Adaptive Management and Monitoring Recommendations
for Grazed San Diego County Conserved Lands

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Table of Contents

Introduction

This report presents recommendations for adaptive management and monitoring on grazed conserved rangelands in San Diego County. The *Grazing Monitoring Plan and Pilot Project* (GMPPP) was initiated in 2021 at Rancho Jamul Ecological Reserve (RJER) and Hollenbeck Canyon Wildlife Area (HCWA) as part of the implementation of the Management and Monitoring Strategic Plan (MSP) Roadmap (SDMMP and TNC 2017) of the San Diego Association of Governments (SANDAG) and the San Diego Management and Monitoring Program (SDMMP). The MSP Roadmap provides a biologically based foundation that supports decision making and sets funding priorities for managing and monitoring species and vegetation communities on conserved lands in western San Diego County. MSP species were identified based on their limited distribution, threats, or need of management in the MSP area. The GMPPP includes a comprehensive literature review (Motamed et al. 2021) and three years of research on the potential to enhance conservation values in grassland and coastal sage scrub habitats of San Diego County (Bartolome et al. 2024). These, together with the research team's long experience developing conservation management and monitoring programs on other rangelands in California, are the basis of this report. The recommendations in this report are intended to provide a framework for developing empirically based adaptive management and monitoring programs that can be applied in conserved rangelands across San Diego County and elsewhere. Within this framework, management and monitoring actions are developed on a site-specific basis based on site characteristics and dynamics, conservation goals and objectives, and models of site-specific resource responses to management.

Concurrent with this report, we prepared a report summarizing results to-date of the GMPPP titled "*Evaluating Grazing for Conservation and Fuel Management Results from a 2-year Study at Rancho Jamul Ecological Reserve and Hollenbeck Canyon Wildlife Area"* that gives a detailed description of the project sites, conceptual models used in the study, pilot study results, and the relevance of the results to the core management questions guiding this work.

One of the deliverables of the GMPPP is to create a monitoring plan with "sampling design, protocols and future monitoring schedule" to guide monitoring on grazed conserved lands in San Diego County. This report outlines such a plan. It is a framework for designing monitoring on San Diego conserved lands that builds on the methods used and the lessons learned in the pilot study. Implementation of this methodology across grazed conserved rangelands in the County will generate a dataset that can inform a regional evaluation of opportunities to use livestock grazing to achieve ecological management objectives.

Core findings from the pilot study that affect our recommendations in this plan include:

1) Species composition, ecological processes, and management potential of conserved lands are strongly influenced by spatial and temporal variation in environmental factors and weather. Different areas of managed properties with similar resource types (e.g., grasslands) exhibit distinct ecological dynamics, functions, and species potential that are driven by site characteristics.
2) Plant community composition and structure change over time, but many of these changes are contingent on interactions of site characteristics with stochastic factors like weather

and fire. Wildfire is a major driver of change in coastal sage scrub (CSS) communities which can lead to multi-decadal effects on shrub cover. Annual weather patterns and topo-edaphic factors greatly influence above ground biomass production and annual plant composition.

3) Identifying and defining ecological sites (ESs) and associated state-and-transition models (STMs) was important for working out spatial and temporal relationships in plant species occurrence, community composition, vegetation structure, potential to support MSP species, and grazing effects. These factors are directly related to several common conservation and management goals. Additional years of monitoring and expansion to new sites will allow us to better work out these interdependent factors.

4) In our study, grazing was associated with changes in vegetation composition and cover in specific ESs. Sites supporting CSS demonstrated increases in cover of some shrub species in association with grazing, while one species, laurel sumac (*Malosma laurina*) decreased in cover with grazing. In one grassland ES, lack of grazing was associated with a transition from forb-rich annual grasslands to a near monoculture of nonnative ripgut brome (*Bromus diandrus*). These findings suggest that management will be most effective when monitoring and decision making are made on an ES basis – with tailored management goals, objectives, strategies, and monitoring practices that consider a site's potential and constraints.

The monitoring approach described in this plan is designed to support development of ecological site and vegetation state classification, so that vegetation potential and ecosystem drivers (including grazing) can be identified. Given the unique nature of ecological preserves and the variation in special resources and the conditions that support them, additional monitoring methods for specific conservation lands may be needed to address the goals, objectives, and site conditions of individual preserves. In many cases, these additional metrics can be integrated into the ecological site framework to better inform where on the landscape management interventions may be most effective for supporting specific conservation goals.

Goals, Objectives and Performance Standards

Well-considered management goals and objectives form the foundation of a successful adaptive management and monitoring program. In the context of this plan, goals are typically high-level statements representing desired conditions in the future. They reflect the major priorities of the land managing entity. An example of a goal is to *enhance habitat for rare or threatened species*. Objectives are more specific desired outcomes associated with each goal. For example, associated with the above goal might be the objective of *improving habitat for burrowing owls in grazed grassland areas of the preserve*. Some planning frameworks stipulate that objectives should be measurable, which works in many (but not all) cases. Regardless, it is useful to state the standards by which objectives will be evaluated, for example low vegetation height or residual dry matter (RDM) levels could serve as standards for achieving the burrowing owl habitat quality objective. Therefore, we suggest identifying "performance standards" associated with each objective, to provide measurable criteria by which management can be evaluated for meeting a given objective. A performance standard related to the burrowing owl objective could be to *maintain spring vegetation obstruction height below 6 inches in areas of the preserve with burrowing owls*.

Performance standards provide managers and ranchers with target conditions to aim for. They also specify the variables that explicitly link monitoring to evaluation of management objectives. With measurable performance standards, monitoring can be designed to provide data that can be directly used to evaluate progress towards management goals. This helps avoid a common monitoring pitfall: collecting monitoring data which cannot, and therefore do not, get used to inform management.

The GMPPP core monitoring goals were to evaluate whether grazing management can be used to improve ecological health of CSS and grasslands and benefit habitat for MSP species, while simultaneously reducing fine fuel loads to reduce risk of frequent fires. These goals are central to a variety of conservation outcomes on conserved lands. The pilot study showed that in many cases grazing can help achieve these goals.

It addressed a set of study goals and objectives related to conservation of specific vegetation communities and associated MSP species. The study made it clear that setting realistic objectives for each of the pilot study goals requires information about the spatially-variable ecological dynamics of the property. For example, several MSP species occur at RJER and HCWA, however species' occurrence patterns and suitable habitats varied spatially in relation to site factors. The ESs defined in the pilot study captured much of this variation and helped clarify viable outcomes and management challenges for specific MSP species. These ESs were specific to RJER and HCWA, however, the empirical bottom-up approach we employed is adaptable to a variety of locations and management goals. Furthermore, as more sites are monitored using this methodology, regional ecological site patterns and a better understanding of opportunities for grazing to achieve habitat management goals are expected to emerge.

While the GMPPP focused on fine fuel loads and MSP species habitat enhancement, rangeland management planning on conserved lands may consider other goals and objectives. These in turn will require specific monitoring criteria to evaluate compliance and effectiveness aspects of the management program. Common goals included in rangeland management plans on conserved lands include:

1) Biological Conservation
    a. Maintenance or enhancement of native or sensitive species habitat
    b. Avoidance of negative impacts to sensitive or rare species
2) Pest plant management
    a. Limit infestations of existing pest plants
    b. Avoid new pest plant introductions
3) Rangeland health
    a. Minimize erosion
    b. Protect rangeland water quality
4) Manage type-conversions of vegetation
5) Reduce fire hazard
6) Facilitate prescribed burning
7) Avoid conflicts with recreation
8) Maintain feasibility and economic viability of grazing operation

Each of these goals can have associated objectives and performance standards that provide details on the resources affected and the conditions desired.

Ecological Models for Management: Ecological Sites and State-and-Transition Models

We take it as a given that semi-arid annual grasslands in California behave differently than tallgrass prairie or redwood forest. They have a different climate, different soils, different annual weather patterns, different potential vegetation and wildlife, and different management systems. But even within areas of similar climate, differences in soils and topography are primary factors that shape vegetation at a site (Spiegal et al. 2014). At this scale, areas with different environmental characteristics can be classified as different ESs with different management potential. These sites each have a variety of vegetation states, characterized by particular vegetation composition and structure. The pilot study showed that there were several ESs with distinct vegetation states and that these ESs also exhibited unique ecosystem dynamics within RJER and HCWA. Understanding how ecological dynamics vary at landscape, ranch and pasture scales can help us fine-tune objectives and performance standards, formulate effective management strategies and efficiently monitor and adapt management.

The below sections outline methods for classifying ESs and state-and-transition models at scales relevant to management practices and goals on conserved lands.

Ecological Site Data Collection

According to the USDA/NRCS, an ecological site (ES) is "a distinctive kind of land with specific characteristics that differs from other kinds of land in its ability to produce a distinctive kind and amount of vegetation" (NRCS 2024). This definition is helpful for understanding the ES concept, and it is easy to imagine several methods which we could use to classify sites fitting this description. We recommend basing ES definitions on a classification of measured environmental data collected at random points, stratified across major environmental thresholds or gradients of the management area in question. This "ground-up" approach is well-suited to objectively identifying areas of the landscape which differ inherently from other areas with respect to potential vegetation dynamics, grazing management considerations, and relevance to management goals and objectives. This method also incorporates management narratives and observations from field researchers, reserve managers, ranchers, and other relevant stakeholders. But the approach of using measured data collected at study plots over years with varying weather conditions often illuminates relationships that can otherwise go overlooked.

The first steps typically involve interviewing land managers, livestock operators, and other parties who can provide insight into the current management practices, ecosystem dynamics, and geography of the site. When possible, it's best to conduct these interviews and discussions at the site so that it's possible to see the location and discuss issues in situ.

Questions that should be asked at this stage include:

1) Who owns and manages the site? What other entities use the site (utilities, other easements)?
2) What management practices are currently used at the site?
3) What is the recent and longer-term history of management at the site?

4) What research or inventory documents are available for the site? (Geographic Information System (GIS) data, reports, species lists, documentation of past studies or management trials, and historical information/documentation)
5) What is site access like?
6) Any other questions relevant to current conditions, management practices, goals and objectives, ecological dynamics, or past research/monitoring.

In addition to talking with managers and people familiar with the site, it is important to get as much existing documentation of the site as possible. Many conserved lands in San Diego County have had significant monitoring efforts conducted there. What reports, databases, and GIS data exist related to the ecology, management and environmental attributes of the area? The USDA Web Soil Survey is an online tool that provides useful information about soils. USGS geology maps can generally be found for county lands. Additional resources include digital elevation models and vegetation maps. These mapped resources are valuable for getting a sense of the variation in site conditions, which in turn is very helpful when selecting and stratifying study plots. However, maps include significant (often unstated) assumptions or biases which can reduce their accuracy at specific locations within the map. In the GMPPP, we found that measured variables from our plots consistently outperformed mapped variables in predicting multiple species' patterns of occurrence (Bartolome et al. 2024) and we consequently used measured (not mapped) variables for ES classification purposes.

Study plot selection. The main purpose of the initial set of sampling locations is to begin to understand the relationship between environmental drivers and site dynamics. This sample can be increased in future years to include more replication of underrepresented sites, interesting landscape features, or new areas not captured by the initial sample. We recommend a random or stratified-random selection of study plot locations. Randomness in the sample locations can reduce bias in the classification and increase the chances that the plots are representative of the overall management area. Stratifying samples helps ensure the variables (e.g., soil type or slope) considered important are adequately sampled. From the classification perspective, random location of sites is not a strict criterion of the non-parametric clustering models used for ES classification, but conceptually, random samples increase the probability that the classification will include a representative sample of site conditions, including those that do not neatly "fit" into preconceived notions of site categories.

SDMMP created a grid of points spaced 150 meters apart, which we sub-sampled from as the basis for site selection in the GMPPP. This grid worked well for sampling at the scale of environmental features at RJER and HCWA. It may be necessary to adjust the scale of the sample to accommodate some features (e.g., vernal pools) or stratify random samples within units of interest (e.g., unusual soil types) if they do not otherwise occur in the sample set. In the GMPPP we stratified our plot locations to make sure we had samples in all geology types, across different slopes and aspects, in areas with different dominant vegetation (grassland and shrubland), and in all major management units (e.g., grazing pastures).

Study plot rejection criteria. There are multiple reasons to reject a randomly-selected study plot from the sample. Examples include:

1) unusual or extreme human disturbance at the plot (including trash or debris)
2) plot occurs within a livestock "service area" such as adjacent to a watering trough, feeding area or mineral lick
3) plot is at the intersection of multiple aspects, slopes or soil types (this makes ES classification difficult later)

Plots may be rejected for other reasons as well if some aspect of the plot location makes it an unsuitable plot to answer questions about the management goals and objectives. If a plot is rejected, it may be shifted to an adjacent location or moved to another sampling point. For this reason, we recommend identifying enough candidate plot locations before entering the field to allow for some to be rejected without jeopardizing sample size.

Study plot layout. There are many ways to lay out and sample study plots and several of them will produce the type of data that can be used to classify ESs and vegetation states. In the GMPPP we used a 10x10 meter square plot, which we sampled using the relevé, line-point, and line-intercept method (sensu Bartolome et al. 2024 appendix B). This approach efficiently and effectively answered our research questions, and yielded valuable information about species composition, cover and vegetation structure. There is value in using a standardized sampling approach at different preserves, so that data are comparable between sites. As more sites are sampled in this way, generalized ecological site classifications may emerge that can be used as provisional models in unsampled areas of the County. Therefore, we recommend using the approach described below, which builds on the methods established in the GMPPP and provides detailed field data while allowing for reasonable replication of study plots.

Plot shape and size. The purpose of the study plot is to measure environmental attributes and describe ecological conditions (principally vegetation) at points in the study area. We used 10x10 meter square plots in the GMPPP because these plot sizes conform generally to what is used for the relevé method and are similar to plot sizes used in the CNPS vegetation rapid assessment protocol (CNPS 2024). The plot size worked well for detecting vegetation patterns related to the primary goals of the GMPPP. Square plots facilitate setting up linear transects for line-point and line-intercept sampling. These sampling techniques generate accurate, repeatable measurements of plant cover, that are suitable for vegetation classification and also may be used to detect changes in plant cover (see vegetation sampling below).

Soil samples. Soil characteristics are important building blocks of ES classifications. Soil nutrients and texture are important determinants of plant growth and species composition, and some plants show strong relationships to specific nutrients (Gea-Izquierdo et al. 2007). Indeed, in the GMPPP, individual soil nutrients and soil particle size were consistently ranked among the best predictors of species occurrence (Bartolome et al. 2024). We recommend collecting soil samples from 0-15cm depth using a soil auger for chemical, texture, and phytolith analyses. Three to four samples should be collected at each study plot and combined into one composite sample for analysis. These samples can be taken at the four cardinal directions of each study plot,

just outside the 10x10 meter plot area. Before sampling soils, first scrape the soil surface to remove vegetation and litter and to expose bare mineral soil.

We recommend analyzing soils for the following properties:

1) Nitrogen (Total %)
2) Carbon (Total %)
3) Extractable Phosphorus
4) Extractable Sulfate
5) Exchangeable Potassium
6) Exchangeable Sodium
7) Exchangeable Calcium
8) Exchangeable Magnesium
9) Sand (%)
10) Silt (%)
11) Clay (%)
12) pH

In addition to nutrients and texture, soil samples can also be analyzed for phytolith content and composition. Phytoliths in soil provide valuable information about vegetation history and reference conditions at study plots (Evett and Bartolome 2013). This information can inform goals and objectives and shed light on long-term ecological dynamics of the site. See Appendix C in Bartolome et al. (2024) for more detail on phytoliths.

Topographic/geomorphologic measurements. When plots are first sampled, measurements of plot geomorphology should be recorded. These features can be important determinants of ecological function (Devine et al. 2019) and vegetation composition (Bartolome et al. 2024). Measurements of these variables can be important for classifying ESs (Bartolome et al. 2024), and they generally only need to be measured once, as they do not typically change much during the timeframe of the research. Topographic and geomorphologic measurements include:

1) Percent slope of the site (measured with a clinometer)
2) Aspect of the slope (measured in degrees using a compass with the proper declination). Typically, this is measured from the top of the slope looking downhill. A north-facing aspect (0°) is therefore one that slopes down to the north.
3) Elevation (generally taken from GIS)
4) Landform – is the plot on an alluvial flat, hill, terrace, mesa, or other?
5) Position on slope – is the plot at the summit, shoulder, backslope, footslope, or toeslope (sensu "Hillslope Profile Position" in NRCS 2024)?
6) Record notes on other observations about geomorphology of the plot area.
7) Geomorphologic data can also be derived from digital elevation maps in GIS. Potentially useful variables include elevation, slope, aspect, solar radiation, and topographic wetness index (Heller et al. 2022).

Other site variables. Soil and geomorphology will likely form the core of the ES classification, however other variables may shed light on important ecosystem drivers at a study plot. These include the following:

1) History of intensive cultivation or other soil disturbance at the plot.

2) Fire history at the plot.
3) Grazing use for any pastures containing study plots. Ideally, this would include the following information, however in practice grazing records may not include this much detail:
    a. Total animal unit months (AUM) / pasture. An animal unit month is the equivalent number of mature cows (with or without an unweaned calf) present in an area for one month. AUM definitions and animal unit equivalent conversions for other livestock species and classes can be found in Bush (2006).
    b. Size of grazing pastures
    c. AUM/acre per pasture
    d. Timing of grazing per pasture
4) Other plot attributes:
    a. Rodent bioturbation percent cover (none, 0-10%, 10-30%, >30%; record species)
    b. Cattle use level (none, light, med, heavy)
    c. Evidence of cattle use (Manure, Trampling, Presence, Herbivory)
    d. Vegetation obstruction height (measured with a Robel Pole, see below)

Field notes about cattle use are not meant to be quantitative nor will they likely be used in analysis. Rather they are meant to provide observational information about whether a given plot appears to have had cattle use within the current grazing season (grazing seasons often begin and end in the fall, but this will vary depending on the grazing operation), and if so, the extent of use at that plot.

Herbaceous vegetation obstruction height can be measured by placing a Robel pole in the center of the plot (or in a grassland-portion of the plot if shrubs are present), standing back 20 feet and looking at the pole from the height of the herbaceous vegetation and finding where the vegetation obscures at least 80% of the black and white squares of the pole. Repeat this measurement from the north, south, east, and west directions.

Vegetation Data Collection

Collecting information about vegetation composition and structure at the study plots fulfills several purposes: 1) it generates data that can be used to classify vegetation states and their associated transitions in STMs associated with each ES; 2) it tells us about the presence and relative cover of special species, weeds, native/introduced plants, and plant functional groups. Understanding the distribution of these species and how they change over time is important in determining the potential conservation benefits (or conflicts) posed by grazing; 3) structural elements like height, density and biomass provide critical information about wildlife habitat, distribution and temporal variation of fuel loads, and distribution of forage production and grazing. Taken together, these factors provide the context and specific conditions to adaptively guide grazing to improve MSP species habitat quality and benefit other conservation goals.

The ES models, and their paired STMs form the conceptual basis for understanding how grazing (or other rangeland management practices) could impact target resources across preserves with spatially-variable soils and topography, and temporally-variable weather conditions. These models can be flexibly applied to a variety of systems and do not rely upon a specific theory of succession (Westoby et al. 1989). This is a valuable approach in semi-arid rangelands, where

succession is often non-linear, and potentially includes multiple stable states (Vetter 2005). State-and-Transition Models take a relatively simple approach to modeling vegetation dynamics in these systems: they provide a catalog of different vegetation states (which can be variously defined but are generally related to plant species composition and structure) and an associated catalog of the conditions that are associated with transitions from one state to another (Westoby et al. 1989). The flexibility of this approach and its ability to describe vegetation conditions and drivers of change makes it a powerful platform for generating management hypotheses, developing predictive models, and guiding goal-oriented management decisions (Jackson, Bartolome, and Allen-Diaz 2002).

STMs can be created using different types of data and states and transitions may be classified in a variety of ways, blending scientific, historical and anecdotal information. We recommend an approach that utilizes these elements in combination with a classification based on the coincident presence of species. This approach emphasizes presence or "occupancy" of a plot by different plant species and is based on simple presence/absence of plant species on the monitoring plots. The GMPPP found that a classification based on simple presence/absence produced states with different percent cover values of key species (Bartolome et al. 2024). Vegetation classification can be performed on percent cover data as well. One consideration when performing classification on percent cover data is whether (and how) to transform data to better represent species with low percent cover.

Data from a single year of vegetation sampling can be used for classifying vegetation states associated with the different ESs. Assuming that multiple states in an ES are identified using this initial sample, the different states represent spatial variation in vegetation communities within the ES. In order to see how vegetation changes over time, multiple years of sampling are required.

Vegetation sampling methods. Vegetation data should be collected in the same 10x10 meter plot used to collect ES characteristics. All species that are rooted in the 100 square-meter plot should be recorded. This list establishes the presence/absence of plant species on the plot. In the GMPPP, we were particularly interested in changes in percent cover of key species and functional groups. Adding line-point and line-intercept transects to record the cover of different species in the relevé is an efficient and repeatable method for deriving this information (Figure 1). This information is valuable when evaluating changes in cover of plant species and functional groups over time or in relation to different site and management factors.

Line-point sampling methods generally follow the technique described in Herrick et al. (2017), with modifications. The general sampling procedure is:

1) Each plot uses five 10-meter line-point transects, stretched from the north side to the south side of the plot (Figure 1).
2) The West and East sides of the 10x10 meter relevé are each used as a transect. The border of the relevé should be set up using a 50-meter transect tape, so the sides of the relevé square will have meter marks on them. The three interior transects can be set up using shorter transect tapes with metric units.
3) Line-point samples are collected starting at 0.5 meters (near the north side of the plot), and every 0.5 meters thereafter. This includes samples at the following meter locations on

each transect tape: 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, 9, 9.5, 10. Thus, each transect has 20 line-point samples and each plot has 100 samples.

4) At each location along the tape, use a sampling pin (this can be a long pin flag or a welding rod with a sharpened tip) to measure the vegetation. The pin should be extended toward the ground at the sampling location and the following information should be recorded:
    a. The species and height of the top vegetation hit by the sampling pin.
    b. The species of all subsequent hits (additional species encountered by the pin on its way to the ground). Heights are not recorded for subsequent species hits.
    c. The ground cover where the pin intercepts the ground. One of these classes:
        i. Organic Dirt (bare ground, soil contains some organic matter)
        ii. Sandy Soil (sandy soils with no organic component)
        iii. Leaf Litter (plant matter covering soil surface)
        iv. Bare Rock (rock outcrop, or boulder >25cm)
        v. Cobble Stone (rock 7.5 – 25 cm in diameter)
        vi. Moss/Lichen
        vii. Cryptogamic (refers to cryptogamic soils other than moss/lichen)
    d. If biological soil crust (e.g., cryptogamic soil) is visible within 10cm of the point at which the pin hits the ground, record whether the crust is: cyanobacteria, lichen, or bryophyte (see: Rosentreter et al. 2007 for details about cryptogamic soil identification). Record the distance from the pin to the nearest patch of soil crust, to the nearest 1cm.

Generally, in Mediterranean-climate California grasslands, vegetation composition monitoring should be conducted in the spring when herbaceous plants are most readily identifiable. Ideal timing can vary between years due to different rainfall patterns. One of the benefits of using presence/absence data for classification is that accurate results rely on detectability of species rather than cover of species. Cover of herbaceous species can vary significant throughout the growing period, whereas occupancy of a species is a binary state in a given growing season. Well-timed surveys minimize detection error.

Other plot variables. If vegetation data are recorded at a different time than the ES data, variables such as rodent bioturbation, obstruction height, and grazing use should be recorded at the time of vegetation sampling as well.

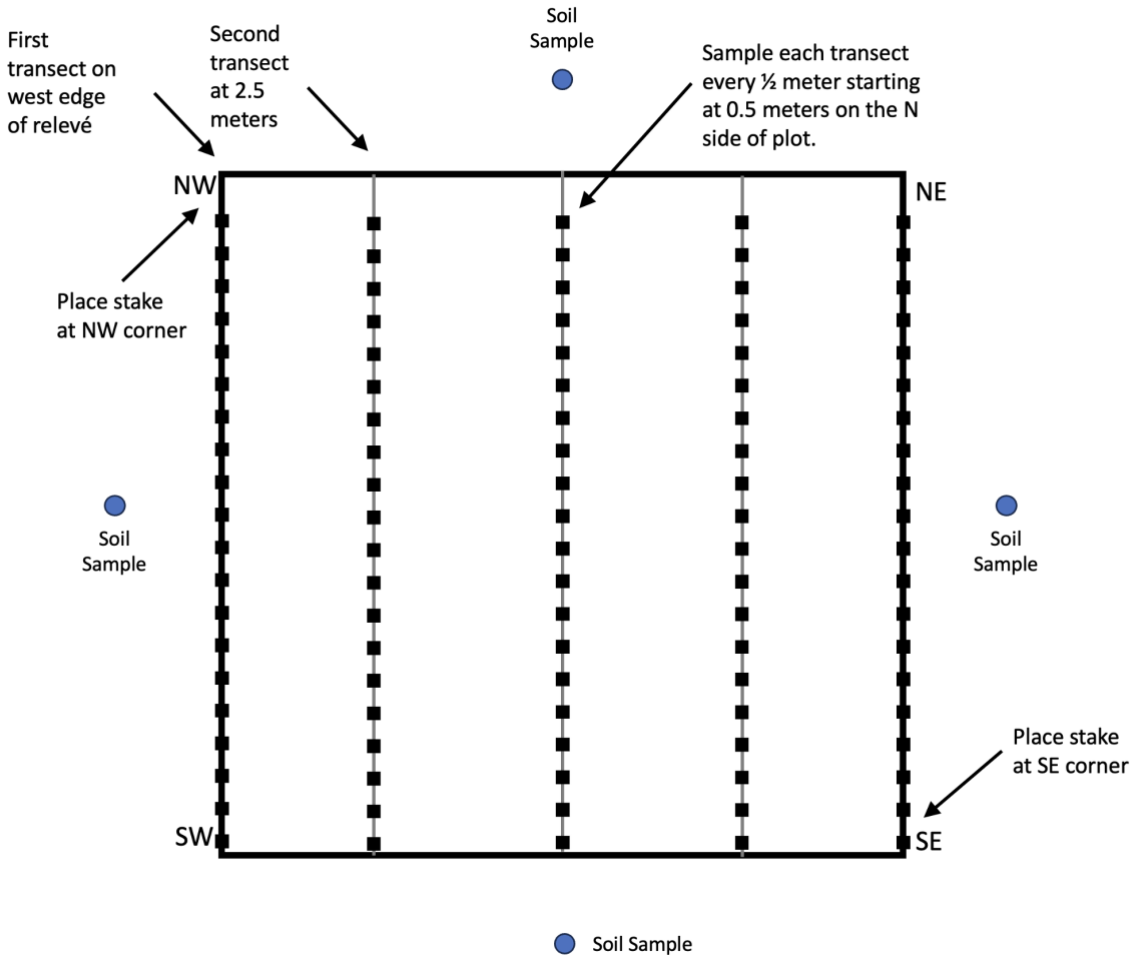

Figure 1. Layout of 10x10 meter plot with five line-point transects and soil sampling locations.

Residual Dry Matter. Residual Dry Matter (RDM) is the old herbaceous vegetation left standing at the beginning of the rainy season (typically in October in southern California). It is a management standard used to evaluate grazing capacity and use, and the amount of residual biomass in the fall can affect species composition, forage production, and erosion in the subsequent year (Bartolome et al. 2006). Bartolome et al. (2006) describes methods for clipping RDM samples. This method entails clipping all above-ground herbaceous biomass (excluding summer annuals and tree or shrub leaves) in a quadrat of known size, collecting the sample in a paper bag (generally a paper lunch bag suffices), then drying and weighing the sample. Measurements are then converted to pounds/acre of RDM. If using a 1-square-foot quadrat, then RDM weights (in grams) can be multiplied by 96 to produce pounds per acre. For example: 20 grams of dry sample weight * 96 = 1,920 lbs/acre of RDM. We recommend collecting RDM data on all grazed plots within the monitoring area each fall.

Another option for monitoring RDM is to create RDM maps. RDM maps are continuous records of RDM conditions which can be useful for inferring ranch-scale patterns of production and

grazing utilization, as well as fall herbaceous fuel conditions. In this procedure, RDM is visually estimated into categories throughout the project area. The categories can reflect thresholds that are meaningful for the goals and objectives of a particular site. For example, the lowest category might reflect RDM below the minimum RDM standard in the grazing lease (e.g., <600 lbs/acre). There might also be a "high" threshold that represents undesirable conditions for wildlife habitat or fire (e.g., >3000 lbs/acre). In this case, there would be three categories that the entire area would be mapped into: <600 lbs/acre, 600-3000 lbs/acre, and >3000 lbs/acre.

Frequent calibration using the clipping methods described above are important for improving accuracy of visual estimates and for adjusting to new vegetation conditions. RDM mapping requires determining a minimum mapping unit and representing RDM conditions that occur at the scale of that unit or larger.

RDM mapping takes more experience than plot-based clipping and adds time to the overall RDM monitoring data collection. It can provide useful insights about grazing activity and the distribution of fuels, but depending on the goals and objectives of the preserve, it may not be necessary to perform this monitoring procedure.

Monitoring Photographs. All plots should have photographs taken every time they are monitored. One photograph should be taken in each cardinal direction and should include the monitoring plot in the foreground. Be sure to take photographs in "landscape" (or horizontal) orientation and to include the horizon or other notable features in the background which can be used to relocate photograph locations. We recommend using a camera app on a smartphone that records a timestamp with the date, time, and location of the photo. One such app is the Solocator app, which also lets the user add notes, such as the plot name, to the photograph.

ES and STM Data Analysis and Interpretation

The next step after collecting data using the procedures above is to use those data to inform ES and state-and-transition model classification. These are two separate (but related) processes can be iterative. Generally speaking, it makes sense to classify ESs before attempting to classify vegetation states. Each ES has its own associated ST model, and ideally ST classifications are performed on the subset of plots falling into each ES. Having said that, classification is not a purely objective practice, and iteratively testing different classifications is an important step in fine-tuning the models. This may involve evaluating how plant species are distributed among the different ESs, what their cover is in each ES, or how a vegetation classification based on all plots together compares to vegetation classifications broken out by ES.

Ecological Site Classification

The first step in classifying ESs is determining which of the environmental variables should be included in the analysis. In the GMPPP, we used Random Forest Analysis to identify which environmental variables best explained the occurrence of the 138 species occurring across the 54 sample plots. Variables that were deemed "important" (based on mean decrease accuracy) for a larger number of species were included in our analysis, whereas variables that were important for fewer species were omitted from the analysis. Other techniques, such as BIOENV, can also be used to select environmental variables to include (Heller et al. 2022).

After selecting the variables to use for classifying study plots into ESs, the next step is to use cluster analysis to describe groups of the study plots that have the most similar environmental variables to one another. These groups of plots form the basis of the ES classification. Several algorithms exist for performing cluster analysis, each of which will give a somewhat different result. A helpful overview of clustering methods is provided in Borcard et al. (2011, p. 53).

In the GMPPP, we used Bray-Curtis distance to create the distance matrix. If the environmental variables include categorical (non-numeric) values, an alternate distance measure that can incorporate both numeric and non-numeric values should be used, such as Gower's Distance. We used a flexible beta linkage method to identify groupings within the data, this approach provides a more balanced dendrogram. We used three methods to determine the optimal number of clusters: a Mantel Test (Borcard et al. 2011), indicator species analysis (Dufrene and Legendre 1997), and visual inspection of the cluster dendrogram to identify areas with large breaks between groups. After selecting an optimal number of clusters, the resulting clusters comprise the different ecological sites. In practice, this process may be iterative, where different parameters and different numbers of total clusters are experimented with to see how the resulting clusters relate to landscape-level patterns and relationships to environmental variables and plant species occurrence.

State-and-Transition Classification

Just as plots are classified into groups with similar environmental attributes to create the ESs, plot*years are classified into groups with similar vegetation to create the vegetation states. A plot*year is a plot sampled in a given year. Thus, if "Plot 1" is sampled in 2022 and 2023, "Plot 1_2022" and "Plot 1_2023" are unique plot*years considered separate entities in the state-and-transition cluster analysis.

Before performing this analysis, we recommend discarding any species that only occur on one plot*year. This helps ensure that states are classified based on shared species between plot*years. Additionally, the vegetation data should be carefully curated before performing cluster analysis. Every unique plant taxon can influence the results, so it is important to remove overly ambiguous species or pseudo-species. These are typically created when a plant could not be identified to the species level in the field and a higher taxonomic level is used. An example of an overly-ambiguous species is "Asteraceae sp." – a plant belonging to the plant family "Asteraceae". If this code comes up on different plot*years, it may refer to several different species, but in the classification, they would be treated as the same – potentially skewing results. An example of a pseudo-species is when one or more species is identified within a genus (e.g., *Avena fatua* and *A. barbata*), and there is also an ambiguous species at the genus level (e.g., *Avena sp.*). In this example, *Avena sp.* is almost certainly an ambiguous form of *A. fatua* or *A. barbata* and should not be treated as a separate species. Solutions to this problem include 1) lump all members of the genus *Avena* into "*Avena sp.*", 2) delete *Avena sp.*, and leave the two *Avena* species, and 3) distribute the *Avena sp.* entries to the two species (if it's possible to reliably determine which species *Avena sp.* was at each plot it occurred on).

The next step after formatting data is to perform cluster analysis on the plot*years to determine which plot*years have the most similar vegetation to each other. This is the state-and-transition classification process. Ideally, there are enough plots occurring in each ES, that it is possible to

break the vegetation data into groups of plots classified as each ES and perform the cluster analysis on the ES subsets of the total plot data. This is an important step because the purpose of classifying ESs is to find plots with the potential to produce similar kinds and amounts of vegetation. Thus, a cluster analysis based on just the plots in a given ES identifies vegetation patterns within the range of variation observed for that site. Although species percent cover data can be used for this classification, we recommend using presence/absence data for the following reasons:

1) Using percent cover data (instead of binomial data) can over-emphasize the importance of common species. It is difficult to find an objective reason for data transformations (such as square-root or cube-root transformations) to increase the importance of less-common species.
2) Line-point sampling often misses small-statured or uncommon species that may be important indicators of different vegetation states. If relying on ocular estimates, then the cover estimates are subject to observation bias. Binomial data are more reliable by comparison.
3) In the GMPPP, we found that presence of a given species in a class (e.g., "state") often is correlated to high percent cover for that species in that class (Bartolome et al. 2024).

Cluster analysis for state-and-transition classification can use similar methods to that of the ES classification. Bray-Curtis distance, with a flexible beta linkage method is a common approach (Ratcliff et al., 2018, Spiegal et al. 2014). The same three methods used to trim the dendrograms in the ES classification can be used to determine the optimal number of clusters in the State-and-Transition classification: a Mantel Test (Borcard et al. 2011), indicator species analysis (Dufrene and Legendre 1997), and visual inspection of the cluster dendrograms.

The resulting clusters represent vegetation states associated with each ES.

Drivers of Transitions. Transitions occur when vegetation on a given plot changes from one state to another. There are different ways to infer what caused these transitions. A good starting point is to gather all available temporal data for the study plots over the course of monitoring, including weather records, management records (including grazing timing / amount), and records of disturbances (fire, flooding, etc.). With these data in hand, it is possible to look at when and where transitions took place to identify whether any of the potential drivers are systematically associated with transitions. There are also quantitative methods that can be used to decipher these relationships, such as: classification trees (CART analysis) and Random Forest Analysis. The advantage of CART analysis is that it shows which variables are associated with specific transitions. It may take several years of monitoring data before there are enough transitions in the vegetation dataset to detect drivers of transitions.

Monitoring

While conservation monitoring programs must be tailored to resources and questions, ESs and STMs provide a framework for developing conservation-oriented monitoring and prioritizing sites for monitoring. Conservation goals and objectives will determine which ESs should be prioritized. For example, goals and objectives for California gnatcatcher conservation would lead to monitoring of ESs that support STMs with California sagebrush and flat-topped buckwheat. Monitoring the recovery of burned CSS for California gnatcatcher habitat would likely entail

quantitative monitoring of shrub composition, cover, and demography across these ESs. For other conservation goals and objectives, qualitative or presence/absence monitoring may be adequate to determine if objectives are being met.

Adaptive Management

The first section of this report discussed the importance of clearly-defined goals and objectives that reflect the mandates and conservation values of the implementing agency as well as the realities of ranching in heterogenous and unpredictable conditions. The paired ES and STM framework provides a lens with which to interpret and fine tune objectives and performance standards. The ES/STM framework can help answer questions like:

1) Which ESs do the management objectives apply to? In which ESs are the objectives likely to be attainable?
2) What types of management strategies can optimize attainment of objectives in each ES?
3) What are the constraints posed to grazing management in each ES? How might this affect the rancher's ability to implement strategies to achieve management goals?

Answering these questions will lead to fine-tuning the management objectives, performance standards, and management strategies. In a sense, the ES/ST models provide a filter showing ***what*** goals and objectives are most appropriate for ***where*** on the landscape, and ***how*** management can be used to increase the probability of achieving the objectives. These ES-informed objectives, performance standards, and management strategies then form the basis for future monitoring.

The process outlined above is the first step in adaptive management. Adapting goals and objectives based on insight from the ES/ST models will help tailor goals and objectives to situations where they are most relevant and will lead to the development of more effective management strategies. ES-informed goals, objectives, and performance standards provide the basis for developing monitoring strategies that answer the basic question of whether or not our management activities are meeting our performance standards. They will also help answer the follow-up question of *why* we are or aren't meeting these standards.

Example of using the ES/STM framework to hone goals and objectives and to create management strategies:

1) Start with a (hypothetical) management goal: *use livestock grazing to enhance disturbed native grassland and forbland habitats.*
   a. Associated with this goal is the following objective: *reduce nonnative grass cover and height and increase forb cover and bare ground to improve habitat for burrowing owls.*
   b. If specific grazing management related habitat criteria are known for burrowing owl (BUOW), they may be listed as performance standards (e.g., *reduce visual obstruction height of vegetation to <6 inches in occupied habitat, reduce absolute cover of annual grasses to < 60%*).

2) Now let's say that (thanks to the ES model) we know that burrowing owls are known to only inhabit alluvial and low-slope sites with granitic soil parent material. Monitoring for BUOW habitat conditions might then focus in these areas.
3) If the initial ES/ST models show that grazing has little effect on species composition and percent cover within these ESs, then the performance standard may need to be revised to something achievable by management. The new performance standard could include only the standard associated with height (not composition).
4) Furthermore, if production in these sites is known to be very high under certain annual weather patterns (resulting in unfavorable BUOW habitat conditions), management strategies should incorporate increasing grazing intensity in these areas when conditions require it. However, knowing that cattle herd sizes can only be incrementally increased each year, and that there may be other resource demands on the rancher, the land manager should have back-up options (such as line-trimming) for managing vegetation height in specific areas.

If we possessed perfect information about the ecology of our system, the effects of management on target resources, the effectiveness of performance standards to indicate progress towards meeting management objectives, or even the appropriateness of our goals and objectives, then we could simply evaluate whether performance standards are being met and judge and adapt our management program accordingly. If (as is generally the case) we possess incomplete knowledge about these factors, or the systems we're managing are strongly influenced by unpredictable exogenous factors like fire and precipitation, then monitoring gives us the opportunity to improve our understanding of ecosystem dynamics and the role of management and to adapt our objectives, performance standards, management strategies, and monitoring practices going forward.

In this sense, the ES/ST model framework is at the heart of adaptive management. Thankfully, both these models are easy to update, and in the case of STMs, they are based on adaptive principles. STMs are fundamentally catalogs of known information. As monitoring generates more information (through adding new monitoring plots or monitoring existing plots over time), these models will adapt to provide better classifications of vegetation states and more descriptions of drivers of transitions. Thus, STMs should improve over time and provide an improved basis for management decision making.

The burrowing owl provides an example of how these adaptive principles could be applied. After 5 years of monitoring, it might become apparent that burrowing owls in your study area do not use burrows when vegetation is above 4 inches of obstruction height in the burrow vicinity in the spring breeding season. Our understanding of BUOW ecology will be amended to say they prefer vegetation obstruction heights <4 inches. At the same time, if the updated STMs show that in the alluvial ES of the study site, plots with less than 2000 lbs/acre of residual dry matter tend to fall into a vegetation state defined by having less annual grass cover and more forb cover and bare ground (a state thought to be more favorable to BUOW), then the ST model should be updated to include information about residual dry matter as a driver which can be controlled by grazing. With this knowledge, we can update our performance standards for management in these areas to the following: *maintain spring obstruction height in the vicinity of BUOW at <4 inches and keep fall residual dry matter in these areas < 2000 lbs/acre*.

In order for monitoring to be useful for adaptive management, it needs to simultaneously address the conditions resulting from management, and also the key areas of uncertainty in the management system. We should not just ask *what do we know and how can we use that to achieve our management goals?* When managing in the face of uncertainty, we should also ask: *what key uncertainties undermine our ability to use management tools to achieve our goals and objectives, and how do we reduce this uncertainty?* If our monitoring does not answer these questions, then we will continue to apply misguided performance standards and base management decisions on flawed ecological models. However, this means that monitoring methods must be tailored specifically to management objectives and include methods that can produce reliable information about key areas of uncertainty.

Summary

Conserved rangelands in San Diego County are characterized by high spatial diversity in soils and topography as well as strong influences from stochastic exogenous factors such as weather and fire. These factors largely shape vegetation structure and function on conserved lands and can strongly influence conservation outcomes. Livestock grazing is potentially a valuable tool for meeting conservation goals on conserved lands, but spatial and temporal variability create substantial uncertainty about the impacts of grazing on plant composition and structure and about the ability of grazing to meet conservation and other management goals. Adaptive management is an effective strategy for conservation management in the face of uncertainty, but to be effective, adaptive rangeland management should incorporate the following aspects:

1) Clearly-defined goals, objectives, and performance standards
2) Ecological models that situate grazing impacts in the context of site factors and weather, preferably defined at the scale of the preserve (or ranch)
3) Monitoring techniques that evaluate conditions relevant to management practices, management objectives, and performance standards

The field sampling and analysis methods listed in this document provide an example for how to develop ecologically based management models. However, there are other conceptual approaches that can also create useful models to guide management. No model is perfect; it is instead a case of finding the model with the best fit for the purpose. It is appropriate to approach management with an open mind, ready to update or improve the management model as more information is generated about the system. In this regard, the ES and ST modelling framework is ideal as it is easy to update when new information becomes available.

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