. The image on the left shows polygons delineated based on differing spectral characteristics. The image on the right shows how these polygons were grouped into fuel models (unsupervised classification) (images from Technosylva 2014).

II.C. Data Management

The data management system must address quality assurance and efficiently produce a complete, accurate database to support timely analysis. A well organized and documented database supports collaboration among related programs and facilitates unanticipated uses of the data, maximizing the cost-effectiveness of the monitoring program to mission readiness. Figure 14 provides a workflow overview of data generation and management.

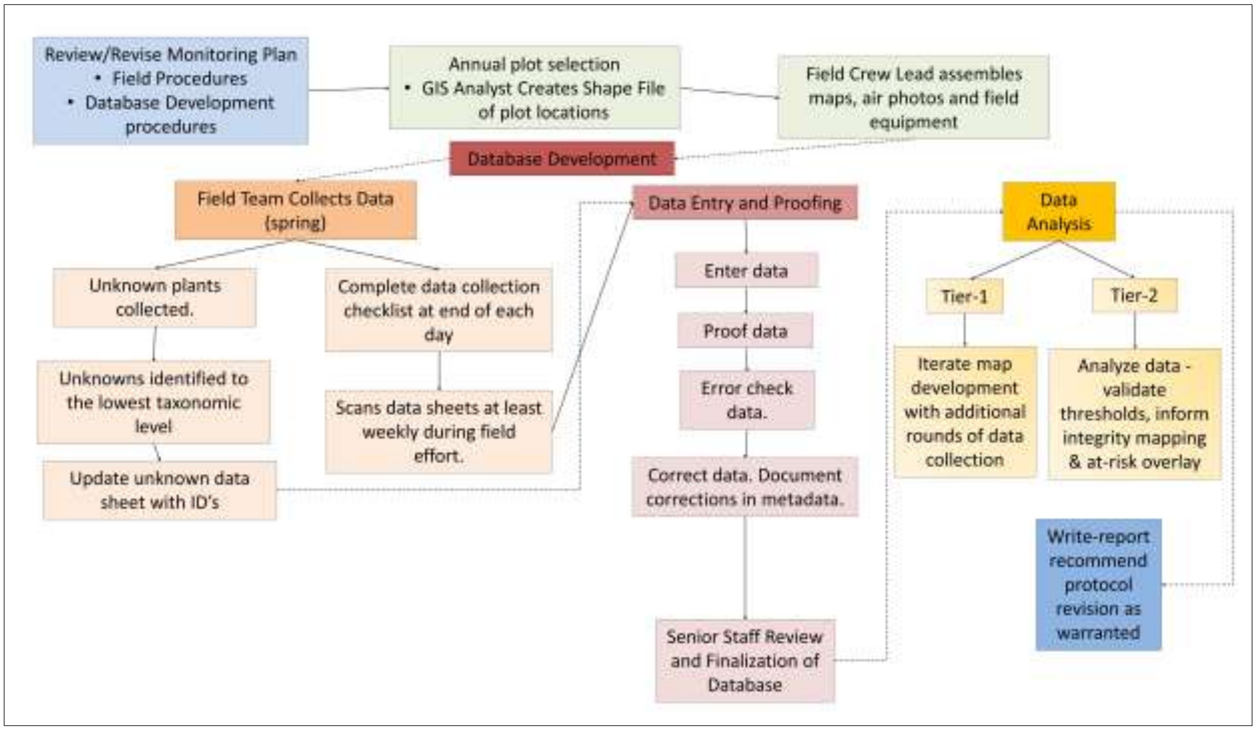

Figure 14. Data generation and management workflow.

II.C.1. DATA QUALITY ASSURANCE/QUALITY CONTROL

II.C.1.a Quality control SOP

Efficient quality-control measures save money, support more accurate and rapid data analysis and reporting, and generate quality databases that are better suited to support needs identified in the future. There are a number of problems that can happen in the field such as measurement errors, including species misidentification, recording the wrong units (i.e. mm instead of cm), forgetting to collect or record data, and illegible handwriting. Once the data is collected, errors can arise in the process of transcription and data can be lost. Quality control begins with a clear, concise description of field protocols. This is needed to increase the consistency among field crew members, reduce errors and increase the utility of the data in the future if applied to other programs. Minimizing and detecting and correcting errors is a critical part of monitoring.

II.C.1.b Field Data Collection

The field data collection process will be governed by the following quality control guidelines.

1) Electronic field data collection is encouraged to speed data processing and analysis.
2) Field crews working in teams of two must have at least one person who knows the flora and recognizes most species encountered.
3) Unknown species must be documented on iNaturalist, collected, provided a temporary identification number, (this number will be included in the iNaturalist entry), pressed the same day, and promptly identified. A database of unknown specimens will be maintained and include collection date, field crew names, plot number, unknown number, and species identification.

4) Any species not on the “CPEN Plant Voucher Checklist” should be collected and submitted to the Base botanist if it is in the appropriate phenological condition. At a minimum it will be reported in the annual report with the plot location information so that it can be collected in the future.
5) At the end of each plot and each field day the daily field checklist will be completed.
    a. For data collection on paper forms:
        i. The data sheets will be tallied.
        ii. Entries will be visually reviewed to ensure that all fields were filled and that the handwriting is legible.
        iii. If data was missed it will be entered if possible and noted missing if not possible to recall or recreate it.
        iv. Photographs will be reviewed to ensure that all were entered into the photo log.
    b. For electronic data collection:
        i. The data will be downloaded and run through a simple programming code that will identify outliers in numeric data, species codes not consistent with the species list, and missing data. This will be done daily (preferable in the field).
        ii. If data was missed it will be entered if possible and noted missing if not possible to recall or recreate it.
        iii. Photographs will be reviewed to ensure that all were entered into the photo log.

6) At least weekly the data sheets will be scanned and emailed to project lead and/or data manager to ensure backup. In the case of electronic data collection, the raw data will be emailed to these people to ensure backup.

II.C.1.c Database Development

Database development will be governed by the following quality control guidelines.

1) The data will be housed in a Microsoft excel database.
2) There will be nine tables within the database (Figure 15): aerial cover line point data, aerial cover line intercept, ground cover, belt transect data, plot data, metadata for all the variables, unknown plants, Base species list, and plot species lists.

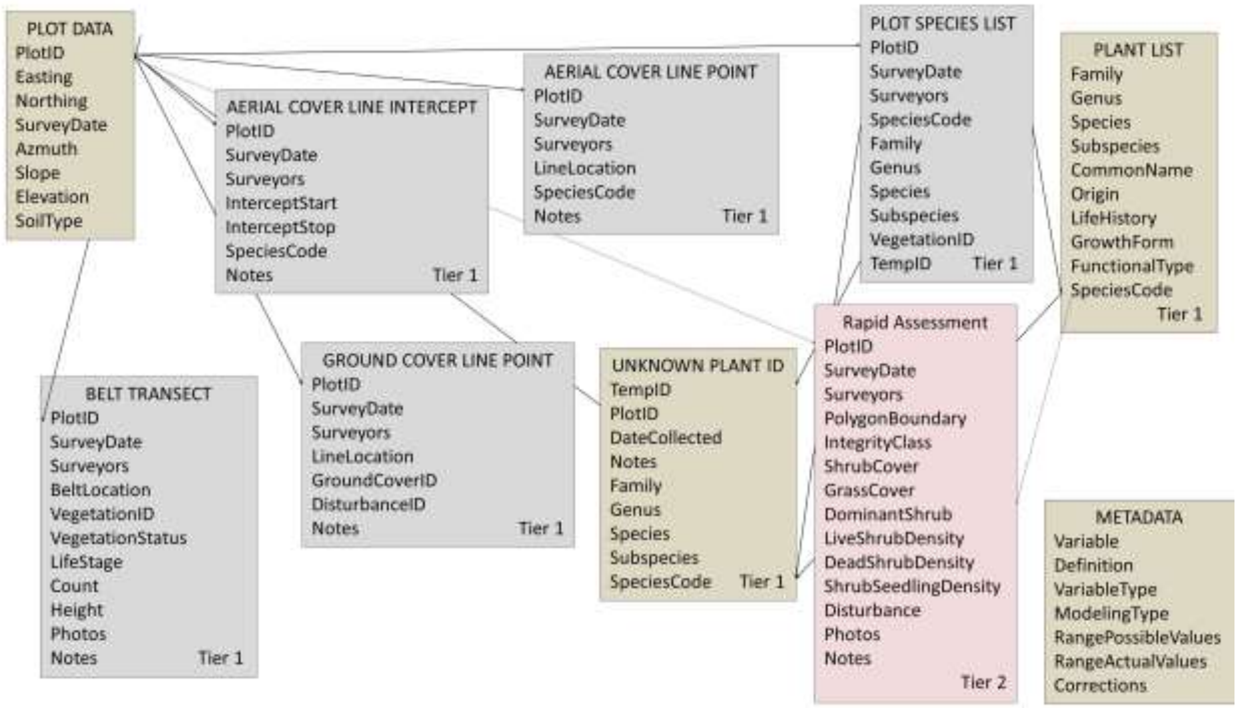

Figure 15. Database structure with relationships to be implemented in Microsoft Excel

Data entry and proofing will use a two-stage process with different people entering and proofing the data. Electronic data collection is highly recommended to speed data processing and reduce errors associated with data entry and proofing.

3) Data will be error checked, as follows:
    a. Data range for each variable will be determined and entered into the metadata sheet each year.
    b. The list of species codes will be compared with the "CPEN Plant Voucher Checklist." Any code errors will be corrected if it is possible to determine the likely species. Species not on the voucher list will be called out in the report and vouchered if feasible.
    c. Distributions of each variable will be plotted and outliers identified using boxplots. Outliers will be verified to ensure that they are not mistakes relatively large or small values compared to the rest of the data set. Validated outliers will be summarized in the "Data Summary and Exploration" section II.D.2.
    d. Data will be corrected and corrections documented in metadata.
4) The database will be reviewed and finalized prior to conducting any data summaries and analyses.
5) Once the database is finalized, error checking will be completed in the data summary and exploration phase of data analysis (sections II.D.2). In this phase the first step after the data are summarized will be to look at the data for odd values, patterns and outliers. Those data will be identified and then researched from the data sheets through the database and will either be confirmed as valid or corrected.

II.C.2. DATA MAINTENANCE AND ARCHIVING

II.D. Data Analysis and Reporting

Timely data analysis and reporting is important to maximize utility of the field data. In this section basic data summary and analysis procedures are included. In combination with the data quality and assurance protocols in section II.C.1 this guidance is intended to facilitate analysis and ultimately reporting at the end of the field season.

There are limited key drivers that affect this system (figure 3), sampling will be done across environmental gradients that assess these drivers, and the analysis will be used to clarify how the system responds.

II.D.1. VERIFICATION AND VALIDATION

II.D.2. ANALYTICAL APPROACH AND REPORTING

II.D.2.a Tier 1 Vegetation Sampling (section II.B.4.a).

The data will be analyzed by vegetation type (coastal sage and chaparral) and integrity class (section II.A.1). In the first year this will be done to validate and refine the map. In the second year and beyond they will be used to validate the integrity map and in combination with environmental variables (e.g. precipitation, CLCF, max summer temperature etc.) refine figure 9 (projected integrity transitions). This will likely need to be done iteratively; e.g. plots are selected, figure 9 is updated, the integrity map update is recreated, and then new plots are selected to validate the second map.

II.D.2.b Data Summary and Exploration Tier 1

Data summary and exploration, a valuable tool to look at patterns in the data and the final step in error checking (Zuur et al. 2010), will begin with the following:

1) Calculate the percentage of polygons whose boundary is correct within approximately 10m. This will identify whether there are problems distinguishing the transition from one integrity class to another in the field. Errors will be characterized by integrity class, slope, aspect, shrub and grass density and cover, and dominant shrub species.
2) Complete the following contingency table (table 11) and calculate the accuracy of the integrity class predictions and error rates. This will highlight whether some errors are more common than others and support revision of figure 9.

Table 11. Contingency table for calculating integrity class prediction and error rate accuracy.

Observed (Tier 1 Sampling)	Predicted (using vegetation map & crosswalk table)			Prediction Rates		
	Low Integrity (n)	Medium Integrity (n)	High Integrity (n)	Low Integrity (%)	Medium Integrity (%)	High Integrity (%)
Low Integrity				correctly identified as low integrity	low incorrectly predicted as medium integrity	high incorrectly predicted as low integrity
Medium Integrity				medium incorrectly predicted as low integrity	correctly identified as medium integrity	high incorrectly predicted as medium integrity
High Integrity				high incorrectly predicted as low integrity	high incorrectly predicted as medium integrity	correctly identified as high integrity

3) Plot the mean values and standard deviations (SD) of shrub and grass cover estimates, live and dead shrub density estimates and shrub seedling density for each integrity class in both coastal sage scrub and chaparral.
4) Identify the percentage of polygons where the dominant shrub species occur for both coastal sage scrub and chaparral.
5) Using the fire history GIS database calculate the number of times that each polygon has burned since 2005 and plot mean values and SD for each integrity class for both coastal sage scrub and chaparral. 2005 was chosen as the starting point of this analysis because the accuracy of fire mapping has improved substantially since that time. This will

II.D.2.a Baseline map validation.

Complete matrix (table 11). Visually evaluate patterns in abundance and frequency of errors. Report prevalence and accuracy (did predicted and observed match) for each integrity type. For each cell in table 11, summarize cover, density, dominant species, seedlings and disturbance to evaluate characterize conditions under which correct classifications are made by the classification model (figure 9).

Calculate map accuracy from the completed table 11. Characterize integrity classes using shrub cover, grass cover, live and dead shrub density and seedling density (mean values and SD, number of plots with 0 seedlings) and dominant species, total number of species, most frequently encountered species.

II.D.2.b Map adjustment

Refine the map by correcting the errors in integrity classification identified using the plot data.

II.D.2.c Refine transition model

Use a correlative modeling approach to validate and refine the integrity class transition model (figure 9). Use 90% of the data to develop a model (figure 9) and then use the remaining 10% to test. If this better predicts the integrity transitions then revise figure 9. The updated transition model along with projections in disturbance (e.g. wildland fire) and other factors (e.g. site and weather) as they are incorporated into the model to project trends in integrity.

II.D.2.d Tier 2 Vegetation Sampling Analysis (section II.B.4.b)

II.D.2.e Data Summary and Exploration Tier 2

Data exploration is an important step to ensure that data sets meet statistical assumptions prior to conducting statistical analyses (Zuur et al. 2010) will begin with the following:

1) The data will be summarized by integrity transition type and vegetation type (coastal sage scrub or chaparral).
2) Data exploration will also be used to identify unanticipated patterns and generate questions that can be evaluated with future monitoring data.
3) The influence of outliers in the results will be considered. The outliers will be validated and confirmed not to be mistakes. They need to be considered carefully as they may reflect important processes or patterns that were uncommon or under sampled because they were not anticipated.
4) Homogeneity of variance will be evaluated by plotting boxplots and for regressions plotting the residuals against the fitted values of the model. If the variance isn't homogeneous then the data have to be transformed or another statistical method chosen.
5) Calculate correlation coefficients among covariates and don't include of variables with correlation coefficient >0.4 (Wintle et al. 2005).

II.D.3. CALCULATION OF RELATIVE COVER FOR INTEGRITY CLASSIFICATION.

For this protocol, relative cover of woody vegetation, invasive annual grass cover, and shrub density (number of shrubs per unit area) were chosen. Vegetation cover is the amount of the ground surface covered by plants (this can be measured by species or groups of species). It typically consists of multiple layers of plant material and depending on methods can sum to 100% (relative cover) or be reported as the total number of intercepts which will not necessarily sum to 100% (absolute cover). Absolute cover is measured by recording taxa that intercept a vertical projection at a point or plot. Estimating cover from a distance (e.g. tier 1 sampling, section II.B.4.a) over larger area typically only captures the top layer and does not allow for detection of multiple layers of cover. On the other hand, recording at points along a transect (e.g. tier 2 sampling, section II.B.4.a) or from a close position on a small plot allows for detection of all the layers. Under this protocol we measure cover in two different ways (section II.B.4) but use relative cover to assign integrity class. Unlike some calculations of relative cover portions of the community not covered by plants (e.g. bareground, rock, lichens) are included in the relative cover calculations.

Conversion of tier 2 sampling results to relative cover essentially converts a multidimensional description of the community into a one-dimensional description. Under this protocol this is done by the following method. For each point if there is a shrub hit this is counted record as shrub for relative cover purposes, if it is grass or forb record the functional group of the tallest individual is counted, other land covers (e.g. bare ground, rock, lichen) counted as those land cover types. Because non-native grasses can fluctuate widely year to year point intercept data may result in a sites' integrity class changing due to annual grass flushes even though shrub cover does not change. Calculating and reporting cover in this way is intended to moderate swings in integrity class due to weather drive fluctuations in annual grass cover.

II.D.3.a Analysis of Threshold Dynamics and Shrub Recovery.

1) Validate threshold dynamics in general and the specific thresholds identified in section II.A.1 by analyzing the data to look for abrupt transitions in seedling establishment and survival rates, sharp spatial boundaries, interactions among drivers and feedbacks that control recovery and resilience.

2) Data exploration will also be used to identify unanticipated patterns and generate questions that can be evaluated with future monitoring data.
3) The influence of outliers on the results will be considered. The outliers will be validated and confirmed not to be mistakes and their influence on the results will be documented.
4) Predictors of number of seedlings that survive fires based on fire patchiness. Evaluation of the LTETM disturbance data will tell us about patchiness, if patchiness varies then we will evaluate fires, intensity, fire weather seedling survival to see if we can develop predictors of the number of seedlings and adults that survive fire. In addition to determine how many shrubs may escape fire in a burned area the 1) range of small scale (e.g. <10m2) fire patchiness not captured in the wildland fire mapping minimum mapping unit will be evaluated in burns of different fire intensities and different integrity classes and 2) influence of fire patchiness on shrub mortality and seedling establishment will be evaluated.
5) To understand the effect of weather on shrub seedling establishment and recruitment separate variables will be used to evaluate 1) early precipitation that contributes to a competitive advantage of annual grasses over shrub seedlings (Pitt and Heady 1978, Eliason and Allen 1997); 2) total winter precipitation that contributes to the maintenance of deep soil water that shrub seedlings must tap into to survive the summer drought and compete effectively with annual grasses; 3) factors that mitigate the summer drought including fog, coastal low clouds and infrequent summer precipitation. Separating these variables should all more accurate identification of annual weather patterns resulting in more accurate projections of stand recovery and degradation that in turn result in more accurate integrity class and at-risk of short fire interval assignment.
6) Shrub recovery and integrity class transition rates will be analyzed using the variables in table 12 and the tier 2 data. Monitoring plots will be stratified to capture a range of factors that contribute to aridity and thus could result in different sites recovering at different rates including: precipitation, solar insolation (aspect), nitrogen deposition and CLCF. The initial hypotheses will be: 1) For coastal sage scrub if a site has burned within in the last 15 years then it will have an elevated exotic grass component that decreases with time since fire and a suppressed native shrub component that increases with time since fire. When the site is burned again in the first year after the fire in long unburned stands there will be sufficient density and distribution of native shrub seedlings and resprout to restock the stand to more than 80% shrub cover through autosuccessional processes. In stands that burned less than 15 years prior the density and distribution of seedlings and resprouting shrubs will be insufficient to restock the stand.

Table 12. Variables and data sources.

Variable	Data Source	scale	reference
Burn area	MCPCP Fire Mapping	1 acre	
precipitation			
temperature			
CLCF (coastal low cloudiness & fog)	SIO	4 km	Clemesha et al. 2016
nitrogen deposition		4 km	Tonnesen et al. 2007
aspect			
slope			
elevation			
PDSI (Palmer drought severity index)			
annual grass phenology	MCBCP fuel moisture monitoring/NDVI		
soil type	NRCS soil survey		

II.E. Protocol Review and Revision

Each year the protocol will be evaluated based on the results from the sampling and the published literature and any recommended changes to the protocol will be written up in the annual project report.

II.F. Protocol Implementation

Pilot studies are important in developing cost-effective monitoring programs (Deutschman and Strahm 2011).

II.F.1. Pilot Phase

In the pilot phase of the protocol implementation both tier 1 and tier 2 vegetation sampling (section II.B.4) will be done across gradients (e.g. precipitation, fog, aspect, fire) and used as the basis for how to interpret data and refine figure 9; this should take about two to five years to clarify empirical relationships and improve the efficiency of creation of annual map updates. In addition, vegetation data from the California gnatcatcher project (section II.B.5) will be evaluated to determine if it can be used to substitute for or augment both Tier -1 and Tier – 2 vegetation monitoring. During the pilot phase the data will be evaluated to validate threshold presence and the values proposed in this protocol. This protocol will take a heuristic approach to the evaluation of threshold dynamics (Bestelmeyer et al. 2004 and Briske et al. 2005). As recommended by Suding and Hobbs (2009) the data will be evaluated for abrupt transitions, sharp spatial boundaries, interactions among drivers and feedbacks that control recovery and resilience. A better understanding of threshold behavior will help avoiding either 1) expensive interventions when the lack of threshold dynamics means they were not warranted or 2) missed opportunities to implement less expensive management actions before thresholds are crossed. The information generated will be used to validate or modify tables 3 and 4 and figure 9.

The pilot phase will be used to refine sample stratification (e.g. by site factors such as distance from the coast) to minimize field effort and sample size needed to achieve desired statistical power.

Validate the accuracy of polygon boundary identification (section II.B.4.a.3.b.iii). The initial objective will be to classify integrity correctly more than 80% of the time; the feasibility of this will be validated in the pilot phase and changed if necessary.

II.F.2. BASELINE INTEGRITY MAP GENERATION (SECTION II.B.1)

II.F.2.a Crosswalk between Integrity Classification and Vegetation Mapping

Initial protocol implementation will begin with developing a crosswalk table to translate the new vegetation map developed by AECOM (AECOM 2019) to a shrubland integrity map using the thresholds and classes identified in tables 3 and 4.

II.F.2.b Update Baseline Map if Required (section II.B.2)

If implementation is delayed and the field work used to develop the vegetation map is more than two years old an additional step of updating the baseline integrity map using figure 9 will be conducted.

II.F.2.c Map Validation (Tier 1 Vegetation Sampling)

While it is anticipated that the map quality will be high given the level of effort involved in the vegetation mapping, tier 1 sampling (section II.B.4.a) will be done to validate the map.

II.F.3. OVERLAY DEVELOPMENT

II.F.3.a Develop At-Risk of Short Fire Interval Overlay

Using the methods in section II.B.3.a develop this overlay.

II.F.3.b Develop Old Growth Conservation Value Overlay

In order to validate and refine the Old Growth Conservation value overlay (section II.B.3.c), stem cross sections from the base of the plant will be collected and aged using growth ring counts (Keeley 1993, Lawson 2010). Sites that haven't been recorded as burned during the period of record will be surveyed and a minimum of three cross sections will be collected and processed for ring counts to determine date of last fire.

II.F.4. TIER II VEGETATION SAMPLING

In the first year it is anticipated that Tier II vegetation sampling will be limited to questions identified in this protocol development process. Those includes evaluating recently burned stands to:

1) to determine if a relationship can be established between seedling survival, fire intensity and fire weather variables on short interval fires to better predict shifts between high and medium and medium and low integrity stands based on mapped fire data and 2) and to develop a more complex model of seedling survival with weather variables so that increases and decreases in integrity are better predicted by fire mapping data, and existing weather data. Depending on the distribution of fires on the Base it is

possible that insufficient stands will be available in a single year to evaluate fire patchiness and multiple years of data will be required to develop the relationship between weather variables and seedling survival. In future years, evaluation of classification errors will be used to refine predictions of transition from one integrity class to another given fire history and factors such as timing and amount of precipitation and improve the first step of annual integrity snapshot map development in (section II.B.2). This should reduce the number of errors in the first draft of the maps and thus work to reduce the cost and effort of map validation and refinement.

Additionally, in future years, once the updates are completed (section II.B.2), an analysis of the misclassifications found during the process of map validation and refinement will be conducted and the Tier II sampling will be designed to develop information that will reduce those errors.

III. BIBLIOGRAPHY

AECOM. 2019. MCBCP Vegetation Classification Report. Prepared for: MCI West-Marine Corps Base Camp Pendleton, Environmental Security, Land Management Branch. Prepared by: AECOM. Mayl 2019.

AMEC. 2006. 2003 Draft-Final Upland Vegetation Mapping and Change Analysis, Marine Corps Base Camp Pendleton. Prepared for: AC/S Environmental Security, Marine Corps Base Camp Pendleton. Prepared by: AMEC Earth & Environmental, Inc. December 2006.

Atkinson, A. J., P. C. Trenham, R. Fisher, A. Hathaway, Stacie, B. S. Johnson, S. G. Torres, and Y. C. Moore. 2004. Designing monitoring programs in an adaptive management context for regional multiple species conservation plans. U.S. Geological Survey Technical Report. USGS Western Ecological Research Center, Sacramento, CA. 69 pages.

Bestelmeyer, B.T., J.R. Brown, D.A. Trujillo, and K.M. Havstad 2004. Land Management in the American Southwest: A State-and-Transition Approach to Ecosystem Complexity. Environmental Management 34(1): 38–51

Briske, D.D., S.D. Fuhlendorf and F.E. Smeins. 2005. State-and-Transition Models, Thresholds, and Rangeland Health: A Synthesis of Ecological Concepts and Perspectives. Rangeland Ecol Manage 58:1–10 | JBonham C.D. 1989. Measurements for Terrestrial Vegetation. John Wiley and Sons. New York. 338 pages.

Cario, A. J., and P. H. Zedler. 1995. Post-fire vegetation recovery on Camp Pendleton. Unpublished technical report Marine Corps Base Camp Pendleton, California. Contract No. N68711-94-LT-4060.

Clemesha, R. E. S., A. Gershunov, S. F. Iacobellis, A. P. Williams, and D. R. Cayan. 2016. The northward March of summer low cloudiness along the California coast. Geophysical Research Letters 43:1287–1295.

CNLM. 2013. The Center for Natural Lands Management-San Diego: Coastal Sage Scrub Monitoring Plan (Revised in 2013). San Diego, CA.

Cox, R.D., K.L. Preston, R.F. Johnson, R.A. Minnich, and E.B. Allen. 2014. Influence of landscape-scale variables on vegetation conversion to exotic annual grassland in southern California, USA. Global Ecology and Conservation 2 (2014) 190–203Dario H., 2014. Differential survival of chaparral shrub species in response to severe drought. Pepperdine University, All Undergraduate Student Research. Paper 135. http://digitalcommons.pepperdine.edu/sturesearch/135

Deutschman, D., and S. Strahm. 2011. Four years of vegetation monitoring on the Nature Reserves of Orange County in central Orange County, CA. Nature Reserves of Orange County Technical Report. Nature Reserves of Orange County, Irvine, C+A.

Diffendorfer, J. E., G. Fleming, J. Duggan, R. Chapman, and D. Hogan. 2004. Final report for “Creating an Index of Biological Integrity for Coastal Sage Scrub: A tool for habitat quality assessment and monitoring”.

Diffendorfer, J. E., G. M. Fleming, J. M. Duggan, R. E. Chapman, M. E. Rahn, M. J. Mitrovich, and R. N. Fisher. 2007. Developing terrestrial, multi-taxon indices of biological integrity: An example from coastal sage scrub. Biological Conservation 140:130–141.

Eliason, S. A., and E. B. Allen. 1997. Exotic grass competition in suppressing native shrubland re-establishment. Restoration Ecology 5:245–255.

Gallegos-Torell, Å., & Glimskär, A. (2009). Computer-aided calibration for visual estimation of vegetation cover. Journal of Vegetation Science, 20, 973–983. https://doi.org/10.1111/j.1654-1103.2009.01111.x

Hickman, James C. (ed.). 1993. The Jepson Manual. Berkeley, CA: University of California Press.

Hanes, T.L. 1971. Succession after fire in the chaparral of southern California. *Ecological Monographs*, 41:1 pp. 27-52.

Heady, H.F., R.P. Gibbens, and R.W. Powell. 1959. A comparison of the charging, line intercept and line point methods of sampling shrub types of vegetation. J. Range Manage. 12:180-188.

Hedrick, D. (1951) Studies on the succession and manipulation of chamise brushlands in California. PhD, Texas A & M College.

Jones, D. S., and M. D. Kunze. 2008. Long-Term Ecological Trend Monitoring (LTETM) Evaluation Report for Marine Corps Base Camp Pendleton, CA. Unpublished technical report Marine Corps Base Camp Pendleton, California. Subcontract No. M-04-123.

Karr JR, Chu EW. 1999. Restoring Life in Running Waters: Better Biological Monitoring. Island Press, 443 Washington, DC.

Keeley, J. E. 1992. Recruitment of seedlings and vegetative sprouts in unburned chaparral. Ecology 73:1194-1208.

Keeley J.E. 1993. Utility of growth rings in the age determination of chaparral shrubs. *Madroño*, 40(1) pp 1-14.

Keeley, J. E., Fotheringham, C. J., & Baer-Keeley, M. (2006). Demographic patterns of postfire regeneration in Mediterranean-climate shrublands of California. Ecological Monographs, 76(2), 235–255.

Keeley, J. E., and T. J. Brennan. 2012. Fire-driven alien invasion in a fire-adapted ecosystem. Oecologia 169:1043–1052.

Keeley, J.E., C.J. Fotheringham, and M. Morais. 1999. Reexamining fire suppression impacts on brushland fire regimes. Science 284:1829-1832.

Lawson, D.M. and J.E. Keeley. 2019. A Framework for Monitoring Shrubland Community Integrity in California Mediterranean Type Ecosystems: Information for Policy Makers and Land Managers. Conservation Science and Practice e109. https://doi.org/10.1111/csp2.109

McEachern, K. 2001. Vegetation monitoring program review for Channel Islands National Park. U.S. Geological Survey Technical Report. USGS Western Ecological Research Center, Sacramento, CA. 25 pages.

Margoluis, R., N. Salafsky, and A. Balla. 1998. Measures of Success: Designing, Managing, and Monitoring Conservation and Development Projects. Island Press. 362 pages.

Morrison, L.W. 2016. Observer error in vegetation surveys: a review. J. Plant Ecol. 9 (4) 367-379.

Moreno, J.M. & Oechel, W.C. (1989) A simple method for estimating fire intensity after a burn in California chaparral. *Acta Oecologia-Oecologia Plantarum* **10**(1)**,** 57-68.

National Park Service. 2003. *Fire Monitoring Handbook*. Boise (ID): Fire Management Program Center, National Interagency Fire Center. 274p.

National Park Service, 2005. Mediterranean Coast Network — Vital SIgns Monitoring Plan. Natural Resources Technical Report NPS/MEDN/NRTR—2007/00?, National Park Service, Thousand Oaks, California

Pitt, M. D., and H. F. Heady. 1978. Responses of annual vegetation to temperature and rainfall patterns in northern California. *Ecology* 59:336–350.

Poole, D.K. and P.C. Miller. 1975. Water Relations of Selected Species of Chaparral and Coastal Sage Communities. *Ecology*,56(5):. 1118-1128

Preston K.L., Mock P.J., Grishaver M.A., Bailey E.A., and D.F. King. 1998. California gnatcatcher territorial behavior. *Western Birds* 29:242-257

Sampson, A.W. (1944) Plant succession and burned chaparral lands in northern California. Bulletin 685. University of California Berkeley, Agricultural Experiment Station.

Sasaki, T., Furukawa, F., Iwasaki, Y., Seto, M., & Mori, A. S. (2015). Perspectives for ecosystem management based on ecosystem resilience and ecological thresholds against multiple and stochastic disturbances. Ecological Indicators, 57, 395–408.

Scheffer M, S Carpenter, JA Foley, C Folke, and B Walker 2001. Catastrophic shifts in ecosystems. Nature 413 591-596.

Scheffer M and SR Carpenter 2003. Catastrophic regime shifts in ecosystems: linking theory to observation. TREE 18(12) 648-656

Scott, J., Burgan, H., & Robert, E. (2005). Standard fire behavior fuel models: A comprehensive set for use with Rothermel's surface fire spread model. Gen. Tech. Rep. RMRS-GTR-153. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Seiger, L., P. Zedler, Z. Venzor, K. Cummins, K. Tae, T. Zink, and G. Fleming. 2001. Long Term Ecological Trend Monitoring Program for Marine Corps Base, Camp Pendleton: 1998 Field Season Final Report. San Diego State University Foundation account 50176A.Sproul, F., T. Keeler-Wolf, P. Gordon-Reedy, J. Dunn, A. Klein and K. Harper. 2011. Vegetation Classification Manual for Western San Diego County. Prepared for San Diego Association of Governments.

Suding KN and RJ Hobbs 2009. Threshold models in restoration and conservation: a developing framework. *Trends in Ecology and Evolution* 24(5): 271-279.

Technosylva, Inc. (2014). Marine Corps Base Camp Pendleton wildland fire risk assessment: Task 1: Fuels mapping final methods report. Report prepared for Naval Facilities Engineering Command.

Tetra Tech Inc. 2016. 2015 Final Annual Report – Mission Driven Wildland Fire Mapping Project. 63 pages. Prepared under contract N62470-08-D-1008; Task Order 53 for the Land Management Section, Natural Resources Division, Environmental Security Department.

Tonnesen, G., Wang, Z., Omary, M., Chien, C.J., 2007. Assessment of nitrogen deposition: Modeling and habitat assessment. California Energy Commission, PIER Energy-Related Environmental Research, CEC-500-2005-032.Vasey, M. C., M. E. Loik, and V. T. Parker. 2012. Influence of summer marine fog and low cloud stratus on water relations of evergreen woody shrubs (Arctostaphylos: Ericaceae) in the chaparral of central California. Oecologia 170:325–337.

Williams, K., Hobbs, R. J., & Hamburg, S. P. (1987). Invasion of an annual grassland in Northern California by Baccharis pilularis ssp. consanguinea. Oecologia, 72, 461–465.Wintle, B.A., Elith, J. & Potts, J.M. (2005) Fauna habitat modelling and mapping: A review and case study in the Lower Hunter Central Coast region of NSW. *Austral Ecology*, **30,** 719-738.

Zuur A.F., E.N. Ieno and C.S. Elphick. 2010. A protocol for data exploration to avoid common statistical problems. Methods in Ecology and Evolution. 13–14

APPENDIX A. DATA SHEETS

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Table 13. Belt Transect Data Sheet (Woody Species).

BELT TRANSECT DATA SHEET
(WOODY SPECIES)

PLOT # ____________

DATE ____________

SURVEYORS ____________

Page ____ of ____

Quad Loc	Species	Status (S/A)	Live Dead	Max Ht	Count	Quad Loc	Species	Status (S/A)	Live Dead	Max Ht	Count
STATUS CODES (S A): Seedling ($\leq$20cm), Adult (>20cm)											

Table 14. Cover Data Sheet (Ground & Canopy).

COVER DATA SHEET
(GROUND & CANOPY)

PLOT # ______
DATE ______
SURVEYORS ______

Page _____ of _____

Line Loc	Disturbance	Ground Cover	Aerial Species	Height #.# m	Line Loc	Disturbance	Ground Cover	Aerial Species	Height #.# m
	N GR B FT T R P FB O					N GR B FT T R P FB O			
	N GR B FT T R P FB O					N GR B FT T R P FB O			
	N GR B FT T R P FB O					N GR B FT T R P FB O			
	N GR B FT T R P FB O					N GR B FT T R P FB O			
	N GR B FT T R P FB O					N GR B FT T R P FB O			
	N GR B FT T R P FB O					N GR B FT T R P FB O			
	N GR B FT T R P FB O					N GR B FT T R P FB O			
	N GR B FT T R P FB O					N GR B FT T R P FB O			
	N GR B FT T R P FB O					N GR B FT T R P FB O			
	N GR B FT T R P FB O					N GR B FT T R P FB O			
	N GR B FT T R P FB O					N GR B FT T R P FB O			
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	N GR B FT T R P FB O					N GR B FT T R P FB O			
	N GR B FT T R P FB O					N GR B FT T R P FB O			
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	N GR B FT T R P FB O					N GR B FT T R P FB O			

N GR B FT T R P FB O: **N**one, **G**razed, **B**urned, **F**oot **T**rail, **T**rail (jeep), **R**oad (maintained dirt), **P**ass, **F**ire**B**reak, **O**ther

Table 15. Unknown Species List.

UNKNOWN SPECIES LIST

Plot # ________________

Date ________________

Surveyors ________________

Unknown #	Flr	Leaf	Per/Ann	Height	Other	Identification	ID By	Ent.

Table 16. Species List.

SPECIES LIST

PLOT # ____________

DATE ____________

SURVEYORS ____________

List all plants identified to species level here. Any unidentified or partially identified plants should be assigned an Unknown number and listed on this list AND on the UNKNOWN SPECIES LIST.

If a plant is not rooted in the 100m x 1m belt, add -NR after the species code (eg. BRODIA-NR)

NOTES ABOUT THE PLOT:

Table 17. Plot Checklist.

PLOT CHECKLIST			
Location			
Survey Date			
Surveyor(s)			
Recorder(s)			
	Check List		
	# Sheets	**Complete**	**Legible**
Photo Log			
Belt transect			
Line Transect			
Unknowns			
Species List			