Point Blue

The Rangeland Monitoring Network:
Handbook of Field Methods

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About the Cover

Cattle grazing in Shasta County, California, in May 2015. Photo credit: Alicia Herrera.

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INTRODUCTION

This handbook provides the Rangeland Monitoring Network (RMN) protocols for sampling soil, vegetation, and wildlife on rangelands. Developed by Point Blue Conservation Science, the RMN provides tools, data, and people that assist ranchers, researchers, and conservation planners and partners in collecting data that expands our knowledge of rangelands and ranching practices.

Rangelands are one of the most extensive global terrestrial land types, encompassing an estimated 28% land cover (Millennium Ecosystem Assessment 2005). This large extent and the value they provide to people makes rangelands economically, socially, and environmentally important. These lands support numerous and diverse plant and animal species and provide natural resources such as water and soil. Rangelands also provide livestock forage, recreation opportunity, open space, and natural beauty. In California alone, rangelands make up over 40% of the land area and include grasslands, deserts, oak savannas, riparian areas, and wetlands (Brown et al. 2004). They provide critical habitat to common, rare, and endangered species, and support a 3 billion dollar cattle industry (USDA 2012).

Rangelands are threatened by urban development and conversion to agricultural crops (Cameron et al. 2014, DeLonge et al. 2014). In California, 45% of the 40 million acres of grazed land is privately owned (CDFFP 1988). Between 1984 and 2008, an estimated 195,000 acres of a 13.5 million acre subset of rangeland in California were converted to other uses (Cameron et al. 2014). With this conversion, many of the ecosystem services these lands can support, including water capture and storage and wildlife habitat, are degraded or lost. In addition, rangeland soils can make a major contribution in the capture and storage of carbon, and conversion of these lands to other uses jeopardizes this biogeochemical cycle (Silver et al. 2010). Given the extensive geography of rangelands, and the threats they face, there is an interest in better understanding the ecological values of rangelands and how they can be maintained, altered, or enhanced by grazing practices.

About the Rangeland Monitoring Network

Monitoring is central to evaluating the effectiveness of management practices. At the scale of an individual pasture or ranch, monitoring helps landowners understand how their land is changing. By providing a standardized yet flexible methodology that captures key components of ecological function, the RMN offers landowners data for use in management decision making. By applying this same methodology at multiple locations, the RMN also generates information that can be used by ranchers, rangeland managers, researchers, conservation planners, and other partners to improve management and stewardship of rangelands. The network is open to participation by anyone managing or working on rangelands. The monitoring network does not assign management or experimental treatments; rather, it relies on the variation in geography and practices to determine the scope and scale of inference.

About this Handbook

Handbooks are useful resources because they provide background information, rationale and study design, references, and written methodology. Handbooks are key components of data standardization, particularly for large scale and long-term monitoring programs.

There are many excellent handbooks and resources on rangeland study that have guided the development of this handbook and provide informative further reading, in particular, *Measuring Soil Carbon Change: a Flexible, Practical, Local Method* (Donovan 2013), *Monitoring Manual for Grassland, Shrubland and Savanna Ecosystems,* Vols. 1 & 2 (Herrick et al. 2005 a & b), and the *Soil Quality Test Kit* (NRCS 1999). This handbook is not designed to replace these other resources, but instead is designed to describe in detail the sampling protocols used for the Rangeland Monitoring Network.

This handbook is designed to take Rangeland Monitoring Network participants step-by-step through the monitoring process.

MONITORING OBJECTIVES

One of the first steps in establishing a monitoring program is to identify why monitoring is needed and what needs to be measured. Establishing monitoring objectives articulates the purpose of monitoring and in doing so, guides the development of monitoring metrics and sampling design (McDonald-Madden et al. 2010, Hutto and Belote 2013). The Rangeland Monitoring Network is focused on the concept of **ecological function**, which simply put is **the capacity of rangelands to support life.** This function includes the flow of energy from the sun into terrestrial ecosystems and the capture and cycling of water by soil and organisms. Rangeland ecological function generates plant productivity, sequesters carbon in the soil, supports robust wildlife populations, and can be viewed as a key factor in financial and ecological sustainability. Within this context, the principle objectives of the RMN are to:

Measure the spatial variation in ecological function on rangelands. To date, data are lacking on the range of spatial variation in the ecological function of rangelands, and this continues to be a major hurdle in understanding the outcomes of land management decisions. Measuring spatial variation in ecological function will help managers and scientists understand and document the outcomes of rangeland management and identify ecological indicators that can guide management. Metrics and methods should be applicable across a wide geography and provide a means for placing local measurements into regional context.

Identify relationships between management practices and ecological function of rangelands. By aggregating data across many properties, variability in ecological function can be associated with historical and current management practices. This will allow us to generate hypotheses about the effects of management practices that can be tested with focused research, carefully controlled experiments, and long-term monitoring. Metrics should capture aspects of ecological function that are expected to have been influenced by historical land management.

Establish a baseline that can be used to understand how ecological function on rangelands changes over time. By having a network of sites with standardized monitoring protocols in place, the RMN will establish a benchmark that can be used to understand short-, mid- and long-term patterns in ecological function. This information will help understand the outcomes of grazing management and other practices. Metrics should capture aspects of ecological function that we expect will change in response to management.

Provide ranchers and other stewards of the land with the tools to monitor ecological function on California rangelands. The tools of the Rangeland Monitoring Network have been designed for use by a wide range of users. The RMN metrics are relatively simple and inexpensive to use, and include clear and well-documented protocols, and a data-entry platform. These tools were designed to facilitate monitoring by many people across a large geographic area, and this facilitates larger scale assessment and comparisons among varied management histories and current practices.

How to Measure Ecological Function? An Overview of Metrics

Given the objectives of the RMN, we identified metrics that most efficiently capture major components of ecological function and can be measured relatively easily in a repeatable, standardized way. To identify metrics for the RMN, we considered a large number of potential techniques and metrics. Within the context of our objectives, we recognized that 1) soil is the engine of life on rangelands, 2) plants convert solar energy into organic compounds that can be used by organisms that cannot make their own food supply and 3) wildlife respond to the flow of energy and water through rangeland ecosystems. As a result of this work, we have identified five metrics related to ecological function that form the base of the RMN and relate these metrics to grazing management (Figure 1).
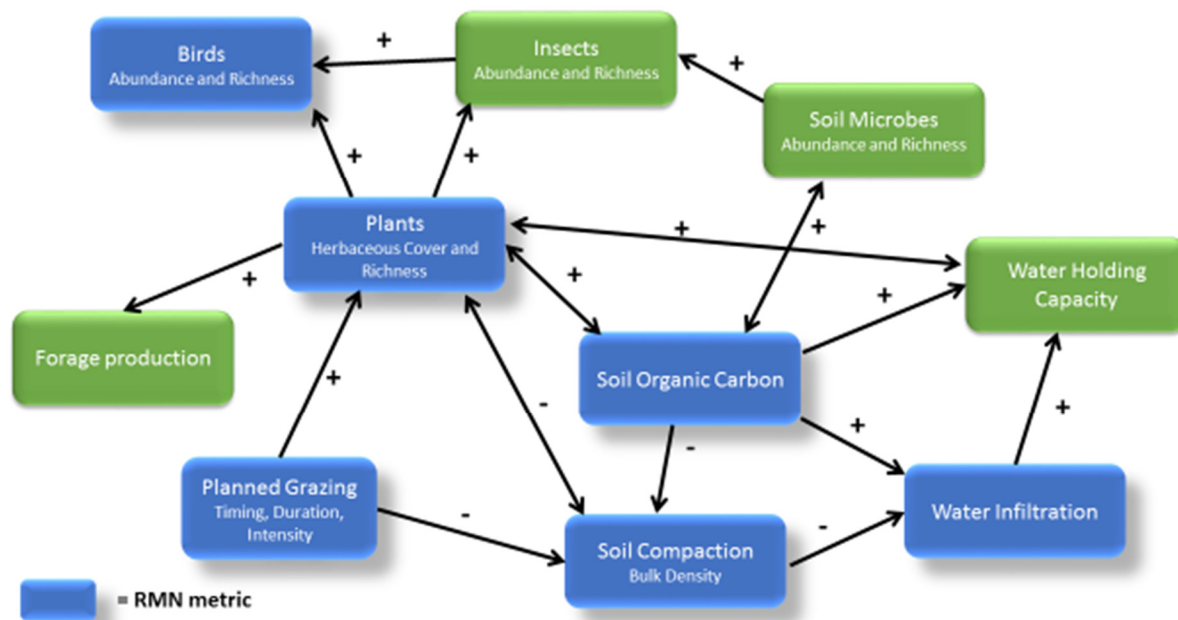

Figure 1: Hypothesized relationships between RMN metrics (blue) and other ecosystem components (green).

For the purposes of the Rangeland Monitoring Network, we define rangelands as areas where domestic and/or wild animals graze or browse. We focus on a subset of rangelands where grasses

and forbs are a principle component of vegetation cover and trees and shrubs can also be present; for example, oak savannah, oak woodland, grassland, chaparral, and coastal prairie and scrub are the primary plant communities in the RMN. The vegetation on rangelands can be managed with many tools, including variation in the timing and intensity of grazing, burning, rest, and/or mowing (Appendix 1A).

Soil. On rangelands, soils capture, retain, and release water from rainfall and snowmelt, provide nutrients and structure to support the germination and growth of plants, and sequester carbon from plant material and exudates. Soil properties can be classified as either inherent or dynamic. Soil inherent properties remain relatively constant over time and are not capable of being changed by management practices. Inherent soil properties include, texture, (percentage of sand, silt, and clay) and mineralogy. Dynamic soil properties depend on inherent properties as well as land use or management and thus can be altered over time (Doran and Jones 1996).

We monitor three soil dynamic properties:

1. **Water Infiltration.** Water infiltration is the process of water entering the soil. Infiltration rate is a function of soil texture, soil structure, and soil water content, and it can be impacted by plant roots, grazing practices, and other activities that impact the soil (Abdel-Magid et al. 1987, Lal 1998). Measuring water infiltration allows us to relate the ability of land to assimilate water to variation in vegetation composition, soil carbon, and management practices (e.g., Russell et al. 2001).
2. **Bulk Density.** Bulk density is the dry weight per unit volume of soil, and is a measure of soil compaction, or how tightly soil particles are packed together. Compacted soils have reduced pore space for water infiltration, water retention, root growth, soil aeration, and seedling germination (Lal 1998). Like water infiltration, soil compaction can be influenced by the physical impact of grazing animals (Trimble and Mendel 1995). Measuring soil compaction allows us to evaluate its relationship with management, plant community composition, and other covariates (e.g., soil type).
3. **Soil Organic Carbon.** Productive soils have an abundant microbial community that contributes to high levels of soil organic matter (Nielsen et al. 2011). Soil organic matter (SOM) is a primary organic source of carbon in soil, has a high capacity for storing water, and plays a key role in soil stabilization (Tiessen et al. 1994, Schmidt et al. 2011). Measuring the percent of organic carbon in soils across the RMN informs our understanding of the spatial variability in soil carbon and generates hypotheses about the effects of management practices on soil carbon (e.g., McSherry and Ritchie 2013).

There are a many excellent soil textbooks and references available. We recommend Doran and Jones (1996) and Brady and Weil (2007) for further background reading on soils and measuring soil quality.

Vegetation. Plants convert sunlight into biomass, produce forage for livestock and other herbivores, and provide habitat for wildlife. Assessments of vegetation cover and composition provide information about how vegetation communities and cover vary across rangelands and how they relate to variation in land use practices, livestock production, and wildlife diversity and abundance. Particular interests are soil cover, invasive weeds, vegetation structure, and variation in functional groups (Gondard et al. 2003), especially annual and perennial plants (Henneman et al. 2014).

Birds. Among terrestrial wildlife, birds serve as an excellent indicator group because they are high on the trophic system, have diverse life histories, are sensitive to environmental variability, and are relatively easy to study (Mac Nally et al. 2004). In addition, birds provide ecosystem services such as insect control, pollination, and seed dispersal. Monitoring birds across the network of rangelands in concert with the above metrics provides an understanding of the relationship between physical ecosystem processes, plant community composition, and avian abundance and diversity (Henderson and Davis 2014).

Other important sources of variation. While the primary focus of the RMN is to understand the relationship between the ecological metrics described above and grazing management across space and through time, there are other factors that are responsible for substantial variation in this system. In particular, geographic variation that can be captured from a digital elevation model (e.g., slope, aspect and elevation), and soil texture are important covariates and are also measured.

DELINEATING THE AREA TO BE MONITORED

The RMN monitors lands that are owned by private individuals, land trusts, the state and federal government, and non-governmental organizations. These areas are not a random sample of rangelands, but instead reflect the distribution of landowners interested in the data generated by RMN. RMN study areas include areas with and without active grazing by livestock as well as lands that are subject to other management practices such as planting, mowing or burning. Even though properties vary in size from a few hundred acres to several thousand acres, it is often useful to think about rangeland ecology on the scale of the ranch because areas under the same ownership are often managed similarly. That said, this sampling design allows scaling of inference from the point to the pasture, ranch, watershed, or region. The process for selecting sampling locations on a ranch is described on page 9.

RECORDING GRAZING PRACTICES

Understanding the relationships between livestock grazing and ecological function is one of the principal objectives of the RMN. Grazing management is described by the type, class, and number, as well as the temporal and spatial distribution of animals (Heitschmidt and Taylor 1991).

In order to translate current grazing strategies to metrics that can be related to ecological function, we collect a summary of grazing management annually. Specifically, we record each animal class on the entire ranch, and for each animal class, we record their frame class (cow and pairs only) number of animals, calendar months grazed and primary grazing strategy. For more information, please see the data form which is available in Appendix 4.

SAMPLING DESIGN

Identifying Point Count Locations for Bird and Vegetation Monitoring

Point Count locations for the RMN are identified using the Generalized Random Tesselation Stratified (GRTS) approach. GRTS is a commonly used and useful tool for selecting a set of spatially-balanced and random samples. Survey locations are selected using a 250 m square point grid. The point grid sampling frames were derived from the Military Grid Reference System (see https://griffingroups.com/groups/profile/39935/mgrs-and-usng-grid-standards for a discussion and resources on grid standards in bird monitoring). The R package 'spsurvey' was used to pull the GRTS selections (R Core Team 2015, Kincaid and Olsen 2013). We recommend excluding points from areas within 100m of management boundaries and riparian areas or dense scrub or chaparral. Additional points can be set up in the riparian for other monitoring goals, but the RMN is primarily focused on upland habitat. The number of points chosen for each GRTS selection should be a function of management unit or property size and logistical feasibility given the amount of time each biologist has to devote to point counts. We estimate that a biologist can survey 10-15 points in hilly terrain and 15-20 in flat terrain on a given morning. For each GRTS selection, the desired number of points can be specified as well as a list of 'over samples,' thus the biologist can use oversample points if any of the primary points are not accessible.

For step by step instructions on how to create sampling points, please see Appendix 2.

Choosing Soil Sampling Locations

The three RMN soil metrics can be affected by land use and management, but they also vary by inherent soil characteristics. In particular, soil texture (the percent sand, silt, and clay) and topography (e.g., slope, aspect, catenal position) can play a substantial role in water infiltration rates, bulk density, and organic carbon concentrations. Thus, any correlation between management practices and soil dynamic processes must be interpreted in the context of these inherent soil characteristics and identifying sampling locations should be done with this in mind.

Soil sampling sites are chosen from a subset of the bird point count locations. The overall goal is to choose a set of sites that are representative of the majority of the ranch with respect to soil type and management. Secondary goals include choosing sites that are balanced across the dominant vegetation types present on the ranch (e.g., grassland and oak woodland). Sites are not chosen specifically by topography, although slope is a component of soil series delineation; instead these characteristics are included as covariates.

The process for choosing at which of the point count locations to sample soils uses the following guidelines, and is further tailored to each ranch according to the interests of the landowners and land use:

- Sampling should focus on dominant vegetation types. Unique vegetation types, such as those in riparian areas (within 100 m of a waterway), should be excluded.
- Soil sampling locations should be representative of the dominant soil series (summing at least 75% of the land cover) on the property. At least one soil sample should be collected in each of the dominant soil series. If the number of dominant soil series on a property exceeds the number of sites that can be sampled at a ranch, sample at least one point in each texture category (e.g., if there are several series that are clays, they can be combined).
- Select points that are representative of major management practices. For example, if half of a ranch is continuously grazed and half of the ranch is in extensive rotation, make sure to get at least one sampling point in each grazing system. If possible, make both of these points in the same soil series or texture category.
- Consider sampling in areas of special interest. These can include areas that will have upcoming changes in management, including changes to the grazing system, vegetation management, or compost addition.
- Try to avoid sampling points that are within 50 meters of a fence line or water trough.
- If several points are equivalent in the above respects, choosing between them can be randomized using a variety of methods, or may be selected based on other logistical constraints (e.g., accessibility, or minimizing travel time between points).

Below is an example that is representative of many of the ranches where we work. In this example, there is a four pasture extensive rotation. Based on the above guidelines, we would make the following choices about which points to sample:

- We would not sample points 15, 16, 18, 19 because they are within 100 meters of stream (meaning they are in riparian areas that are not a dominant vegetation type or soil type).
- We would sample the Bolinas sandy loam, Arroyo cobbly clay, and Chamaea clay series because they represent the majority of the soils on the ranch
- We would sample in each of the four pastures

Based on this and assuming there aren't any additional considerations (e.g., infrastructure or treatments), we would sample Point 1, either Point 4, 5, or 6 (chosen randomly or for logistic considerations), Point 10, and either Point 13, 14 or 12 (chosen randomly or for logistic considerations).

Legend:

	= fence line
★	= point count location
〜	= riparian
(yellow)	= Arroyo cobbly clay, 10-30% slope
(light green)	= Bolinas sandy loam
(orange)	= Arroyo cobbly clay, 10-30% slope
(olive)	= Chamaea clay
(blue)	= DiGaudio complex
(dark red)	= Dogtown loam
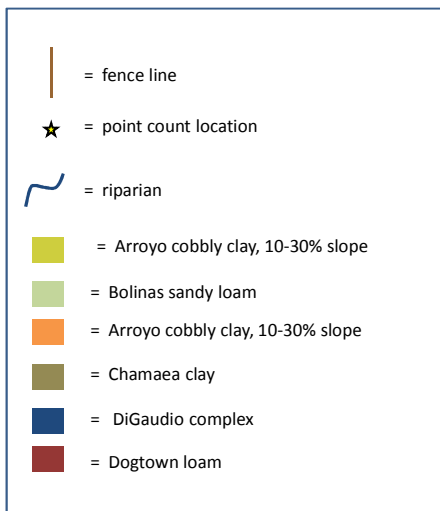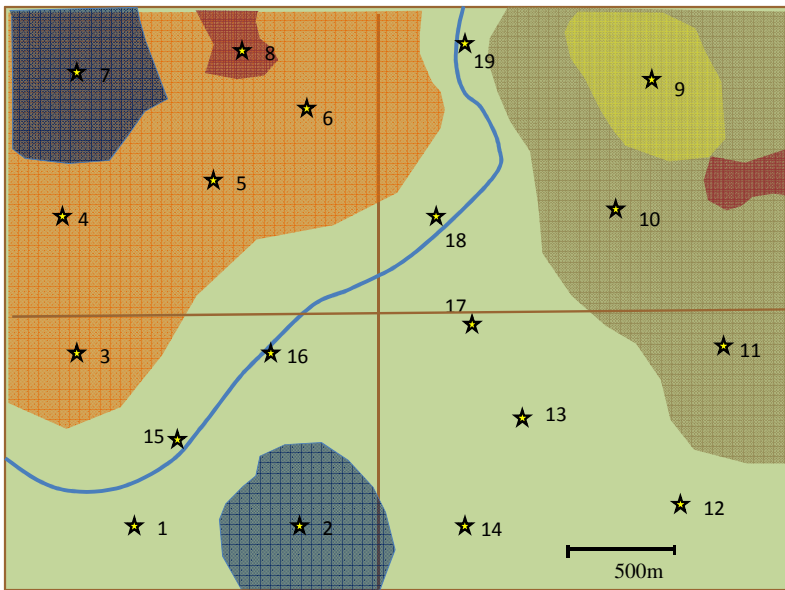
SOIL SAMPLING

Assembling the Soil Sampling Kit

One of the aims of our soil sampling protocol is to utilize equipment that is simple to assemble. Most of the equipment can be purchased from a hardware store. For soil probes, we recommend a simple step probe, which can be ordered from a number of online retailers. If a step probe is not available, a hole can be dug with a sharpshooter shovel. If PVC pipe is used to make the infiltration and bulk density rings, the edges can be beveled with a grinding or chiseling power drill attachment. Alternatively, steel rings can be custom made by a machinist or purchased from a scientific supply company.

Soil Sampling Protocol

Equipment

For the Field:

Single ring infiltrometer – 15.2 cm diameter, 15.2 cm depth
Clear plastic or glass water bottle, with 450 mL volume delineated
Plastic wrap or plastic sheet
Stopwatch or timer
Water – 2.5 gallon plastic container liters
Bulk density rings – 5.1 cm diameter, 7.5 cm depth
Hand sledge or rubber mallet
Wood block
Garden trowel
Flat blade knife
Sealable quart-sized bags and sharpie
2   5-gallon buckets (optional)
Soil probe – 40 cm length
Sharp shooter shovel
Bare ground quadrat (see below)
GPS with spare batteries
Compass
Small ruler (cm)
Data sheets
Clipboard or data binder

For the Lab:

Scale – accurate to 0.1 g
Mortar and pestle
1 inch paint brushes
2mm mesh sieve
Drying containers -3 in x 2in x 2in
Graduated cylinders – 50 &100mL
Buckets or dish pans
Oven – conventional or microwave

Before you go in the field:

1. Generate a list of random distances and directions every 3 to 4 days of sampling. There are a number of ways to do this. We create the list in R using the following code:

```
a<-round(runif(50, 0, 50))
b<-round(runif(50, 0, 359))
c<-data.frame(a, b)
write.csv(c, file.choose())
```

2. Measure the diameter of your infiltration ring and the diameter and height of your bulk density ring to the nearest 0.1 cm. Record on data forms.

3. Build a bare ground square quadrat (pictured at right). A quadrat can be assembled using 1-inch PVC pipe and string. The quadrat should have 9 strings on a side, totaling 81 intersections that are spaced 2 inches apart. The inner dimension of the frame is 18 inches.
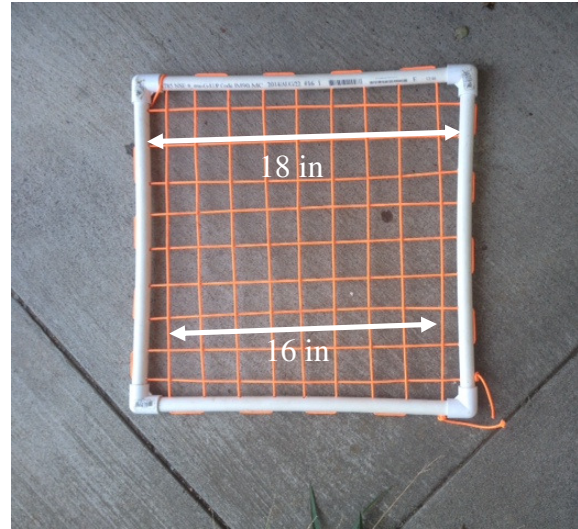
In the Field:

Soil sampling will occur within a 50m radius of point count locations. At each point count location identified for soil data collection, sampling sites will be randomly identified and a minimum of 5 water infiltration, 5 bulk density and 5 soil carbon samples will be taken. Additional samples will be taken as time allows. Soil carbon samples will be bulked, mixed, and resampled on-site such that 1 sample will result from each location but it will represent an aggregate of the area within 50 m of the sample location.

The soil data sheet is broken down into two sections: Site characteristics which are to broadly describe the 50 m radius plot around the point count location, and the sample data which describe each of the individual sample sites within the plot.

AT EACH POINT COUNT LOCATION:

1. Locate point count location that is the center of the 50-m radius plot. Record the point count location code at the top of the data sheet.

2. Location Description: Write 2-3 sentences describing the location, paying particular attention to note any evidence of livestock grazing. Livestock grazing information will be collected from the land-manager, but it is good to also check for grazing evidence while in the field. Walk around the 50-m circle and look for evidence of recent grazing. The most obvious sign of grazing (outside of livestock being present) is manure. Be aware that manure (especially cow pies) can persist for a year or more, so the presence of severely dried manure may not be evidence of recent grazing. Also, livestock may concentrate their manure in areas where they rest and therefore little may be present in the circle even if recent grazing occurred. Other evidence is trampling of vegetation and plants that have been bitten. Livestock will trample vegetation and lay plant material on

the ground. If grasses and plant material from the most recent growing season are lying on the ground (not standing up) over large areas of the circle, this may be evidence of recent livestock presence. Numerous bitten plants may also be evidence of recent livestock or wildlife grazing, so be cautious about using this evidence alone. If you are uncertain, describe clearly in the notes.

3. Record the size of the infiltrometer and bulk density rings used as well as the volume of water used for infiltration for the samples at the point. Make special note in the location description of any tools that you use that may differ from the standard sized tools outlined in the equipment list above.

4. Locate soil sampling site: Using a list of random directions and random distances, identify sampling points. If the point is unsuitable (e.g., due to large boulders, etc), select a new sampling point.

AT EACH SAMPLE SITE: The following measurements are taken at each of the 5 sample sites within a 50 m radius of a point count location.
The grey fields on the data sheet and in the following instructions indicate measurements that are done in the lab. All other fields should be recorded in the field.

1. After determining a sample site, record the sample number (1 through 5) on the data sheet. Record the distance (in m) and the bearing of the sample site in relation to the point count location.

2. Bare Ground. At each site, lay the quadrat grid flat on the ground. If vegetation is tall, try to work the plants through the grid, as opposed to the grid flattening the plants on the ground. Looking directly down at the grid, count the number of intersections of string that overlay bare ground. Record this number on the data sheet. This should be a whole number (0-81).

3. Litter depth. At each site, measure the depth of litter at 3-5 locations within the bare ground sampling grid and record the average of these measurements. Litter is dead plant material that is more or less lying on the ground; standing straw is not included; thatch that is laying on the ground and acting as litter should be included. Litter depth can be recorded to the nearest 0.1 cm.

4. Catenal Position: Record whether the sample site is on the crest, shoulder, midslope, footslope or bottom.

Crest

Shoulder

Midslope

Footslope

Bottom
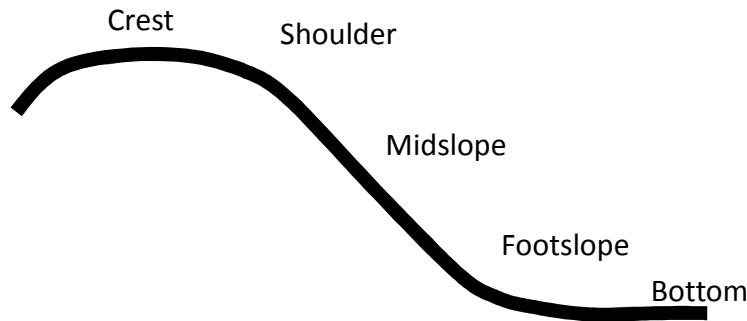
5. <u>Water infiltration</u>. Our protocol for water infiltration is based on the NRCS (1999) protocol. We take one infiltration trial. While the NRCS (1999) protocol specifies two trials, we found the first and second trial to contain much of the same information (Porzig et al. *in press*) so only perform the first trial.

    a. Clear litter from the surface of the soil.
    b. Insert the 15.2 cm diameter ring ~5 cm into the ground. Be careful to apply even pressure. Use wooden block and hand sledge if necessary.
    c. Lay plastic sheet inside ring covering inner walls and extending out of the ring.
    d. Pour 2.5 cm water (450 mL for a 15.2 diameter ring) into ring, on top of plastic wrap.
    e. Carefully and quickly remove plastic wrap, making sure all water remains within the ring, and start timer.
    f. Wait until approx 95% of the water has sunk into the soil; record end time. If infiltration is slow, it can be difficult to be confident of the exact time to stop the timer. 5% of 450 mL is 22.5 mL. You can measure this amount out in a graduated cylinder in the lab to improve your estimate of the finishing time.

If infiltration is very slow such that there is still water in the ring after 45 min, stop the timer at 45 min and measure the height of the remaining water. Extrapolate the infiltration time using the equations on the 'slow water infiltration' worksheet, on page XX. Record the <u>extrapolated time</u> in "Infiltration Time" column, don't simply record "45 mins". Document the depth of water at 45 mins in the notes field for any of the sample numbers that need to be extrapolated.

6. <u>Bulk Density.</u> Our protocol for bulk density is based on the protocol in NRCS (1999). In the field:
    a. Identify sampling point, within 1 m of water infiltration location.
    b. Remove vegetation, loose litter and duff, being careful not to remove surface soil, or disturb soil crust.

   c. Insert ring (5.1 cm diameter, 7.5 cm high) until top of ring is level with surface. Be careful to apply even pressure. Use wooden block and hand sledge if necessary.

   d. Excavate ring using trowel. Lift ring out using trowel underneath it to ensure no loss of soil.

   e. Use flat blade knife to level soil with bottom of ring.

   f. Place soil in sampling bag and label with the ranch code, point count location, the sampling site number, and date.

   g. Make sure bag is sealed completely.

   h. **As soon as possible after sampling:** weigh sample, subtract bag weight. Record weight under 'wet weight.' This can be done in the field if a field scale is available, or that evening. Note, that different types of plastic bags can have very different weights – make sure to subtract weight of exactly the same bag.

   i. After the wet weight is taken, open bags to air dry sample.

In the lab: (See section on pg. 19 for more detailed directions for processing soil for bulk density in the TomKat soil lab.)

   a. Grind sample. If sample is very wet, such that you cannot grind and sift it, you can pre-dry it in a microwave for several 2 minute cycles or an oven at 200°F for 3-5 hours. If microwaving, be extremely careful that the sample does not start to burn.

   b. Sift sample using 2mm mesh sieve, keep rocks separately. For very large pieces of plant material that are not ground up and cannot pass through the 2mm mesh sieve, keep with rocks.

   c. Dry in microwave for 2 minute cycles or oven for 24 hours until the weight doesn't change after drying. If microwaving, be extremely careful that the sample does not start to burn.

   d. Weigh again, record weight to the nearest 0.1 gram.

   e. Weigh rocks (and large plant material, if applicable), record weight to the nearest 0.1 gram.

   f. Calculate volume of rocks (and large plant material, if applicable) by filling a graduated cylinder half way with water, inserting rocks and recording volume displacement in mL.

   g. Bulk Density (g/cm^3) = $\dfrac{\text{oven dry weight of soil}}{\text{(volume of bulk density ring)} - \text{(volume of rocks)}}$

7. <u>Soil Carbon.</u> Our protocol for soil carbon is based on the protocol in Donovan (2013). Our decision to sample soil carbon at 0-10 cm and 10-40 cm depths is justified in Appendix 1E.

Soil samples obtained in the following manner will be sent off for carbon and texture analysis.

    a. Remove vegetation, litter, and duff, to mineral soil, being careful to not remove the surface soil, or disturb soil crust.

    b. Using soil probe or shovel to dig a pit, take soil sample to 10 cm. If using soil probe, take a couple of samples at each subsample site because you will need at least 100 g of soil per sample site for soil carbon analysis and 300-400 g for carbon and particle analysis. Repeat the process for the 10-40 cm depth.

    c. Keep samples from 0-10 cm and 10-40 cm in separate buckets.

    d. Record the maximum depth of sampling. This should be 40 cm, but in some cases (e.g., shallow soils), it will be less.

    e. Repeat this process at 5 sample sites within 50 m of the point count location. For each of the two depths, all subsamples from the 5 sites should be bulked and mixed together and a sample taken from the composited subsamples.

    f. Bag the composite sample from each depth and label each with the date, ranch code, point count location, core depth, and number of sampling points. Each bag should have soils from 5 sites.

    g. **Before the samples are shipped to the soil lab, open bags to let samples air dry**

Measuring Soil Carbon

We recommend measuring organic soil carbon with the dry combustion method. Dry combustion involves heating the sample up to about 900°C and measuring the combusted CO_2 via gas chromatography. An acid pretreatment will remove any inorganic carbon. This method can be performed by many soil analytical labs. Other methods, such as Loss on Ignition or the Walkey Black method are less accurate. See Appendix 1E and Donovan (2013) for further discussion.

Slow Water Infiltration Worksheet

What to do when infiltration time is taking forever . . . In four easy steps

i.   Stop the clock at 45 min, and measure the depth of the remaining water. To measure the depth on an uneven surface, take a series of 5 measurements to the nearest 0.1cm around the infiltration ring, and average the total to get the overall water depth.

ii. Calculate how much water has infiltrated in 45 min:
     Water Infiltrated = Total Water (2.5 cm) – Water Remaining

iii. Calculate the volume of the water infiltrated using

$$Volume = \pi\, r^2 * h$$

Where π =3.14, r = radius of the ring (7.6 cm) and h is the height of the water that has infiltrated.

iv. Using this equation, cross multiply to solve for Extrapolated Time. Round to the nearest whole minute.

$$Extrapolated\ time = \frac{45\ \text{min} * 450\ mL}{Volume\ infiltrated}$$

Processing Bulk Density Samples in the Lab

1. Organize the soil samples by point on the shelves. Every point should have 5 samples.
2. When you're ready to process the soil, take all soil samples corresponding to a point from the shelf. Label a baking pan for each of the samples with the point name and sample number. (Ex. SABE-15-1-3 #1 would be SABE-1-3 #1. Note that the 15 refers to the year and can be left out when labelling baking pans since it remains constant for all points for that year)
3. Empty soil from each sample into their respective baking pan.
4. When processing soil for more than one point, make sure to keep the samples from each point together and in order from 1 to 5.
5. Bake the soil overnight at 200 degrees F.
6. The next morning the points will be dry enough to grind. Turn off oven and let it cool down.
7. Take the soil out of the oven.
8. Bring all of the soil samples for a point over to the grinder, continuing to make sure that the samples stay in order from 1 to 5 in case a label falls off at any point. This way if more than one label falls off you can still determine what samples they were.
9. Check the grinder:
    a. Inspect the filter inside the hopper to make sure it is flush with the metal. This will prevent gaps where rocks can fall through.
    b. Attach the hopper to the grinder and ensure that it is securely fastened.
    c. Check that the grinder is plugged in
    d. Clear off any excess dust in the area
10. Before grinding the samples, be sure that you have the following close by:
    a. An extra plastic bag to catch the falling soil (the original plastic bag for the sample will be used to hold any rocks that are separated from the soil)
    b. A 2mm soil sieve and a mortar and pestle
    c. Ear plugs and a face mask
11. Grab the first sample from the point you want to process.
12. Remove the top of the grinder and pour the soil sample into the hopper so that it is resting on the metal slide. Replace the top of the grinder.
    Note: Use ear plugs and a face mask for the following steps.
13. Hold the extra plastic bag around the bottom of the hopper to catch falling soil. Once you have the bag in position turn on the grinder using the cord switch.
14. Place your hand on top of the hopper to ensure the lid stays on. Now that the grinder is on and the bag is in place, pull the metal slide out to let the soil fall into the grinder. Continue holding the lid so that any rocks that shoot up from the grinder won't open the lid of the hopper.
15. Continue grinding the soil until it sounds like everything has been ground and only rocks are left (this usually takes somewhere from 10 to 60 seconds). Turn off the grinder.
16. Before pulling the bag away from the grinder, first slide the metal slide back and forth to release any soil trapped on it. Then tap the side of the grinder several times to release excess dust that hasn't fallen through yet.

17. Once all of the soil is out of the hopper, remove the bag and pour the soil back into the correctly labeled baking pan.
18. Remove the hopper from the grinder. Once it is off you can see the rocks that were stopped by the filter.
19. Grab the mortar and tip the hopper over the mortar so all of the rocks fall into it.
20. Test to make sure that none of the rocks are clay by grinding them with the pestle.
    a. If any of the rocks are clay, break them up with the pestle and sift the resulting soil through the 2mm sieve. Anything that you sift through the sieve should be placed with the rest of the soil from the sample in the respective baking pan.
    b. Place all of the rocks in the original, labeled soil bag and set aside.
21. Check the filter and hopper for any rocks or debris. Reattach the hopper to the grinder and make sure that the filter and the metal slide are both in place.
22. Repeat steps 12-21 to process all of the samples for a point.
23. Once the soil samples are ground they are ready to be dried in the oven. The soil ovens can hold up to 30 baking pans of soil (or six points of 5 samples each). When drying soil from multiple points, keep samples from the same point together and keep them in order from sample number 1-5.
24. Turn the oven on to 200 F. Soil should be dried at 200 F for 24 hours. It is helpful to place a sticky note on the oven with the time that the samples began drying so that everyone knows how long the samples have been in.
25. Next you can measure the weight and volume of the rocks that were separated from the soil samples. Gather the sample bags that contain the rocks, a few different sized graduated cylinders, a funnel, a scale, a tub or bucket and data sheets.
26. Record the weight of the rocks by taring an empty bag on the scale and then weighing the bag containing the rocks. Record to the nearest 0.1 gram. Make sure that the bag that you are using to tare is the same type as the bag with the rocks
27. To measure the volume of the rocks, fill a graduated cylinder with water (make note of the volume of water) and place the funnel on top. Pour the rocks into the cylinder and record the displaced volume of the rocks to the nearest whole mL.
28. Once the volume is recorded, toss out the rocks and water into tub or bucket.
29. Repeat steps 26-28 for all samples that contain rocks. When all samples have been measured, you can discard the water and rocks outside. Keep all of the labelled plastic bags.
30. Once the soil samples have been drying for 24 hours, turn off the oven and let it cool down.
31. Take the dry weight of the soil samples. Tare the scale <u>with the correct baking pan</u>, and weigh the soil in the baking pan. There are three types of baking pans in the soil lab, one of which is 0.5 gram different.
32. Once you have taken the weight of a sample, pour the soil back into the appropriate labelled bag and seal it. <u>Make sure that you put the correct samples in the correct bag</u>.
33. Take the label off of the baking pan and place to the side.

34. When all of the samples are fully processed, place them in a storage bin. Fill out an inventory for each bin and record each sample as it is placed in the bin. Keep the inventory on top of all of the soil samples so that it is easy to find.

Soil Data Entry

Soil data is entered into the Soil Survey tool in CADC. Data on point location and sample site description, water infiltration, bulk density, and soil carbon and texture are all entered into the Soil Survey. This includes data collected in the field, in the lab, and data obtained from soil sent off for soil carbon and texture analysis. Be sure to keep track of what information has been entered.

The Soil Survey tool can be accessed through the Biologist application in CADC. To create a New Soil Survey Event, choose the appropriate project for which you will be entering data and click on the "Soil Surveys" link in the Project Observation Types column on the right-hand side of the page.

The "Soil Surveys" link will bring you to the Soil Survey Events page which displays all of the existing soil survey events. From this page you can either make changes to an existing survey event by finding and clicking on the desired survey event, or you can create a new event by clicking on "Add New Soil Survey Event". This will bring you to a blank event page.

Under "Event Details" select the date, site, location, and the observer of the sampling event. Please note that once you save changes to the survey event, you will be able to make changes to the sampling date, **but you will not be able to make changes to the site, location, or observer**, so double check that you have entered these fields correctly! If you discover later that you have entered the incorrect site, location, or observer, the only way to change it is to delete the event and re-enter everything correctly.

Entering Soil Data:
The "Edit Event" page is formatted similarly to the soil data sheet. Helpful info regarding each of the different data fields is outlined below:

· Evidence of recent grazing: this is an integer field- type 1 for true, 0 for false. If there is no information on the data sheet regarding presence or absence of recent grazing, leave this field blank.
· Ring Infiltrometer Diameter (cm): this is a decimal field for diameter of the infiltrometer used
· Water Volume (mL): this is an integer field for volume of water used in infiltration trial
· Bulk Density Diameter (cm): this is a decimal field for diameter of the ring used to obtain bulk density sample

- Bulk Density Height (cm): this is a decimal field for the height of the ring used to obtain bulk density sample
- Soil texture data: these are decimal fields for the % Carbon, % Clay, % Sand, and % Silt at both 0-10cm and 10-40cm. If there is no data for any one of these fields, leave it blank.
- Event Notes: enter site description and any additional notes in this field. There is also a notes field at the end of each line of sample data at the bottom of the page for sample specific notes.

The following fields are entered for each of the soil samples taken at a point. Once a line of data is started, a new blank line will appear below it.

- Sampling location-
    - Sample Number: an integer field (generally 1-5) for soil sample number
    - Distance: an integer field for distance in meters of the sample site from the point count location
    - Degree: an integer field for the degree bearing of the sample site from the point count location
- Location Characteristics-
    - Bare Ground: an integer field (0-81) for the bare ground quadrat measurement
    - Litter Depth: a decimal field for depth of litter in cm at sample site
    - Catenal Position: drop down list for the catenal position of the sample site includes:
      CR –Crest; SH – Shoulder; MS – Midslope; FS – Footslope; BO – Bottom;
      NA - Not Applicable
- Water infiltration-
    - Infiltration time 1: a numeric field in the format hh:mm:ss for time of first water infiltration
    - Extrapolated?: an integer field- type 1 for true, 0 for false. If the extrapolated field is true, make sure that the extrapolated time has been calculated.
- Bulk Density-
    - Wet Weight: a decimal field for the weight in grams of the soil sample before it is dried
    - Dry Weight: a decimal field for the weight in grams of the soil sample after it is dried
    - Rock Weight: a decimal field for the weight in grams of rocks present in the soil sample (if applicable)
    - Rock Volume: an integer field for the volume in mL of rocks present in the sample (if applicable)
- Composition-
    - Max Depth: an integer field for the depth in cm of the soil sample taken for soil carbon. Should be no deeper than 40cm.
- Other-

· <u>Notes</u>: this notes field is for sample specific notes. Any missing, unrecorded, or unusual data should be explained here. Additionally, information for extrapolating infiltration times should be entered here.

Important: Data that has been entered into the Soil Survey will not be saved until you click the "Save" button at the bottom of the page. Any time that you make changes to a point you must click "Save" to save your changes.

Once you have entered a complete point into the soil survey tool write "entered", your initials, and the date at the top of the raw data sheet.

VEGETATION SAMPLING

Part 1: Quantifying the Herbaceous Component with Line-Point Intercept

This protocol is modified from Herrick et al. 2005. The line-point intercept is a relatively rapid and highly repeatable method for measuring soil cover. This method is used to determine plant community structure and can provide a minimum estimate of plant species richness.

Methods
1. <u>First-time sampling:</u> At the point count location, determine the random direction of the 50 m transects by spinning a compass. You will conduct two 50 m transects, each starting at the point count location and running in opposite directions. **Record the direction of each transect on the data form using magnetic north.** The point count location is "0 m" on each transect.
<u>Resampling established sampling points:</u> Use the directions of the original sampling
2. Pull out the tape and anchor each end with a steel pin
- Line should be taut
- Line should be as close to the ground as possible
3. Begin 1m from the point count location. Survey vegetation at every meter along the tape. Always stand on the same side of the line.
5. Drop the rod pointer, or pin, to the ground
- The pin should be vertical.
- The pin should be dropped from the same height each time. A low drop height minimizes "bounces" off of vegetation but increases the possibility for bias.
- Do not guide the pin all the way to the ground. It is more important for the pin to fall freely to the ground than to fall precisely on the mark.
6. If the pin, or the vertical projection of the pin, touches a tree or a shrub, record this species in the "Canopy." If no woody species are present, leave this column blank
- If more than one species of tree or shrub lies on the vertical projection of the pin, you can record multiple species in the canopy layer. There is an option to add canopy layers in the electronic data entry.
7. Once the pin is flush with the ground, record every plant species it intercepts.
- Record the species of the first **herbaceous** stem, leaf or plant base intercepted in the "Top layer" column using the 4 to 6 character USDA plant codes. Also record height in cm. **Height is the height at which the plant hits the pin**, not the maximum height of the individual plant. **Only record herbaceous species in the Top layer.** Data for woody shrubs or trees should not be entered in the top layer or height columns.
- If no leaf, stem or plant base is intercepted, record "NONE" in the "Top layer" column and record a "0" or a "-" in the height column.
  - Litter should **not** be recorded in the Top Layer
- Record all additional species intercepted by the pin. Leave Lower Layers blank if there are no additional layers.
- Thatch is dead plant material that is the previous year's growth and that is still rooted to the ground. Thatch is recorded as its species ID and the USDA code is then circled in the data cell. If you cannot tell what species the thatch is, record

the appropriate unknown plant code (e.g., unknown grass). When Thatch is the Top Layer, it can be recorded in the Top Layer column

- Record herbaceous litter as "L," if present.
    - Litter is defined as <u>detached</u> dead stems and leaves that are part of a layer that comes in contact with the ground.
    - Record "WL" for detached woody litter that is in direct contact with soil. Woody litter is litter that came from a woody plant species. Woody litter does not include pine needles or oak leaves, just the woody component of the plant.
- Record each plant species only once, even if it is intercepted several times.
- If you can identify the genus, but not the species either use the PLANTS database genus code (http://plants.usda.gov) or record a number for each new species of that genus. ALWAYS define the genus portion of the code and the functional group at the bottom of the data form (Artemisia species = AR01).
- If you cannot identify the genus, collect a sample off of the transect line and give the plant a temporary unique name, for example "WhiteFlower#1". Store the sample in a Ziploc bag, label with the temporary unique name, the date and the location code. Identify the plant to genus as soon as possible after the field day. **See supplement "Recording unknown plants" on page 32 for further information on naming and identifying unknown plants.**
- Foliage can be alive or dead but only record each species once. If both live and dead material for the same species is hit on the same point, record the live.
- Be sure to record all species intercepted.

8. Record one of the following in the 'soil surface' column to describe where the pin intercepts the ground. Soil surface should never be left blank:

[plant species code] = if the pin intersects the ground at the base of a plant, record the plant ID

R= Rock (> 5 mm or ~1/4 inch in diameter)

AM = Animal manure

EM = Embedded litter, or non-decomposed detached plant material partially implanted or set in the soils surface such that if the litter is removed, it will leave an indentation in the soil's surface.

M = Moss

S = Soil that is visibly unprotected by any of the above

LC = Visible biotic crust

If when you drop the pin, it is stopped on a part of a plant that is not part of the soil component, continue the vertical projection of the pin through that plant and down to the mineral soil. You might have to move that specific piece of vegetation out of the way in these cases, but treat it on the data form as if the pin has gone through it. IF the leaf was in contact with the ground such that it is embedded in the soil surface, then record that species as the soil surface. But if the leaf is just lying on the soil surface or if it is attached to a plant and elevated above the soil surface, continue recording what is beneath it.

Part 2: The Releve

Part 2a: Measuring presence of additional grasses and forbs

Spend an additional ~ 20 minutes walking a 50 m radius circle around the point center in spiral or zig zag; on the back of the data sheet, check off presence of grasses and forbs not observed on the transects. 20 minutes should be the time you spend observing plants; subtract time spent identifying them. The purpose of this is **not** to generate an exhaustive list of all plant species present in the circle – this cannot be done in 20 min! The purpose of this is to record any species that occur frequently at the point but were missed by the transects. Take special care to record presence of any plant that may be especially ecologically influential (for better or worse) such as perennial grasses, nitrogen-fixing plants, or any plant considered highly invasive by the California Invasive Plant Council.

Make sure to record both the full name (scientific and/or common name) and the USDA code for each plant encountered. If you are unsure of either the name or the USDA code while in the field, confirm the name or code once in from the field and record on the data sheet.

At locations with low diversity, you may get a good species list in less than 20 minutes. If the rate at which you check off a new species slows a great deal (a new species every few minutes), it's probably okay to stop. Conversely, at locations with high diversity, if 20 minutes passes and you are still checking off new species very frequently (several species a minute), then you can spend up to an additional 10 minutes.

Part 2b: Measuring Shrubs and Trees

Record presence and estimate cover of woody species on the back of the data form. When estimating cover, record the estimated **canopy cover**, or the vertical projection of the tree or shrub over the ground. Estimate the cumulative area of this projection for each species of separately. It can be helpful to use the cover estimators, below. Note that cover estimates are absolute estimates, independent for each species within the 50 m radius circle. The sum of the cover of shrubs or trees does not need to equal 100%. Record the percent cover in increments of 1%. For species that appear to cover <1% of the 50 m radius circle, record as "1%". Snags should not be included in the cover estimates because they are not always identifiable to species.

Estimate average height of each species of shrubs (cm) and trees (m).

Total the number of trees in each of three DBH classes (<23 cm, 23-38cm, >38cm) and the number of snags, or dead standing trees, and record on the bottom of the data sheet. For our purposes, we consider trees to be woody species >5 m tall. Thus, oak saplings that are <5m tall shouldn't be tallied in the DBH information. However, they are still included in the cover estimate. If a tree has several trunks that split below chest height, measure the trunk with the largest DBH.

Note evidence of grazing this growing season. Evidence can include manure (but be aware that manure can persist for a year or more), trampled vegetation, and plants that have been bitten. If you are uncertain, describe clearly in the notes.

Vegetation Data Entry

All vegetation data is entered into the RMN veg tool (http://data.pointblue.org/apps/rmnveg/). At this point, the veg tool does not have a link from the CADC Biologist website so you will have to follow the above URL.

To create a new site visit, choose the appropriate project for which you will be entering data and then click on "Create new sampling event" at the bottom of the Sampling Events page.

You can also make changes to an existing site visit by finding and clicking on the desired site visit in the list on the Sampling Events page.

On the New Sampling Event page, select the study area, point ID, observer, and the date of the sampling event. Please note that once you click "create new event" you will be able to make changes to the observer and the sampling date, **but you will not be able to make changes to the study area or point ID**, so double check that you have entered these fields correctly! If you discover later that you have entered the incorrect study area or point ID, the only way to change it is to delete the event and re-enter everything correctly.

Entering Line-Point Intercept (LPI) data:

The "Edit Sampling Event" page is formatted similarly to the data sheet which makes entering LPI data intuitive. Helpful info regarding each of the different data fields is outlined below:

a) **First/second direction**- this is a numeric field for compass direction of the LPI transect
b) **Top layer**- the top layer is linked to a database of USDA and RMN project accepted plant codes. These include species specific codes, genus codes, family codes, and unknown plant codes.

When you begin typing a plant code into the top layer field, a list drops down with codes containing the letters you have typed. If at any point you press enter or tab while you are typing, the field will populate with the code that is highlighted in blue at the top of the drop down list. To choose the desired code, either type the entire code into the field, click on the code in the drop down list, or press enter/tab when the code is highlighted in the drop down list. **Be careful** that the code that populates the field is the one that you do in fact want! If you simply type in the entire code and press tab/enter without allowing the program to catch up to you, the field may be left blank. This is especially true for the first time that you type in a code that is new to the sampling event.

While the scientific name of the plant appears in the drop down list, you can only search by plant code, not scientific name.

When you move to the next field, the field that you just entered will turn green. This means that the data has been saved.

If you enter a code that the program doesn't recognize it means that either a) you have typed it incorrectly, b) the code you've entered is for a plant that doesn't occur in California, or c) the particular synonym that you have entered is not in the veg tool database. Check on the USDA Plants Database website to determine the range and the most up to date code for the plant that you are entering.

In addition to the standard 4-6 character USDA plant codes, there are also several unknown plant codes, all which start with the number 2 (ex. 2GP, 2FORB, 2FA - perennial grass, unknown forb, annual forb, respectively).

When there is no plant in the top layer, enter the code "NOPLANT".

c) **Height**- this is a 4 character numeric field. The number that you enter must be greater than 0. Leave the field blank when you have a height of 0 (when the top layer is "NOPLANT").

If for some reason you don't have a height that corresponds to the plant entered in the top layer (reasons for this include- someone forgot to fill out the height field; height is illegible; or the height that is written corresponds to a woody, not an herbaceous plant) then enter 9999 in the height field, don't leave it blank.

d) **Lower layers**- like the top layer, the lower layer fields are linked to a database of USDA and RMN project accepted plant codes. Any codes entered in the top layer can also be entered in lower layers.

Additionally, litter and woody litter (L and WL, respectively) can be entered in the lower layer fields.

If you have two of the same unknown plant code on the same point (ex. AST01 and AST02, different unknown species within the same family, Asteraceae) and you are unable to identify them any further, you can enter both under the same code (AST01 and AST02 would both be entered as "ASTERA"). Since the protocol states that you should only enter a species once at each point, regardless of whether it hits the pin more than once, entering an "unknown" plant code (genus level, family level, or growth habit level) more than once implies that the repeated code represents two distinct species. In this way, information about species diversity isn't lost, even in the event that you can't ID all plants to species.

When you create a new sampling event, the default setting displays 3 lower layers. If you have more than three lower layers to enter, you can add another column by clicking on the "+" button in the upper right corner of the LPI window where it says "lower columns", opposite the transect direction field.

Make sure that you enter lower layers consecutively- there should be no blank fields in between plant codes.

e) **Soil Surface**- the soil surface field is similar to the top and lower layers and is also linked to the plant code database.

> In addition to the standard 4-6 character plant codes, you can also enter the unique 1-2 character soil surface codes (see page **Error! Reference source not found.Error! Bookmark not defined.**)
>
> If for some reason no soil surface was recorded, is illegible, or is incorrect, you can enter the code "UNKNWN" so that the field is not left blank.

Make sure to enter all data for both directions of a point. If you couldn't sample a section of the transect in either direction (due to dense brush, fence line, etc.) leave those points blank and provide an explanation in the notes at the bottom of the page. **Points should not be left blank without an explanation.**

Entering Species Checklist and Visit data:

· The plant species checklist is below the LPI data section. The checklist is divided into "Grasses and Forbs", "Shrubs", and "Trees".
· The veg tool will only allow you to enter a species code once in each of the different checklists. If you attempt to enter a code that you have already entered, under the box it will read "no results".
· You can not make changes to the species codes that are entered and displayed in the checklist. If you have entered an incorrect species code you must delete the incorrect entry by clicking the "X" beside the code. You can then enter the correct code.
· In the "Shrubs" and "Trees" checklist columns you must enter a percent cover for each of the species. If you do not enter a percent cover, the % cover box will turn yellow, prompting you to enter a number.
· Because you record absolute percent cover of each species, the veg tool will allow you to enter percent covers that add up to >100%, however it will display a message when this happens as a reminder to check that what you've entered is accurate.
· Enter the number of trees of each DBH class and the number of snags. The field will not allow you to enter 0, so if there were no trees for any of the categories, leave the field blank.
· Finally, fill out the grazing check box (check the box if there was evidence of the point being grazed that season, leave the box unchecked if there was no evidence of grazing) and provide any notes, explanations, or observations about the point.

Once you have entered a complete point into the veg tool (LPI data, species checklist, and visit data), write a check mark on both the front and back of the data sheet and write your initials and the date at the top of the page.

RMN vegetation data can be downloaded from CADC. It is divided into three separate files- RMN visit data, RMN LPI observation data, and RMN vegetation checklist data.

Vegetation Sampling Supplemental Information:

Supplement A: Cover Estimator

1%   2%   3%   5%

7%   10%   15%   20%

25%   30%   40%   50%
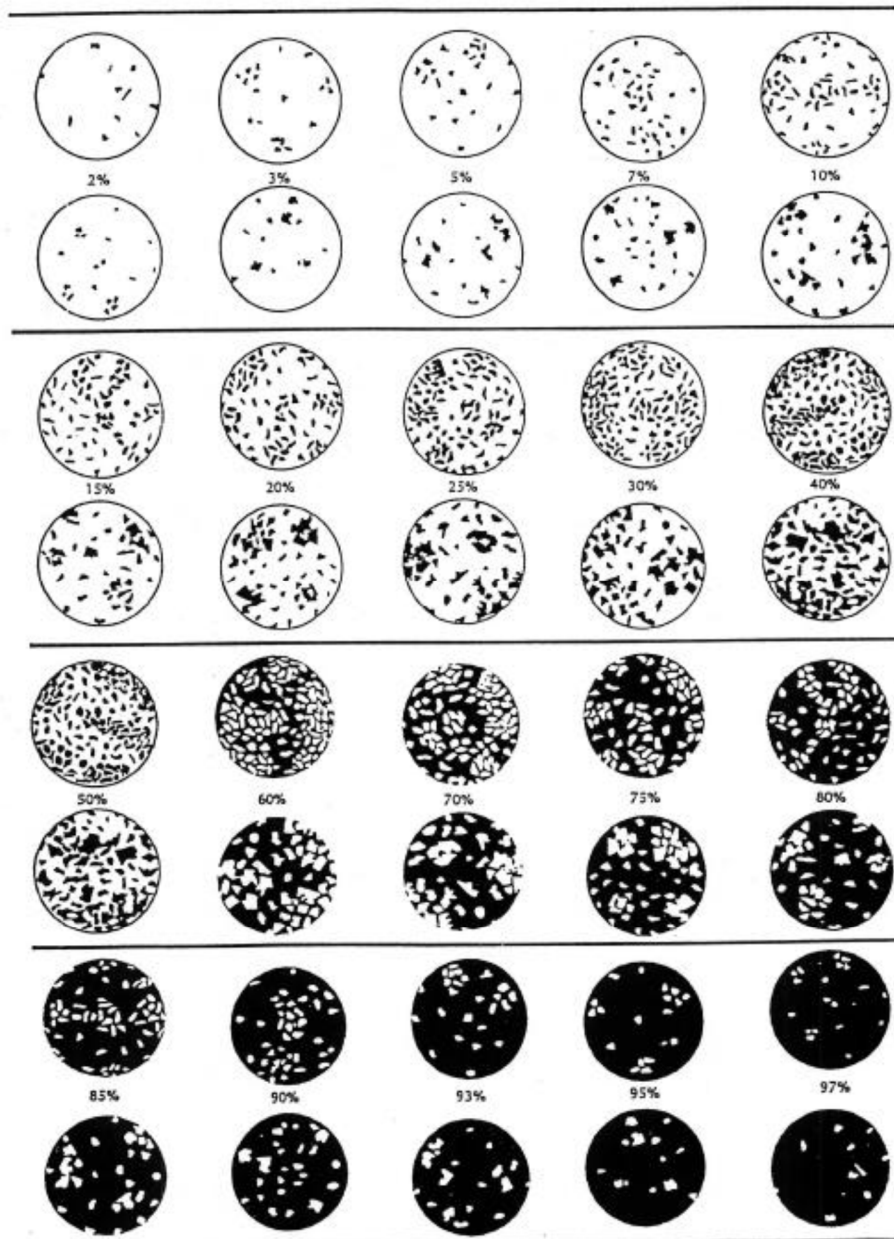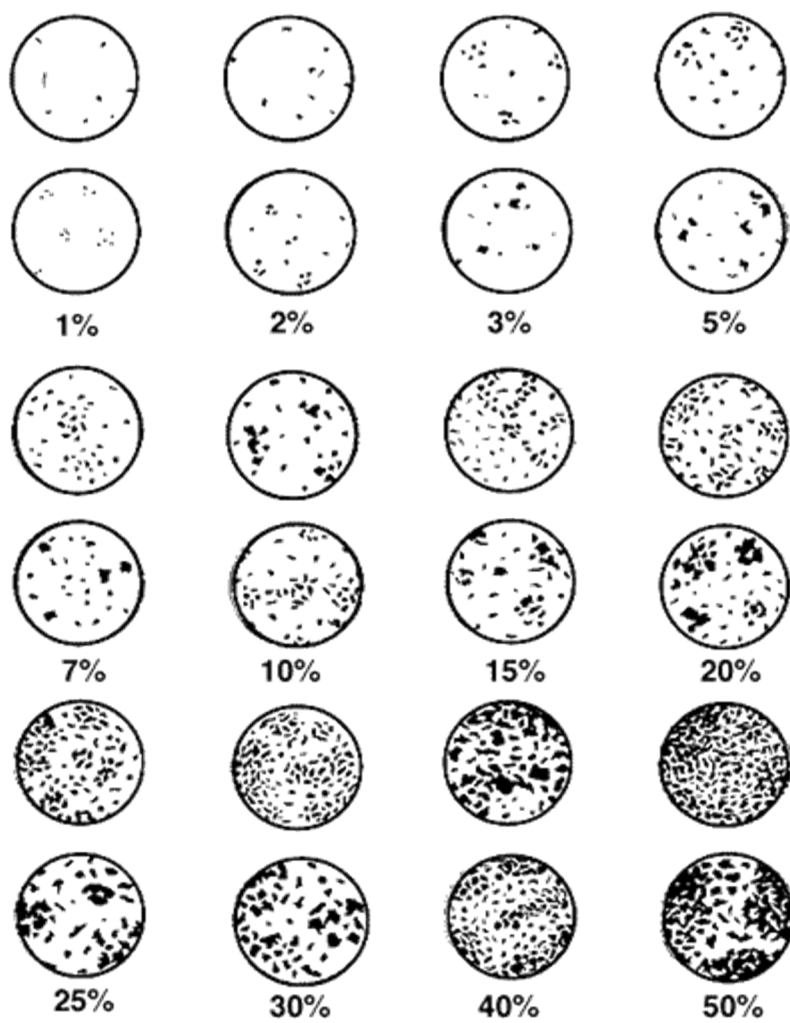
Supplement B: Recording unknown plants

You've come across a plant that you can't identify to species. What next? You'll need to record a description of the plant and collect a sample to take back with you to try to identify it later. But first, use the following to assess how much you *do* know about the unknown plant:

1. Do you know the **genus** of the plant?

       - If yes ⟶   Create a unique code according to the genus (use scientific or common name, but make sure to record the scientific name in the description, if known) and record a number for each new and unknown species of that genus.

       - If no

            Ex.   BAR01= suspected perennial hordeum species; long alms- foxtail barley?

                     BAR02= annual barley; smaller seedheads

2. Do you know the **family** of the plant?

       - If yes ⟶   Create a unique code according to the family (use scientific or common name, but make sure to record the scientific name in the description, if known) and record a number for each new and unknown species of that family.

       - If no

            Ex.   AST01= purple flowered aster

                     AST02= many small yellow flowers; fuzzy, linear leaves; asteraceae family

3. If you don't know the genus or family, label the unknown plant according to its duration and growth habit. The following is a list of some unknown plant codes for reference.

       FA = annual forb
       FP = perennial forb
       FORB = unknown forb
       GA = annual grass
       GP = perennial grass

As with the examples above, use numbers in the code to denote multiple unknown plants within the same duration and growth habit category and provide a description.

       Ex.   FA01= white flowers on top of stalk; long, thin petioles with small heart-shaped leaves

                  FA02=Wide, palmate leaves; no apparent flowers

When you get back to the office, look up the unknown plants as soon as possible while they are still fresh in your mind. If you are able to determine any of the unknown plants that you encountered, **be sure to record the USDA code and the full name on the raw data**, next to the code and description that you came up with in the field.

Try to narrow the plant down as much as you can. If you can only get it identified out to genus or species, find the USDA approved genus or species code and record that next to the code and description that you came up with in the field. If there are more than one different unidentified species within a given genus (or family), write the genus code (or family code) next to both descriptions.

Supplement C: Resources for identifying unknown species

http://www.calflora.org

http://www.enature.com/home/

http://www.wildflower.org/explore/

https://picasaweb.google.com/rdigaudio/JennerPlants?authuser=0&authkey=Gv1sRgCIvUn6Ojz
6q5lAE&feat=directlink

http://www.sonomalandtrust.org/pdf/herb_book/HerbariumFinalHigh_2011.pdf

http://www.sonoma.edu/cei/prairie/prairie_desc/grasses_rushes_sedges.shtml#comparison

BIRD SAMPLING

The Point Blue point count protocol is described by Ballard et al. 2003 (http://data.prbo.org/cadc2/index.php?page=songbird-point-counts). Additional references include Ralph et al. 1993. Below is an expanded description that provides details relevant to the RMN that was compiled by A. Hererra and A. Fogg.

Point count surveys are conducted a minimum of two times during the peak of the breeding season (April – June), dependent on geographic location.

What to bring
Every survey, make sure you bring:
- high-quality binoculars
- bird field guide (phone app with songs are best)
- data forms
- clipboard
- black ink pens
- directions and maps
- GPS unit & extra batteries (always have extra batteries; the charge meters on the GPS units are not very reliable)
- range finder & extra batteries
- watch with countdown timer
- thermometer
- field backpack
- hat for sunshade
- water and food for up to 6 hours in the field

It's highly recommended you also bring:
- cell phone for emergency communications
- waterproof field notebook
- camera

Preparation
At least one day before your point count survey, make sure you check your GPS unit's batteries, upload point count waypoints onto GPS unit, grab new point count data sheets, directions, narratives and needed maps, and obtain landowner permission to enter the property to complete the survey. Make sure to check the weather beforehand, paying close attention to predicted hourly wind speed. A good website to check is: www.weather.gov. You can start with a zip code or the closest town and then when the 7-day forecast page comes up, click on the map exactly where your ranch is located for an accurate forecast. If you scroll down the page, you can click on the Hourly Weather Graph button which is located just below the Radar & Satellite Images.

You can check to see what time of day wind and precipitation is forecast and plan your survey accordingly.

Daily schedule

Counts should begin between sunrise and 15 minutes thereafter, and should be completed within 3-4 hours, generally by 1000, and normally never later than 1100. However, do not end at 1100 if you have not completed your transect by then – keep counting until you finish. Generally on cooler and less windy days, birds may stay active, but if it heats up or wind increases, you may need to stop surveying earlier in the morning. Use your GPS to check the local sunrise time (Main Menu < Calendar or Sun & Moon) or use an online sunrise calendar such as http://www.timeanddate.com/worldclock/sunrise.html or http://www.sunrisesunset.com/usa.

The first visit should be completed between April 15 – May 15; the second visit should be completed between May 15 – June 15, with a <u>minimum of 10 days between point count visits</u>. On your second visit reverse the order in which points are surveyed if possible (i.e. if first visit went 1 – 15 then the second should be 15 – 1). If possible, have another biologist complete one of the visits in order to reduce observer bias.

Adverse weather conditions

Do not conduct surveys during weather conditions that are likely reduce detectability (e.g., high winds, fog, or rain). If you can't see clearly 100 meters away and up to the top of trees, you should not be counting. If you have to shield your datasheet from the rain, you should not be counting. If you have to work considerably harder to hear birds than on calm days, the count should be postponed. Use your instincts. It is critical to be honest with yourself about this because **biased data is worse than no data at all.** The consistency of the data collection is your first priority. If conditions change for the worse while on a point count transect, remain on site and wait to see if the conditions improve. If conditions do not improve and you have to abandon the survey, any remaining points can be completed within 3 days.

Approaching the point count station

Approach the point with as little disturbance to the birds as possible. Allow the birds to resume normal activity after any disturbance your walking created. You can use your range finders to delineate distances for a minute before you start. If you are breathing hard on a steep transect, crashing through bushes, or arrived in a vehicle go ahead and take more time as necessary. If you approached on a vehicle, either park the vehicle at least 200m away and then approach your point on foot as normal; or you may park the vehicle at the point location, but will need to wait longer for normal bird activity to resume. Attracting devices, recordings, or "pishing" should never be used BEFORE or DURING a count. Chasing unknowns after a count is fine. Also wear drab "earth" toned clothing, as bright colors are known to affect bird behavior (bright red or orange, for example, can attract hummingbirds).

Point count duration

Each point count is 5 minutes in duration. Set your countdown timer on your watch to 5 minutes and make sure it beeps once that time elapses. If something **briefly** interferes with your ability to detect birds during the 5-minute count (vehicle drives by, plane flies over, wind gust, short-duration animal alarm call), you may pause the point count and resume once the disturbance has subsided. If a prolonged interruption interferes with your ability to detect birds during the 5-minute count (train, conversation with landowner, consistent animal alarm call/scolding, etc.), stop the count until the disturbance has passed or try moving a short distance away (within 30m) to avoid the disturbance and start over. Cross out the interrupted data and note what happened on your form.

Recording point count data

Header information

Use a new point count datasheet for each transect. Fill out the header information on the first page of each datasheet. Write down the project (RWI), county, and transect identification code. Include the month, day, year and visit number (1, 2 or 3). **Check your watch to make sure you have the correct date**. Write out your first and last name and your three-letter initials. It is extremely important that you fill out all header information.

Point information

At each point, start by writing down the point name/number (e.g. 1, 2, 12, 15, N, S, W, E, X, Y, Z, C), the time in 24-hour format (e.g. 0723). Look at your GPS to verify exactly what point you are at.

Point conditions

We record the following conditions at the start of every point count.

Wind

Wind is recorded using mph, knots, kmph, or Beaufort scale. Make sure to indicate which unit or method you are using to estimate wind speed. The Beaufort wind scale was developed to standardize weather observations on land and at sea. Record consistent wind speeds, not gust speeds. Average the wind speed from the canopy to the level of your head. If the wind is averaging consistently over 5 on the Beaufort scale, do not survey. If the wind is just gusting to 5 on the Beaufort scale, but gusts are occasional and die down quickly, proceed with the survey.
0 – 1 = Great survey conditions
2 – 3 = OK survey conditions, try to shield yourself from the wind
4 – 5 = Marginal survey conditions (evaluate how far away you can hear vocalizations and whether the wind is just gusting to 5, but gusts are occasional and die down quickly)
6 + = Do not survey!

Beaufort #	Description	mph	Land Conditions
0	Calm	< 1	Calm and quiet. Smoke rises vertically
1	Light air	1-3	Wind motion visible in smoke.
2	Light breeze	4-7	Wind felt on exposed skin; leaves rustle
3	Gentle breeze	8-12	Leaves and smaller twigs in constant motion
4	Moderate breeze	13-17	Dust and loose paper raised; small branches move
5	Fresh breeze	18-24	Branches of a moderate size move; small trees sway
6	Strong breeze	25-30	Large branches in motion; whistling heard in overhead wires; umbrella becomes difficult to use
7	High wind	50-61	Whole trees in motion; effort needed to walk against wind

Temp
Use your thermometer to record the temperature in Celsius.

Percent Cloud Cover
Estimate the percent cloud cover (% of sky covered by clouds).

Other conditions to note:
Noise
Make a note in the footer of any consistent ambient noise. Ambient noise includes that from insects, creeks, rivers, constant vehicles passing on roads, and mechanical equipment like chainsaws or a generator. **Wind noise does not apply to the ambient noise scale.**

Bird data
Every species detected at a point is recorded, regardless of distance from the observer. Each species gets its own line and is recorded as a standardized 4-letter code (e.g. OATI for Oak Titmouse). Point Blue uses codes based on the AOU checklist of North American bird species: http://www.wec.ufl.edu/birds/SurveyDocs/species_list.pdf
Proper identification of all birds is of course important but don't be distracted by birds you cannot readily identify until you have gotten an accurate count of known birds. If you are uncertain of a species identification, make a note as described below; **remember, no data is much preferred over wrong data**. Furthermore, closer birds should be given greater attention than distant ones as these observations are more valuable. Chase down unknown birds after the five-minute count if you have time; an unidentified woodpecker drum 150 meters away in the opposite direction of your next point count is not worth the effort. Keep in mind that this is a survey, not an absolute census and not all species/individuals present will necessarily be detected during your 5 minute counts. It is ok to write other species detected between 5 minute counts in the notes or field notebook. But do not spend time searching for birds not detected before or after counts to "build up" the point count survey. **Point counts are designed to be repeatable samples of species/individuals present. They are not a complete census of all species or individuals present.**

Unknown bird detections
For unknown species you heard <u>during the count</u> but weren't sure what they were, record "XXXX." For unknown members of various families, use "XX" plus two letters to signify the family – "XXHU" for unidentified hummingbird, for example. You can pish for unidentified birds after the completion of a survey in order to verify identification. Make a note in the margin

of your point count form or in your notebook on any sounds or field marks you may have noticed before the bird disappeared. Never record XXXX without describing in detail in the notes section what it sounded like. A list of four-letter codes for unidentified birds are given in CADC. As a rule of thumb you should not be getting more than 1 or 2 unidentified birds within 100 meters per transect.

No detections
If no birds are detected at a point, write "No birds detected" on your form in the bird data field.

Detection cue codes
We record the behavioral cue that alerted us to the presence of the individual bird:
        S = song
        C = call
        V = visual
        D = drumming woodpecker
        H = wing whir (e.g., hummingbirds, doves)
        J = juvenile birds (birds born that year – see note below)

If a bird sings or a woodpecker drums after it has been detected via a different cue, circle the original detection ("C" or "V"). For behaviors such as bill snaps (e.g., Black Phoebe), or bark foraging (woodpeckers and nuthatches), simply use the default "C" for call. Song and call distinctions can sometimes be subjective, but remember that the "S" and "D" detection codes and circling calls and visual detections, signifies a territorial behavior and is used as an indicator of breeding. If you feel a bird is vocalizing in a territorial manner, use the "S" or "D" code as appropriate; if you are unsure, use the default "C" code.

Juvenile birds
Juvenile birds are recorded regardless of their behavior but are not normally included in analyses. This includes birds in the nest, fledglings following parents and birds in juvenal plumage like a spotty robin. **If you see or hear a juvenile bird always record it as "J" – not by its detection cue.**

Distance estimation
Point counts involve recording distance to bird detections at some resolution. We recommend using exact distance estimation up to 300 meters, in which the distance to each individual detection is recorded. Estimating distance requires practice and experience. Prior to field data collection you will receive training in distance estimation. Before or after each count, estimate the distance to visible objects using your rangefinder to verify your estimates. Pick 2-4 landmarks before the survey (e.g. large tree, fence line, big boulder) to determine the distance using your rangefinder. This will allow you to focus more on bird species identification and behavioral observations during the survey.

How to record distance
Record the distance from the point (where you are standing) to the first location an individual was detected (not necessarily identified), regardless of its behavior. If the bird subsequently moves, do not change the original distance recorded. On the RWI project, **all distances are**

recorded in a 2D plane. So if a bird is flying (but not "flying over" – see below), or perched high in a tree, the distance recorded is to the point at which a plumb line would hit the ground if hung from the point at which the bird was first observed. Thus, there is no vertical distance included in the measurement, only horizontal. Similarly, if you are surveying in rough terrain and you detect a bird at the bottom of a drainage or on the hillslope on the other side of a drainage, the distance recorded is to the point at which a plumb line would intersect your horizontal line of view. This distance can sometimes be tricky to estimate, especially if there is no horizontal reference point to serve as a target for your rangefinder. Do not spend too much time "calculating" this distance and realize that the difference between the 2D-distance and 3D-distance to a bird is the most pronounced in only the more extreme circumstances.

Record this distance

Record this distance

Record this distance
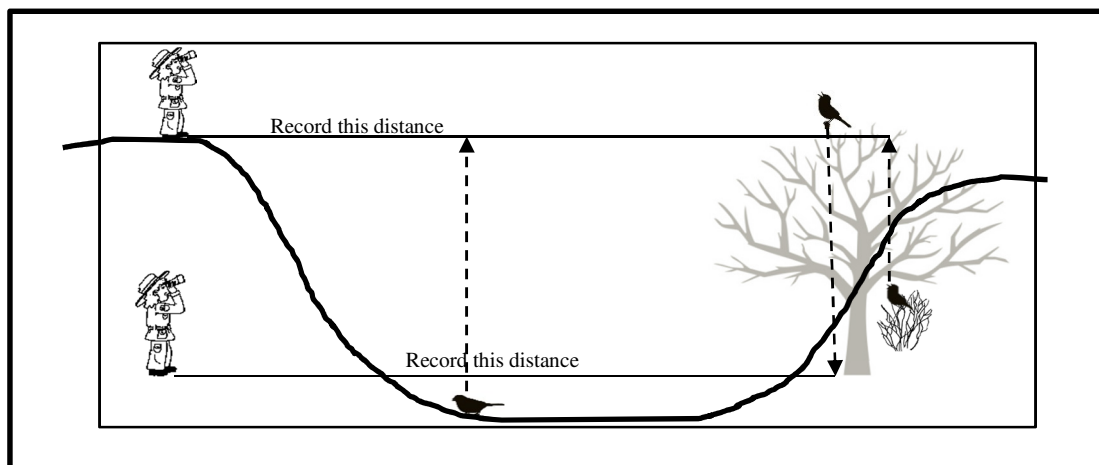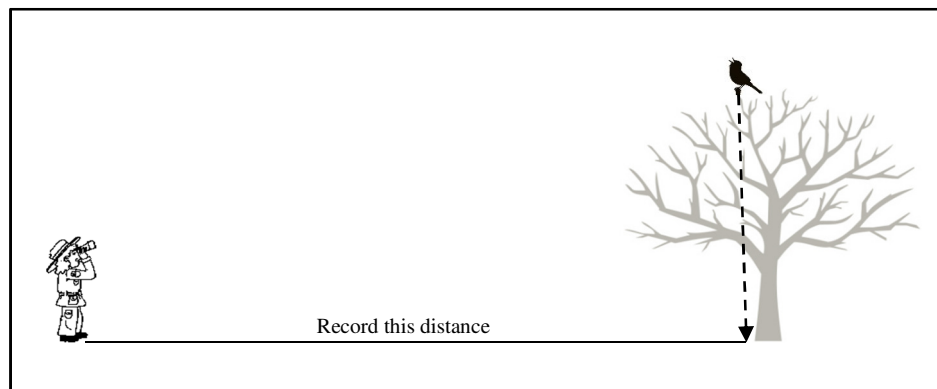
It is common to hear a bird and be unsure of the distance, and so you wait to hear it again before recording it – and then sometimes, especially on busy counts, you never get back to that bird. So always double check after each point to ensure you filled in all the data.

Writing bird data on your datasheet
Bird species are written down in the order they are observed. Only write one species per row but you can include multiple individuals on one line (even if they are detected after other species, you can add these detections to the original species row). You do not have to use only one row for each species, if more space is needed feel free to use as many rows as necessary. Record the data elements by first writing number of individuals (blank assumes only 1), followed by the type of detection, followed by the exact distance up to 300 meters. For example, in a row where "LASP" is written in the species column, the code "2V35, C110" means that there were two individuals detected visually at 35 meters and another individual called at 110 meters. If that individual at 110m subsequently sang, the "C" would be circled. An empty row or a row with a wavy line should be used to separate each point's data from the next.

Fly-overs
Birds that are flying over but not using the habitat that you are directly sampling (e.g. mallards, ravens, gulls) are recorded using the FLO code. Remember to put a detection cue, such as C or V, before the FLO code. Birds flying below canopy level, flying from one perch to another, or actively foraging on or above the study area (e.g. RTHA, TRES) are recorded as described in detection cues section.

Birds flushed at the point
A bird flushed from within 10 m of the point when you arrive should be included in the count. Birds that are flushed from farther away should be noted in the notes of the form if they are species that were not detected during the count.

Double counting
Make every effort to avoid double counting individuals detected at a *single point*. Always keep track of individuals during a point count. However, if an individual is known or thought to have been counted at a previous point (e.g. Acorn Woodpecker), you should still record it at the next point but write in the notes that it is believed to be the same bird from the previous point. Generally this delineation will only be possible for rare or uncommon vociferous species.

Behavioral observation codes
We record any potential indications of breeding in the notes section for each species as follows:

CO-copulation	FS-fecal sac	DD-distraction display
FC-food carry	MC-material carry	DI-display
FL-fledglings	NF-nest found	PA-pair

If you detect breeding behavior between point count surveys, record the behavioral cue next to the appropriate species on a line of data. This way the breeding detection will be captured in the data.

Other observations and notes

Use your field notebook to write down other observations. Please do not clutter the datasheets with notes about wildflowers, alternative routes to the plot or the surrounding habitat. Exceptions include anything that may impact your ability to detect birds such as surprising a bear during a point count, listening to a Red-tailed Hawk scream at you during a survey, chainsaws, road traffic, running water, etc. If you cannot reach a point or transect *for any reason,* write it down on your datasheet.

Bird Data Entry

Bird data can be entered in the California Avian Data Center (CADC), a regional node of the Avian Knowledge Network (AKN) hosted by Point Blue Conservation Science. CADC integrates data on birds and ecosystems, currently hosting more than 50 million bird observations for California spanning more than 40 years. You can enter and download data from:

http://data.prbo.org/cadc2/

To enter point count observations, login to the Biologist application in CADC. To create a new point count visit, choose the appropriate project for which you will be entering data and click on the "Point Count Surveys" link in the Project Observation Types column on the right-hand side of the page.

The "Point Count Surveys" link will bring you to a list of Point Count Transects. Select the desired transect to either enter new data or make changes to existing data. This will bring you to a page where you have the option of creating a new event or editing an existing event.

To create a new event, select the "observation protocol" (should be VCP300 for RMN observations) and "site condition protocol" and click the "Start" button. This will bring you to a "New Point Count Visit" page.

- Choose the specific transect points which you visited, enter a start time for each point, whether the point had observations (yes/no selection) and any point specific notes.
- Enter site conditions. This includes temperature, wind speed, and cloud cover.
- Enter bird observations for each point, including information on time of detection, species detected, detection code, behavior, and any additional notes.

When you are finished entering your point count data, make sure to click the "Save to database" button at the bottom of the page.

Mark the raw data sheet as entered with you initials and the date at the bottom of the page.

APPENDIX 1: DECISION BRIEFS

These decision briefs describe our rationale behind how we defined key terms and decided which metrics to monitor and how to monitor them.

Appendix 1A: How should we define "Rangeland"?

Issue Statement: Definitions of rangeland are legion: http://www.fao.org/docrep/005/y4171e/Y4171E37.htm. In order to communicate clearly and effectively about the Rangeland Monitoring Network, a concise definition of rangeland is needed. Rangeland is a land use term that encompasses many vegetation communities and geographic locations. For the Rangeland Monitoring Network we want a definition that can be used to communicate to a wide audience of researchers, managers, and landowners.

Summary of Recommendation: For the purposes of the Rangeland Monitoring Network, we recommend the following definition:

"Rangelands are areas where wild and/or domestic animals graze or browse. We focus on a subset of rangelands where grasses and forbs are a principle component of vegetation cover and trees and shrubs can also be present; for example, oak savannah, oak woodland, grassland, and coastal prairie and scrub are the primary plant communities in the RMN. The vegetation on rangelands can be managed with many tools, including grazing, burning, and mowing."

Recommendation: We recommend the above definition because it focuses on the interaction of animals and the land through grazing and browsing. It does not limit rangeland to areas used exclusively by domestic animals. It refines the land/animal interaction with information about vegetation communities. It acknowledges other management tools and disturbances such as fire.

Other Methods: A number of other definitions for rangeland exist. Here we review some of these definitions and the reasons that our proposed definition better meets our needs.

Land on which the indigenous vegetation (climax or natural potential) is predominantly grasses, grass-like plants, forbs, or shrubs and is managed as a natural ecosystem. If plants are introduced, they are managed similarly. Rangeland includes natural grasslands, savannas, shrublands, many deserts, tundras, alpine communities, marshes and meadows. Society for Range Management 1998. https://globalrangelands.org/rangelandswest/glossary

The ecological language (e.g., indigenous vegetation and climax vegetation) is outdated and the term "natural" is difficult to define. This definition doesn't capture the importance of management that maintains vegetation of rangeland as grasses. Finally, it doesn't acknowledge

the importance of forests for rangelands, and we know that forests in the Sierra Nevada are important rangelands.

Land that naturally produces forage plants suitable for grazing but where rainfall is too low or erratic for growing crops. British dictionary.

 The focus of this definition on rainfall makes it unsuitable for our purposes. There are many places where rangeland occurs in areas with sufficient rainfall for crops.

"In the United States, the term RANGELAND describes the extensive, unforested lands dominating the western half of the continent. Rangelands around the world are also known as prairies, plains, grasslands, shrublands, savannas, steppes, deserts, semi-deserts, arid lands, swards, and tundra." UC Davis, http://californiarangeland.ucdavis.edu/About_Rangelands/

This definition just defines rangeland as a mash-up of vegetation types and does not include the land-animal interaction. We think that interaction is the key piece of rangeland.

"Rangeland is defined by the NRI as a land cover/use category on which the climax or potential plant cover is composed principally of native grasses, grasslike plants, forbs, or shrubs suitable for grazing and browsing, and introduced forage species that are managed like rangeland. This includes areas where introduced hardy and persistent grasses, such as crested wheatgrass, are planted and such practices as deferred grazing, burning, chaining, and rotational grazing are used, with little or no chemicals or fertilizer being applied. Grasslands, savannas, many wetlands, some deserts, and tundra are considered to be rangeland. Certain communities of low forbs and shrubs, such as mesquite, chaparral, mountain shrub, and pinyon-juniper, are also included as rangeland." NRCS NRI,
http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/?cid=stelprdb1041620

This definition is also a bit of a mash-up of vegetation types and also references climax plant communities.

Appendix 1B: What soil characteristics should we measure?

Issue Statement: This document describes the process used to identify soil characteristics that will be measured by the Rangeland Monitoring Network. A primary focus of the RMN is to measure ecological function on rangelands, and soil is the basis of rangeland productivity. We selected soil metrics that capture variation in the functional capacity of soil, can change as a result of management, and are logistically and financially feasible.

Summary of Recommendation: We recommend measuring water infiltration, soil compaction (via bulk density), and organic carbon.

Recommended Soil Characteristics:

Water infiltration. Water infiltration is the process of water entering the soil, and is integral to the ability of rangelands to support life. Infiltration rate is a function of soil type, soil structure, and soil water content, and it can be impacted by plant roots, grazing practices, and other activities that impact the soil (Lal 1998). We recommend measuring water infiltration because it is a central process to all other soil functions, is sensitive to grazing practices, and is relatively easy to measure. Measuring water infiltration is simple and inexpensive.

Soil Compaction. Soil compaction is a measure of how tightly soil particles are packed together. Compacted soils have reduced pore space for water infiltration, water retention, root growth, soil aeration, and seedling germination (Lal 1998). Measuring soil compaction will allow us to evaluate the relationship between management, plant community composition, and other covariates (e.g., soil type). Bulk density is the weight per volume of soil and is an assessment of compaction. We recommend measuring bulk density because it responds to management over relatively short time scales, is commonly recommended as an indicator of soil function, and it is simple and inexpensive to measure.

Soil Organic Carbon. Soil carbon exists in organic and inorganic forms. Inorganic soil carbon is mineralized carbon (e.g., calcium carbonate). Because it dissolves in acid, it is only present in alkali soils and dry environments. It is less labile than organic carbon. Organic carbon is either charcoal (biochar), or soil organic matter (SOM). Charcoal is more stable than SOM. SOM is the most abundant form of soil carbon in non-alkali soils. SOM is about 50% carbon (Pribyl 2010). It is less stable than other forms, and is thus more responsive to changes in land management (Donovan 2013). Total carbon or total organic carbon is typically used as an indicator of SOM (Schumacher 2002). There are several quantitative and semi-quantitative methods for measuring soil carbon.

Other soil characteristics considered:

Aggregate Stability. "Aggregate stability refers to the ability of soil aggregates to resist disintegration when disruptive forces associated with tillage and water or wind erosion are applied. Wet aggregate stability suggests how well a soil can resist raindrop impact and water erosion, while size distribution of dry aggregates can be used to predict resistance to abrasion and wind erosion." (http://soilquality.org/indicators/aggregate_stability.html). Aggregate stability is measured by repeated agitation of soil in water. At this time, we do not recommend including aggregate stability as a RMN metric because it does not inform our understanding of ecological function closely enough to warrant inclusion.

Cation Exchange Capacity. CEC is a measure of soils' ability to hold and deliver cations. CEC is important because it is a measure of soil nutrient availability. CEC is measured in the lab through direct and indirect measures. CEC varies by soil type. Clay soils and soils rich in SOM generally have a high CEC. We do not recommend CEC as a metric of the RMN because of its sensitivity to both measured and unmeasured environmental covariates.

Earthworms. Who doesn't love an earthworm? As much as they are an indicator of soil health, and as fun as they are to count, we don't think that earthworm counts will add much additional information beyond what will be captured by our three soil metrics.

Electrical Conductivity. Soil electrical conductivity is the ability of soil to transmit an electrical current. This metric is used as an indirect indicator of nutrient availability in the soil. EC will also vary by precipitation, timing of measurement, temperature, salinity, and other factors. Because of the potential for EC to vary by these other covariates which we will not necessarily measure, we do not recommend measuring EC at this time.

Hydraulic conductivity. A measure of soil's ability to transmit water under a hydraulic gradient. Hydraulic conductivity can be measured in the field or in the lab. It is more labor intensive than water infiltration.

Molecular assays of soil microbial communities. Recent advances in molecular techniques enable researchers to characterize the structure and diversity of soil microbial communities quickly and accurately. Molecular methods include genetic fingerprinting, metagenomics, and proteogenomics. Monitoring the soil microbial community in detail may be appropriate in some situations within the RMN, but in general we believe measuring organic carbon to be an ecologically relevant indicator of the functional capacity of the soil microbial community.

Nitrogen. Nitrogen can be measured as total N or in various forms (e.g., mineralizable N, NO_3). Because non-mineralizable forms of N are not useful to ecological function, total N may not be very informative. Measuring mineralizable N might be too labor intensive for us, but we should look into this further.

Other chemical and molecular soil components. It is common to assess soil for concentrations of elements such as magnesium, potassium, copper, phosphorous, zinc, iron and calcium for the purposes of optimizing crop production or pasture forage. Expected or recommended levels of these elements vary regionally by soil type, and we have no *a priori* reason to include them in the RMN metrics at this time.

Penetration resistance. A measure of soil strength, used to assess surface and subsurface soil compaction. A penetrometer can be operated by hand, but might be tough to use in a standardized way. While soil scientists sometimes use this method in addition to bulk density, we could evaluate the potential for this as a less labor intensive alternative to bulk density. However, we do not recommend measuring penetration resistance at this time because of our concerns about standardization across a large number of field technicians.

pH. A measure of the acidity or alkalinity of soil. Mineral solubility is sensitive to variation in pH. pH can be measured with a pH meter or with dyes that turn color according to pH. We do not recommend measuring pH throughout the RMN because it may be sensitive to both measured and unmeasured covariates.

Slaking. "Slaking is the breakdown of large, air-dry soil aggregates (>2-5 mm) into smaller sized microaggregates (<0.25 mm) when they are suddenly immersed in water. Slaking occurs when aggregates are not strong enough to withstand internal stresses caused by rapid water uptake. Internal stresses result from differential swelling of clay particles, trapped and escaping air in soil pores, rapid release of heat during wetting, and the mechanical action of moving water." (http://soilquality.org/indicators/slaking.html)

Soil Respiration. Soil respiration is the production of CO_2 as a result of metabolic processes of the soil flora and fauna (microorganisms, roots, macroorganisms). These are the same metabolic processes that drive the creation of SOM. Soil respiration rates are temporally variable, and can depend on time of day, temperature, season and moisture. While high rates of soil respiration (i.e., 32-64 lbs. CO_2-C/a/d) are generally indicative of ideal soil activity, rates that are too high (>64 lbs. CO_2-C/a/d) can be a sign of rapid organic decomposition (i.e., after tilling), and loss of water holding capacity. Soil respiration is typically measured with a gas analyzer (NRCS 1999). For our purposes, soil respiration fluxes occur on too fast of a temporal scale to be informative. At this time, we recommend not including soil respiration in the Rangeland Monitoring Network. Instead, the long-term influence of soil microbial community will be captured by our measurement of organic carbon.

Appendix 1C: How should we measure water infiltration?

Issue Statement: Water infiltration has been identified as one of the soil characteristics that will be measured as part of the Rangeland Monitoring Network.

Summary of Recommendation: We recommend measuring water infiltration via the single ring infiltrometer because it is a simple, repeatable field method.

Background: Water infiltration is the process of water entering the soil, and is integral to the ability of rangelands to support life. Infiltration rate is a function of soil type, soil structure, and soil water content, and it can be impacted by plant roots, grazing practices, and other activities that impact the soil (Lal 1998). Water infiltration is measured in the field with a ring infiltrometer. We recommend measuring water infiltration because it is a central process to all other soil functions, is sensitive to grazing practices, and is relatively easy to measure.

Other Methods:

Double Ring Infiltrometer. Water can be poured into an outer ring with the goal of stopping lateral spread of water from the inner ring. From Herrick et al. 2005: "While double ring infiltrometers are sometimes recommended, it has been clearly shown (both theoretically and experimentally) that they provide little advantage over single-ring infiltrometers (Bouwer 1986), and the measurements take much longer. The best way to improve the accuracy of ponded infiltration measurements is to increase ring diameter, provided that this does not increase the risk of leaks (e.g., in soils with gravel or woody litter)."

Appendix 1D: How should we measure bulk density?

Issue Statement: Bulk density has been identified as one of the soil characteristics that will be measured as part of the Rangeland Monitoring Network.

Summary of Recommendation: We recommend measuring bulk density because it is a commonly used reliable indicator of soil compaction and is relatively easy to measure. We recommend using the dry weight method because it can accommodate a diverse range of soil types. We recommend measuring bulk density to a depth of 7.6 cm.

Background: Bulk density is the weight per volume of soil and is an assessment of compaction. Compacted soils have reduced pore space for water infiltration, water retention, root growth, soil aeration, and seedling germination (Lal 1998). Measuring bulk density will allow us to evaluate the relationship between management, plant community composition, and other covariates (e.g., soil type). Bulk density will also allow us to convert percent carbon to tons of carbon per unit land area.

The dry weight methods consists of grinding and sifting an undisturbed soil core of known volume, sifting to remove rock fragments, drying and weighing. Bulk density is calculated as the dry weight per volume of soil with the weight and volume of rock fragments removed.

Other Methods:

Ped (or Clod) Method: A large (size of pear or greater) clod of soil is selected, a thread is tied around the clod, it is weighed and dipped in paraffin, and weighed again in water.

If the soil is super sandy, neither method will work well. If the soil is very rocky such than an undisturbed core sample cannot be taken, an alternative protocol for the dry weight method is also possible (NRCS 1999).

Appendix 1E: How should we measure soil carbon?

Issue Statement: Soil carbon has been identified as one of the soil characteristics that will be measured as part of the Rangeland Monitoring Network.

This document describes our process to identify a method for measuring soil carbon. Our goal was to identify a method that is repeatable, easy to implement, and logistically and financially feasible.

Summary of Recommendation: We recommend measuring organic soil carbon via dry combustion with acidification of soils at 0-10 cm and 10-40 cm.

Cost estimate: $24 per sample.

Background: Soil carbon exists in organic and inorganic forms. Inorganic soil carbon is mineralized carbon (e.g., calcium carbonate). Because it dissolves in acid, it is only present in alkali soils and dry environments. It is less labile than organic carbon. Organic carbon is either charcoal (biochar), or soil organic matter (SOM). Charcoal is more stable than SOM. SOM is ~50% carbon (Pribyl 2010) and is the most abundant form of soil carbon. It is less stable than other forms, and is thus more responsive to changes in land management (Donovan 2013).

Total carbon or total organic carbon is typically used as a direct indicator of SOM (Schumacher 2002). There are several quantitative and semi-quantitative methods for measuring soil carbon.

Recommended Method:

Dry Combustion. This process heats a soil sample up to about 900°C, the carbon combusts/is oxidized, and the CO_2 that is produced is measured via gas chromatography (GC). This method oxidizes ALL of the carbon in the sample: SOM, charcoal, and inorganic carbon. The GC also produces a nitrogen spike, so some labs give you % N as well.

In order to isolate only the organic carbon, the lab will treat the sample with HCl to dissolve the inorganic form prior to combustion. We recommend this because of the diversity in soil type across the RMN.

We recommend the dry combustion method because it is more repeatable than Loss on Ignition or the Walkey-Black tests.

We recommend sampling soil carbon to 40 cm because this is a depth that is feasible to sample a large number of times and is where the highest concentration of organic carbon is located (Jobbagy and Jackson 2000, Conant et al. 2001) and is the layer of soil carbon that can be affected by changes in grazing management on a relevant time scale (years to decades). Separating carbon between the 0-10 cm layer and the 10-40 cm layer may provide better

resolution on carbon concentrations (Donovan 2013); the top 10 centimeters is often highly variable due to disturbance by small mammals (O'Geen *pers. comm.*).

Other Methods

Loss on Ignition (LOI). This method is less accurate than dry combustion. LOI measures organic carbon by measuring the change in weight of a sample that has been heated to ~400°C for several hours. It does not measure inorganic carbon. Cost: N/A

Walkey – Black. This method is less accurate than dry combustion. It uses potassium dichromate, does not measure inorganic carbon, and may miss some types of organic carbon. Cost: $21.50/sample

Both of these methods are more traditional than dry combustion and have typically been used to test for SOM for the purposes of herbicide application.

Appendix 1F: How should we delineate plant functional groups?

Issue Statement: Plant species richness, an important measure of biodiversity, is an important focal point of our analyses. However, the diversity of rangeland plant communities poses several challenges for land managers and scientists. Rangeland ecosystems have high numbers of species, also known as richness, and this complexity can be difficult to interpret. Furthermore, species richness does not always capture diversity relevant to ecosystems processes (Diaz and Cabido 2001). Finally, unknown plants that are not identified to species need to still be recorded in some way. To address these challenges, we translate species richness into functional diversity.

Summary of Recommendation: We recommend describing rangeland plants in the following seven categories: annual grasses, perennial grasses, annual forbs, perennial forbs, legumes, sedges and rushes, and shrubs and trees. Two additional categories, native and invasive status, are sometimes also useful to consider, but are not mutually exclusive from the other categories. These categories are created from a combination of taxonomy, growth duration (plants that live one year vs multiple years), and function (i.e., nitrogen fixation). Unknown plant species can often at least be classified to one of these functional groups in the field, and these categories give some information about what roles the species play in the ecosystem.

Recommended Functional Groups:

Annual grasses, an important forage for livestock, dominate California rangelands.

Perennial grasses live for multiple years. They can invest a relatively large amount of their biomass in root production; thus they are a group of interest for their potential to benefit soil health.

Annual forbs, also known as wildflower, are a very diverse group of plants. They provide valuable resources for pollinating insects, and can be an important forage for livestock.

Perennial Forbs are a relatively small, but important, group of species that are often deep rooting and can be valuable for wildlife and livestock.

Legumes have the ability to convert nitrogen from organic forms to inorganic forms through their association with rhizobia. Because they are a source of inorganic nitrogen, legumes play an important role in soil fertility and can influence plant and soil microbial diversity. Legumes are also a valuable forage for livestock.

Sedges & Rushes are plants in the Cyperaceae and Juncaceae families. They often grow in areas with high soil moisture content for much of the year, such as wetlands and seeps.

Shrubs & Trees are woody plants. Woody plants, an essential component of rangeland ecosystems, provide critical habitat for wildlife and perform valuable ecosystem services. They are typically not managed as forage for livestock, but can play important roles in influencing

forage type and quality. Livestock management can influence occurrence and abundance of shrubs and trees.

Native status, an important measure of diversity, describes plants that are indigenous to, or occur naturally (i.e., without human influence), in the places they are found.

Invasive species can impact diversity and ecosystem function. We limit classification of invasive species to those that are considered 'highly invasive' by the California Invasive Plant Council.

Other Functional Groups Considered:

C3/C4 photosynthetic pathways: This describes the different mechanisms through which plants reduce, or fix, carbon dioxide. The relative fitness of C3 (cool season) and C4 (warm season) plants is mediated in part by climate; thus they can represent one of the important ways that climate change can affect biogeochemical cycling and agricultural production. California rangelands are dominated by cool-season growth; therefore this categorization would do little to capture variation within the system.

Deep rooted/shallow-rooted forbs is very similar to the distinction between perennial and annual life cycle duration. Rooting depth has shown high levels of phenotypic plasticity and life cycle duration is easier to determine.

Specific leaf area describes the area of a leaf divided by its mass. It is a commonly used measure of the plant's life history strategy.

Appendix 2: A Recipe for Creating RMN Sampling Locations

Ingredients:

1. ArcGIS 10 (which version of 10 probably doesn't matter)
2. R, with the package spsurvey installed
3. Study site (ranch) shapefiles (polygon of property boundary works best)
4. The Military Grid Reference System 1km grid shapefile for your zone. This can be downloaded from http://mgrs-data.org/, but also stored on Point Blue's server here Z:\Emerging Projects and Partners\RWI\GIS within the subfolders mgrs_10s_100m, mgrs_11s_100m, and mgrs_10t_100m

Part I: Create your base point grid

1. Add MGRS 1 km grid to a new map in ArcGIS- it is important that you start with the MGRS first because this establishes the correct coordinate system for your workspace, which should be:

    Projected Coordinate System: WGS_1984_UTM_Zone_10N

    Projection: Transverse_Mercator

    Make sure you use the correct MGRS 1 km grid based on your zone (For Sonoma County it's **mgrs_10s_100m) Check out this kml if you don't know which zone you're in: Z:\Emerging Projects and Partners\RWI\GIS\MGRS_REF.kmz

2. Add your property boundary polygon (ArcMap will probably convert the property layer projection, this is OK).

3. Select the 1 km block in the MGRS layer that overlap with property.
4. Export the selected MGRS features to a new shp file (e.g. "RanchX_1km_grid").

5. Add RanchX_1km_grid (the new exported shp file) to map, which it ArcMap should do by default.

6. Subdivide RanchX_1km_grid into 250 m blocks. In Arc 10, use Data Management Tools→Sampling→ Create Fishnet
    a. Select "RanchX_1km_grid" in the Template Extent (choose from dropdown)
    b. Name new file and location for 'output feature class'
    c. Enter 250 for Cell Size Width and Cell Size Height

    This will create two shapefiles- a polyline grid, which you can ignore, and the 250 m gridded points- it will be given the name you specified with "_label" tacked on the end.

7. Start an edit session for the fishnet point grid you created above, and delete all points that fall outside of the property polygon. There are a number of ways to do this in ArcMap, the easiest may be to select all points, then using the "Select by Location" tool (under

"Select" from toolbar up top), use 'remove from current selected features' the points that fall within the property polygon. Then delete.

8. Remove points within 100 meter of boundary (of property or management unit, depending on your monitoring objectives)
    a. Use Analyst Tools→ Proximity→Buffer
    b. In Buffer Distance, enter "-100"; it's important to include the negative sign, this is how you get a buffer inside of a polygon.
    c. Set Side Type to "Outside Only"
    d. Use buffer to select and remove points within buffer (must be in an edit session to delete selected points)
9. We recommend to also exclude points within 100 m of riparian corridors or impenetrable chaparral, which may require some ground-truthing but could probably be done with the help of a veg layer or simply aerial imagery.

Part II: Draw a GRTS subsample

Drawing a GRTS subsample from your base point grid is only necessary if the base grid contains more points than you can feasibly cover. Typically the number of points you can cover for point count bird surveys is what determines the maximum number of RMN points. The optimal number of points will be determined by the site's terrain, though given the time constraints of point count surveys, we estimate that a biologist can survey 10-15 points in hilly terrain and 15-20 in flat terrain on a given morning. With the GRTS selection process, you can fine tune the number of points included in your subsample after ground-truthing occurs in the field.

1. Open R, and load the package spsurvey
2. Use the sample R code attached on the following page.
3. The R code produces a new shapefile that doesn't have a coordinate system- sometimes this gets you into trouble down the road, so I recommend assigning a coordinate system using ArcCatalog- and use the same system as the MGRS layer (more details on this below the R code)
4. Add the new shapefile in your ArcGIS map
5. Open the attribute table- look at the column "Panel"; points labeled "Panel1" are the selected GRTS'd selected subset, and "OverSamp" are the oversamples, or 'leftovers', which you can pick up if you either want to add more points to your original target number in your subset (the 'Panel1' points), or substitute in if there's a Panel1 point that you can't access or is in an inappropriate area (e.g. ended up falling in the middle of the barn). But it is important to pick up oversampled points in the order at which they're listed in the table- points are ordered so that they're spatially balance as you go down the list in sequential order.

Annotated R Code for Drawing a GRTS subsample:

GRTS'ing is used to draw a random and spatially balanced subset of points, typically what you want to do for very large properties where you can't possibly survey all points in a 250 m grid

Before using this R code, already have a shp file of grided points across your study area (property, management unit, etc). I normally do this using ArcGIS, but can be done in R (talk to Libby for gridding points in R) Points should be 250 m apart and aligned with the MGRS grid (quartered 1 km MGRS blocks; MGRS data is located in Z:\Emerging Projects and Partners\RWI\GIS).

Gridded points used for 'upland' points in grassland, oak savannah, oak woodland, shrubsteppe, and some mountain meadows. Riparian points are NOT gridded or GRTS'd- riparian points are linear and simply follow riparian corridor.

####Instructions##########################

set your working directory, where your shp files are and where you will be writing the new shp file.
e.g. if working in the "GIS" directory:

setwd("Z:/Emerging Projects and Partners/RWI/GIS/")

Install spsurvey, if not already installed

load required package spsurvey###

library(spsurvey)

specify sampling design
Set 'Panel' do desired number of points to sample and set 'over' to remaining number of points in the grid
In this example the input file has 25 points, and we wish to survey only 15 of those points. So we panel 15 points and oversample by 10 points.

grtsRanchX<-list(None=list(panel=c(Panel1 = 15),seltype = "Equal", over = 10))

##"grtsRanchX" is just an arbitrary name of the function, you can call it whatever you want##
pull the GRTS sample

grts(grtsRanchX, DesignID="RANX", SiteBegin = 1, type.frame = "finite", src.frame = "shapefile", in.shape = "RANCHX_POINT_GRID",xcoord="xcoord", ycoord="ycoord",out.shape = "RANX_GRTS")

Some explanations of code below
'Design ID' creates the point name prefix.
'in.shape' is the input shp file of gridded points
'out.shape' is the name of the output shp file with gridded points
In the attribute table, look at the column "Panel";points labeled "Panel1" are the selected GRTS'd selected subset, and "OverSamp" are the oversamples, or 'leftovers', which you can pick up if you have more time or substitute if there's a Panel1 point that you can't get to. But important to pick up oversampled points in the order at which they're listed in the table- points are ordered so that they're spatially balance as you go down the list in sequential order.
You MAY need to apply a coordinate system to the output shp file; to do this in ArcGIS, navigate to output file in Catalog, double-click on shp, go to tab labeled "x-y coordinate system", click on the little globe in the upper right and 'add coordinate system', choose Import, and select one of the other grid shp files (polygons or points work)

Appendix 3: Soil Microbial Community Sampling Protocol

This protocol follows the normal RMN soil sampling procedure, with a few addendums and modifications. The addendums and modifications are described below.

Equipment (microbe-specific items underlined)

1. You will require the following equipment:
    a. Soil probe – 40 cm length
    b. Shovel
    c. Garden trowel or flat blade knife
    d. Two buckets, one for 0-10 cm soil and one for 10-40 cm soil
    e. GPS with spare batteries
    f. Compass
    g. Notebook
    h. Clipboard or data binder
    i. Whirlpak bags (used instead of normal plastic baggies)
    j. 70% isopropyl alcohol wipes –OR– 70% isopropyl liquid, a spray bottle, and paper towels/Kleenex. 70% ethanol would also work, but may be harder to find.
    k. Pen and permanent marker
    l. Latex gloves (necessary if you are going to dig a pit and collect soil that way)
    m. Mini cooler and ice/ice packs, to keep soil cool in car
    n. Screwdriver (to help get stuck soil out of the soil probe, if needed)

Before you go in the field:

1. You will revisit the same soil sampling points from earlier in the year. Obtain the list of RMN points from which you sampled dynamic properties (SOC, bulk density, and water infiltration). Include distances and directions within each point, so you can revisit as close to the same location as possible.

In the field:

At each location:

1. No modifications to this section. Follow RMN soil protocol, identifying sampling sites using prior GPS coordinates, random distances, and directions within each point.

At each site:

1. You can skip over the bare ground, litter depth, water infiltration, and bulk density sections. We will not be redoing these field analyses.

2. To collect samples for microbial analysis, follow the soil carbon sampling protocol with the following modifications:
    a. Prior to using the soil probe, shovel, and buckets at each point, sterilize with isopropyl alcohol. Wipe down the surface of each so that all areas that will be in

contact with the soil have been treated. If you are using any other materials that may come in contact with the soil (e.g., screwdriver), also sterilize those. <u>You will only need to do this once, prior to sampling at each new point count location</u>.

b. Although microbial analyses require much less soil mass than the carbon and texture analyses, we still want to get a representative sample of soil from the 50 m radius circle that is comparable to our other soil analyses. Therefore, you will take the usual five cores per depth per site. If sampling from a pit*, be sure to sample evenly from across the pit face such that you have an equal amount of soil throughout the profile (e.g., you don't want lots of soil from 0-5 cm and only a little from 5-10 cm). **Always wear gloves when sampling from the face of a pit.*

c. Place all 0-10 cm samples from a given point in one sterilized bucket, labelled appropriately. This will create a bulked sample of the 5 sites within each point. <u>Mix well</u> and transfer a representative sample to a properly labelled whirlpak bag. Do the same for 10-40 cm.

d. It is important to keep these soil samples as cool as possible until you are able to freeze them. You can place them on ice or an icepack in your car, or put them in a refrigerator until you can locate a freezer. Do not place on dashboard or let the samples sit in the sun. As soon as you are able to (within 12 hours), place in freezer.

Note: It is important not to touch the inside of the whirlpak bag. To pull open the bag, use the white tabs on the outside. Also, try not to touch the soil or soil probe surfaces with your bare hands unless you have sterilized them with an isopropyl wipe or are wearing latex gloves. This will help to minimize contamination.

Appendix 4: RMN Data sheets

Rangeland Monitoring Network Vegetation Protocol (updated Mar 2017)

Point ID:

Date: Initials:

Direction:				Lower Layers			
PT	Canopy	Top Layer	Ht (cm)	Lower 1	Lower 2	Lower3	Soil Surface
1							
2							
3							
4							
5							
6							
7							
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9							
10							
11							
12							
13							
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48							
49							
50							

Direction:				Lower Layers			
PT	Canopy	Top Layer	Ht (cm)	Lower 1	Lower 2	Lower3	Soil Surface
1							
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* circle to indicate dead (rooted) material

Species Checklist

County:		PointID:			Observer:		Date:	

Grasses				Shrubs					Forbs		
Common Name	**USDA**	Presence		**Common Name**	**USDA**	Height (cm)	%Cover		**Common Name**	**USDA**	Presence

Trees			
Common Name	**USDA**	Height (m)	%Cover

DBH <23cm: 23-38cm: >38cm:

Number of snags

Other Info			
Grazing?	Y		N

NOTES:

Rangeland Monitoring Network Soil Data

Initials ☐ Date ☐

Point Count ID: ☐

GPS Loc: ☐ - ☐ Datum ☐

SITE CHARACTERISTICS

Location Description: _____

Carbon 0-10cm (%)	Carbon 10-40cm (%)	Clay 10-40cm (%)	Sand 10-40cm (%)	Silt 10-40cm (%)

Water Vol (mL)	Ring infiltrometer Diameter (cm)	Bulk Density Diameter (cm)	Bulk Density Height (cm)

Evidence of recent grazing? (Y/N) ☐

SAMPLE DATA

Sampling Location						Water Infiltration			Bulk Density					
Sample No.	Dist.	Deg.	Bare Ground	Litter Depth (cm)	Catenal Position	Time1 (hh:mm:ss)	Time2 (hh:mm:ss)	Extrapolate?	Wet Wght (g)	Dry Wght (g)	Rock Wght (g)	Rock Vol (mL)	Max Depth (cm)	Carbon
						: :	: :		.	.	.			
						: :	: :		.	.	.			
						: :	: :		.	.	.			
						: :	: :		.	.	.			
						: :	: :		.	.	.			
						: :	: :		.	.	.			
						: :	: :		.	.	.			
						: :	: :		.	.	.			

Equation for extrapolated infiltration time:

$$Extrapolated\ time = \frac{45min * 450ml}{Volume\ infiltrated}$$

Where volume infiltrated = $\pi (7.6cm)^2 * (2.5cm - ht\ of\ water\ remaining)$

Index	Distance	Direction
1	41	211
2	5	243
3	10	348
4	31	75
5	29	322
6	10	114
7	17	146
8	1	253
9	18	198
10	45	85
11	5	217
12	39	340
13	15	170
14	39	11
15	25	330
16	1	184
17	46	7
18	48	53
19	26	218
20	27	159
21	44	47
22	3	28
23	24	321
24	12	37
25	21	258

Index	Distance	Direction
26	2	225
27	4	255
28	12	220
29	46	168
30	13	103
31	19	355
32	10	42
33	37	217
34	39	90
35	33	219
36	8	270
37	30	103
38	27	153
39	37	84
40	32	69
41	14	116
42	42	309
43	50	222
44	46	337
45	5	13
46	20	217
47	31	141
48	9	305
49	31	239
50	43	315

Location Notes:

Site	Notes				

Point Blue Point Count Data Form – Exact Distance version (300m cutoff)

Pg. _____ of _____

Project	County	Transect	Month	Day	Year	Visit#

First Name   Last Name   initials (used in data entry)

Point	Time				Species		Data	Notes

Behavioral codes (record initial detection cue): S = song, V = visual, C = call, D = drumming, H = wing whir (hummingbirds, doves). Circle if the same bird is heard singing after initial detection. Always record juveniles as "J" – not by detection cue.
Breeding Observation Codes (list any that apply in Notes column): CO=copulation, MC=material carry, FC=food carry, NF=nest found, FL=fledglings, FS=fecal sac carry, DD=distraction display, PA=pair, DI=display.

Weather Information: Please estimate temperature, cloud cover (% of sky covered by clouds), and approximate wind speed.
_____ ° F or C (circle one)   _____%   _____ mph, kmph, Beaufort
Temperature   Cloud Cover   Wind Speed   ENTERED_____ PROOFED _____

Grazing Record Summary

This is a property level summary, intended to summarize grazing management on the entire ranch.

Project Name: _____   **Study Area Code:** _____ [e.g. SHA-15-01]

 # Acres Grazed: _____ac. **Grazing Season Start Date:** __/__/__   **Grazing Season End Date:** __/__/__

Length of Grazing Season (days): _____ [this number is 365 if grazing year-round]

List each Animal Class on the entire ranch, and for each Animal Class, note their Frame Class (cow and pairs only) and number of animals. If more than 4 Animal Classes, then include them in the Notes field.

Animal Class	Frame Class	Number of Animals	Calendar Months Grazed	Primary Grazing Strategy*
1.				
2.				
3.				
4.				
5.				

Animal Class: cows, pairs (spring or fall), yearlings, bulls, sheep, etc.
Frame Class: small, medium, or large; only list for cows and pairs and based on skeletal size of the animal given animal type/breed (not age class); majority will be "medium".
No. of Animals: the average number of animals present through the grazing season by class. If this number changes for a class within a year, calculate an average weighted by the proportion of the year.

*Primary Grazing Rotation Strategy (use code A through G below):

  A = No rotation; **B** = ≥ Once a month; **C** = Every 2-3 weeks; **D**= Weekly; **E** = 2-5 days; **F** = Every day; **G** = Multiple times a day

Average rest time per paddock/pasture before re-grazing (in days): _____

Do you feed hay?   Yes_____   **No**_____

If you do feed hay, what is the approximate amount fed on property: _____ approximate tons/year

Notes: In the notes, please be specific; add any clarifying details needed (e.g. whether some fields were rested entirely, or if response to haying is for a drought year or typical management).

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