Draft pollinator monitoring plan for western San Diego County

Task 10
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Executive Summary

This report completes Task 10 under the current SANDAG contract, as data analysis of pollinator data and associated report was completed in November 2023 (another deliverable for this task/contract). While completed, this is still considered a draft pollinator monitoring plan as a 2024 pilot study will: 1) assess pollinator communities across a habitat quality gradient, 2) long-term trends in pollinators, and 3) simultaneously compare several methods of data collection, including the involvement of volunteers. Results from the pilot study will be used to refine this draft pollinator monitoring plan.

A 2021 objective for San Diego Management and Monitoring Program's (SDMMP) Management and Monitoring Strategic Plan for Conserved Lands in Western San Diego County was to begin preparing a monitoring plan to survey pollinator communities and assess ecological integrity of pollinator functions. Previously collected specimens were identified, these data analyzed (Marschalek et al. 2023a), and literature reviewed to inform the development of this draft pollinator monitoring plan. This plan addresses two primary objectives:

1) Assess pollinator assemblages across coastal sage scrub vegetation communities in western San Diego County to describe sensitivity of pollinators to a gradient of habitat conditions.

2) Detect changes in pollinator abundance (trends), richness, distribution (status), and assemblages through time in the same area/vegetation communities.

There are many pollinator monitoring programs being developed around the world and in the United States, often with their unique set of protocols. A sampling approach similar to the EU Pollinator Monitoring Scheme (O'Connor et al. 2019, Potts et al. 2021) will be used to monitor pollinators in western San Diego County with pan traps and transect sampling. This combination of methods provides a more complete description of the pollinator community.

Roughly 40 sites should be sampled each year of monitoring, stratified across habitat characteristics such as quality/degradation, degree of urbanization in the surrounding landscape, and isolation. Each site will have a 90m x 90m sampling plot where pan traps and visual surveys will be utilized to sample the pollinators. Five pan trap stations will be placed in each plot, each station with a fluorescent yellow, fluorescent blue, and white cup filled with soapy water (15 cups total). Transect counts will be conducted by crossing the sampling plot four times (450m in length) and recording the number of each butterfly and bumble bee species observed. Netting surveys will be conducted within the sampling plot, capturing any insect observed on flowers in one hour. Pan traps, transect counts, and netting surveys will start in April and end in early August. Each sampling plot will be sampled with the three different techniques every other week.

Since there are several techniques for trapping or recording abundances of potential pollinators, each with advantages and disadvantages, we will also compare sampling methods

(pan traps, visual counts, netting, photography). Concurrent sampling at the same sites and times is needed to determine the most efficient protocol. Data collection by community scientists will be assessed as a cost saving option for future monitoring. Our goal is to create a user-friendly monitoring plan that can be implemented by wildlife biologists and/or community scientists (not exclusively entomologists). In addition to monitoring protocols, we hope to provide a list of relevant taxa that appear to be most vulnerable to habitat degradation. This will outline a plan for a systematic, long-term pollinator monitoring plan, starting to identify the drivers of declines which is needed to inform management.

Table of Contents

List of Figures

Introduction

Background

San Diego Association of Governments Regional Habitat Conservation Taskforce's (formerly TransNet Environmental Mitigation Program) Regional Management and Monitoring 2021-2022 Workplan includes objectives to improve wildlife movement. These objectives are based on the San Diego Management and Monitoring Program's (SDMMP) Management and Monitoring Strategic Plan for Conserved Lands in Western San Diego County (MSP Roadmap; SDMMP and TNC 2017, SDMMP 2021). An objective for 2021 was to begin preparing a monitoring plan to survey pollinator communities and assess ecological integrity of pollinator functions in coastal sage scrub, chaparral, forblands, and grasslands across the MSP Area. Previously collected specimens were identified, these data analyzed, and literature reviewed (Marschalek and Wall 2022, Marschalek et al. 2023a) to inform the development of this draft pollinator monitoring plan. The two primary objectives of this plan are to assess ecological integrity and detect changes in the pollinator community. We are planning to conduct a pilot study, with field sampling in 2024, to refine this draft plan.

Ecological integrity refers to "the ability of an ecological system to support and maintain a community of organisms that has species composition, diversity and functional organization comparable to those of natural habitats within a region" (Karr and Dudley 1981). Using pristine and undisturbed reference site provide important data about the expected composition and variation for a particular system (Wurtzebach and Schultz 2016). This project is particularly interested in how the pollinator community changes along a gradient from high quality to low quality coastal sage scrub and grassland habitats, also considering time since fire and habitat fragmentation. Many insect species have coevolved with plant species or have adapted to feed on a small number of plant species (theory started with Ehrlich and Raven [1964]; examples of subsequent studies include Maron et al. [2019] and references within Hu et al. [2023]), resulting in insects being useful indicator group (Bisevac and Majer 2002, Kremen et al. 1993, Samways 2005).

Pollinators and insect declines have been of increased interest over the last decade. For example, a recent global meta-analysis of 166 long-term surveys of insects found an average decline of approximately 9% per decade of terrestrial insect abundance (van Klink et al. 2020). Pollinator declines are also well documented (Orr et al. 2021, Tepedino and Portman 2021). Pollination has been linked to species richness (e.g. Vergara and Badano 2009, Garibaldi et al. 2016), and the surrounding landscape is important for supporting populations of pollinators in agricultural systems (Schubert et al. 2022). With the estimated global economic value of crops pollinated by insects is $190.5 billion/year (Gallai et al. 2009), pollinators for both natural and agricultural systems are important.

Determining trends (change in population size) or status (change in distribution), either increasing or decreasing, of insects is often challenging because historic datasets do not exist. For San Diego County, there are many sites with at least one year of sampling targeting pollinators but much is limited to bees (Hung et al. 2019, 2021) or butterflies (Marschalek et al.

2023b, Marschalek and Deutschman unpublished data). Power greater than 80% is considered a sufficient level to detect an effect if it truly exists (e.g. Roy et al. 2007). Breeze et al. (2020) reported that experts (on average) indicated that a 5% annual detection rate for each pollinator response variable would be an ideal standard for a program designed to capture pollinator trends. This is equivalent to a 40% decline rate over 10 years and acknowledges the expected annual variability in insect numbers.

Other Pollinator Monitoring Efforts

Currently, there are many efforts to develop "pollinator" monitoring plans, but the scope of these efforts is often taxonomically limited to either bees or broad taxonomic groups if extending beyond bees. Often butterflies, another pollinator group, are excluded because there are previous and continuing efforts related to these insects. Regardless, taxonomic resolution and cost are important considerations, and not mutually exclusive.

LeBuhn et al. (2012) evaluated whether a cost-effective monitoring program could be designed that would detect regional, national, or global changes in bee assemblages within five years using data collected from seven techniques and computer simulations. They found that 200-250 sampling locations each sampled twice over five-year period would be able to detect 2-5% annual declines in species richness and total abundance for $2 million (at least 300 sampling locations would be required to detect 1% annual declines). Considering inflation, this value at the time of manuscript submission would be about $2.7 million in July 2023 (US Bureau of Labor Statistics 2023).

Efforts are underway to explore a **US national monitoring program for bees** (Woodard et al. 2020, https://www.nativebeemonitoring.org/). To date, efforts have outlined needs and challenges associated with bee monitoring at a national scale. Future actions include: (1) defining the scope, aims, and cost of a national native bee monitoring program; (2) improving the national capacity in bee taxonomy and systematics; (3) gathering and cataloging data that are standardized, accessible, and sustainable; (4) identifying survey methods and prioritizing taxa to monitor; and (5) prioritizing geographic areas to be monitored. Specific tasks of this funded project include: (1) coordinate existing monitoring programs; (2) identify national priority areas for monitoring, (3) generate sets of standardized monitoring protocols; (4) create a training program to support the monitoring workforce; and (5) interface with the public and policy makers (https://portal.nifa.usda.gov/web/crisprojectpages/1022401-national-native-bee-monitoring-plan-for-the-us.html).

Xerces Society has a Monitoring for At-Risk Pollinators program which includes the **Bumble Bee Watch** (https://www.bumblebeewatch.org/) and the **Citizen Scientist Pollinator Monitoring Guide for California** (https://xerces.org/publications/id-monitoring/citizen-scientist-pollinator-monitoring-guide). The broader pollinator program includes the following taxonomic groups/resolution: honey bee, bumble bee, carpenter bee, hairy leg bee, green sweat bee, striped sweat bee, small dark bee, striped hairy belly bee, metallic hairy belly bee, and cuckoo bee. Xerces, along with ICF International Inc., has also developed Pollinator Habitat

Conservation Along Roadways recommendations (https://www.trb.org/NCHRP/NCHRPWOD362.aspx), including a chapter for California.

Global Pollinator Watch is a citizen science program utilizing iNaturalist to help understand pollinator distributions and abundances (https://earthwatch.org/global-pollinator-watch). This effort is relatively unstructured in that there are no field data collection protocols, but does provide tips for taking “research-worthy” pollinator photos for several insect groups.

USGS is leading an effort to use **pollinator eDNA** to assess the ecological resilience of grassland habitats of the northern United States (https://www.usgs.gov/labs/pacific-northwest-environmental-dna-laboratory/science/using-pollinator-environmental-dna#overview). Samples are collected from flowers, promoting the non-lethal sampling and hope of avoiding challenges with identification to the species level. Work started in 2022 with the collection and processing of 2000 flower samples.

The **UK Pollinator Monitoring Scheme** (PoMS, https://ukpoms.org.uk/fit-counts) was established in 2017 and asks volunteers to watch for flower visiting insects for 10 minutes during daylight hours from 1 April to 30 September, with multiple counts at a location encouraged. Observers watch for insects within a 50cm x 50cm area, take a photo of the target flower (14 target plants) and photograph examples of the different insects observed. Taxonomic insect groups to be recorded include bumble bees, honey bees, solitary bees, wasps, hoverflies, other flies, butterflies and moths, beetles (larger than 3mm), small insects (less than 3mm long), and other insects. Average number of insect flower visitors averaged 9.3 and 13.2 insects per count in 2018 and 2019, respectively (Potts et al. 2021).

The PoMS also includes sampling random 1km squares in agricultural and semi-natural landscapes. Each square involves a set of five pan trap stations (each with three colored bowls) and left for six hours. This is repeated on four survey visits between late April and September. Volunteers were trained one-on-one and were able to cover 54 of 74 squares in 2019. Identification to species was attempted for bees and hoverflies, with consultant taxonomists used for challenging specimens. Butterflies have been monitored since the 1970s through the Butterfly Monitoring Scheme so they were not formally included in the PoMS.

The European Commission launched STING (Science and Technology for Pollinating Insects, https://wikis.ec.europa.eu/pages/viewpage.action?pageId=23462107) in June 2019 and resulted in an **EU Pollinator Monitoring Scheme** for the EU Common Agricultural Policy. This includes a review of pollinator data from Europe, finding substantial data demonstrating declines among the status and trends of bees, butterflies, and moths. Fewer studies have included hoverflies (Syrphidae), with mixed results. One knowledge gap identified is also applicable to San Diego County: “In general, most information on the status and trends of European pollinators focuses on diversity and occupancy. However, there is an urgent need to understand how measures of pollinator abundance and biomass are changing, because this is virtually unknown except for some butterfly species.”

The EU recently funded **SPRING** (Strengthening Pollinator Recovery through INdicators and monitorinG, https://www.ufz.de/spring-pollination/index.php?en=49053, https://butterfly-monitoring.net/spring), which started in May 2021 and will run until November 2023. This project supports the preparation for the implementation of the EU Pollinator Monitoring Scheme. SPRING will include: 1) expanding the European Butterfly Monitoring Scheme (eBMS), 2) building up the capacity of citizen science networks on pollinators across Europe, 3) organizing advanced taxonomic training, and 4) piloting a Minimum Viable Scheme (MVS) for wild bees, butterflies, and hoverflies. The Minimum Viable Scheme includes the use of pan traps and conducting transect counts within 1km squares, with flower-insect timed observations optional (https://www.ufz.de/export/data/498/268546_SPRING%20MVS%20Pilot%20Survey%20guidance_incl._recodring-forms_April%202022.pdf). The EU monitoring scheme aims to capture a very broad and representative part of the total pollinator biodiversity, but acknowledges it cannot target all pollinators.

At the 2023 Entomological Society of America Conference, a symposium titled "**Using Statewide Surveys to Assess the Conservation Status of US Pollinators**" included 11 presentations on statewide pollinator efforts. A common theme involved developing an inventory due to the general lack of current information about pollinator distribution and abundance. Some of the states included standardized sampling for trend analyses, although current work may be to establish baseline data for these future analyses. Some efforts also included collecting plant associations data and use of volunteers.

Locally, the Resource Conservation District in San Diego County has established the **San Diego Pollinator Alliance** (https://www.rcdsandiego.org/san-diego-pollinator-alliance). This is a group of agencies and organizations that are working towards the protection of pollinators in the county through outreach, education, and projects.

Pollinator Monitoring Plan Considerations

Monitoring of pollinator communities, like focused sampling for most insect species, requires consideration of spatial and temporal factors. Increased attractiveness of larger floral displays and height of trap are two examples of how spatial factors can influence capture rates. Temporal considerations are important to consider because insect activity and abundances are often dictated by daily and annual temperature and precipitation. This means that the phenology of the adult flight season and numbers present during that flight season would be expected to vary from year to year, depending on annual weather conditions.

Most insect pollinating species are from the orders Coleoptera, Diptera, Hymenoptera, and Lepidoptera. Not that all species within these orders are pollinators, but the species richness of each order provides an indication of diversity often encountered with pollinator work: Coleoptera (400,000 species; 25,200 species in North America), Diptera (153,000 species; 17,000 species in North America), Hymenoptera (153,000 species; 18,000 species in North America), and Lepidoptera (182,500 species; 12,000 species in North America), represent about 40% of all known species on life (Abbott and Abbott 2023). Related to being taxonomically diverse, pollinators also have diverse life histories. This means that a single sampling technique will not capture all species of flower visitors in an area and may have different capture rates depending on the species (Montgomery et al. 2021). In addition, taxonomic expertise is required at times for identification to the species level and is often in short supply (i.e. taxonomic impediment). The EU Pollinator Monitoring Plan offers a relatively complete description of different sampling strategies, with associated advantages/disadvantages, costs, and implementation examples (Chapter 4 in Potts et al. 2021). Also, see Prendergast et al. (2020) for advantages/disadvantages of methods for bee sampling.

Passive Sampling

-Pan Traps (aka Bee Bowls)

A very common sampling technique for pollinators, colored bowls or cups are filled with soapy water are placed in the environment (Droege 2002). Taxa such as butterflies and moths (Lepidoptera), and bumble bees (*Bombus* sp.) are rarely captured using this method with low initial costs. Sampling (trap placement/installation) is relatively easy and can quickly capture many specimens so a cost in the form of effort/time can be substantial to process all specimens.

-Vane Traps

Vane traps typically have blue plastic panels above a yellow plastic collecting container. Installation is relatively easy but requires some sort of support to elevate off the ground. Cost is moderate and trapping is mostly focused on bees. Blue vane traps are very effective in capturing bumble bees, so much so that the use of blue vane traps is being restricted in some cases.

-Malaise Traps

Malaise traps are tent-like structures, with a collection jar at the top, that can be used for Hymenoptera and Diptera, insects that tend to move up when encountering a barrier. If used in combination with a pan trap (pan with soapy water) at the base of the tent walls, Coleoptera can be captured. This is a relatively expensive trap and can result in many specimens so a cost in the form of effort/time can be substantial to process all specimens.

-Light Traps

Light traps could have one of several designs and are an effective technique for sampling moths and other nocturnal insects. A power source is required and can be expensive. Light traps can quickly capture many specimens so a cost in the form of effort/time can be substantial to process all specimens.

Active Sampling

-Netting

Transects or delineated areas can be searched, capturing insects from flowers with nets. All insects observed on flowers or certain groups could be targeted. Netting would require less specimen preparation due to fewer specimens captured compared to some passive sampling techniques. Surveyor experience and skill can influence the specimens captured, especially for skittish and fast flying insects. Training would be required for reliable data.

-Visual Counts

Either associated with a transect, delineated area, or stationary point, visual counts of insects within a certain distance of the observer are recorded. These would most often be conducted when a species can be relatively easily identified (i.e. within a few seconds). Pollard Walks are a widely used method transect method for butterflies. Visual counts could be used for butterflies, western honey bee, and bumble bees to the species level. Other pollinator monitoring plans have incorporated other insect groups, but a higher taxonomic level (e.g. family level). Results can be influenced by surveyor experience and training would be required for reliable data.

-Photography

Photographing insects on flowers provides a record of the observation for review and identification, and potentially providing insect-plant relationship data. Capturing images of insects could be an add-on to transect or point count sampling. Results can be influenced by surveyor experience and training would be required for reliable data.

Regardless of the collection methods, there are options of uploading these data and/or images to an online, publicly available database (e.g. iNaturalist, GBIF, Bugguide, eButterfly). These data would be made available for other researchers and provide an opportunity for taxonomic experts to assist with identifications. Artificial intelligence is being explored for in numerous ways for both data collection and specimen identification (e.g. Hoye et al. 2021) and may provide important time-saving options.

Proposed Monitoring Plan

There are certain criteria important for a well-designed monitoring program for biodiversity assessment in large regions (Buckland and Johnston 2017):

1) Representative sampling locations
2) Sufficient sample size
3) Sufficient detections of target species
4) Representative sample of species (or all species)
5) A temporal sampling scheme designed to aid valid inference

With these considerations in mind, a sampling approach similar to the EU Pollinator Monitoring Scheme (O'Connor et al. 2019, Potts et al. 2021) will be used to monitor pollinators in western San Diego County (Figure 1). The overall pollinator community will be quantified using pan traps, transect counts, and nettings surveys. A combination of methods will provide a more complete description of the pollinator community as certain taxa may be underrepresented with particular sampling techniques (Wilson et al. 2008, Popic et al 2013, Wood et al. 2015). This plan addresses two primary objectives:

1) Assess pollinator assemblages across coastal sage scrub and grassland (Figure 2) vegetation communities in western San Diego County to describe sensitivity of pollinators to a gradient of habitat conditions.

2) Detect changes in pollinator abundance (trends), richness, distribution (status), and assemblages through time in the same area/vegetation communities.

Roughly 40 sites should be sampled each year of monitoring, stratified across habitat characteristics such as quality across the coastal sage scrub (relatively pristine) – non-native grassland (relatively disturbed) gradient, degree of urbanization in the surrounding landscape, and isolation. Each site will have a 90m x 90m sampling plot where pan traps and transect surveys will be utilized to sample pollinators (Figure 3). Five pan trap stations will be placed in each plot, each station with a fluorescent yellow, fluorescent blue, and white cup filled with soapy water (15 cups total). Traps will be left out for four days (installed on Monday and retrieved on Friday, or similar schedule). Transect counts will involve visual surveys of butterflies and bumble bees conducted along transects that cross the sampling plot four times (Figure 3). The number of each butterfly and bumble bee species will be recorded. One-hour netting surveys will be conducted within the sampling plot, capturing any insect observed on flowers. Pan traps, transect counts, and netting surveys will start in April and end in early August. Each sampling plot will be sampled with the three different techniques every other week.

To create a user-friendly monitoring plan that can be implemented by wildlife biologists and/or community scientists (not solely entomologists), it is expected that training and identification guides will be required. In addition to monitoring protocols that are suitable for detecting changes, after the 2024 – 2025 pilot study we hope to provide a list of relevant taxa that appear to be most vulnerable to habitat degradation. A more geographically restricted assessment found that most of the commonly collected insects (overall species richness, Melyridae, Halictidae) exhibited negative relationships with urban land cover, except for the western honey bee (*Apis mellifera*) (Marschalek et al. 2023a). Indicator species found only in high quality reserve habitats suggest the following species are disproportionately vulnerable to habitat loss: Apidae: *Anthophorula torticornis*, *Diadasia laticauda*, *Melissodes communis*, *M. plumosus*, *Eucera dorsata*, *E. tricinctella*; Andrenidae: *Perdita interrupta*; Halictidae: *Augochlorella pomoniella*, *Lasioglossum robustum*, *L. punctatoventre*; Megachilidae: *Anthidium jocosum*, *Ashmeadiella foveata*, *Dianthidium dubium*, *D. pudicum*, and *Megachile* cf. *seducta* (Hung et al. 2019). This will provide the needed foundation of a systematic, long-term monitoring plan for monitoring pollinators, and start to identify the drivers of declines, both urgently needed to inform management (Breeze et al. 2020).

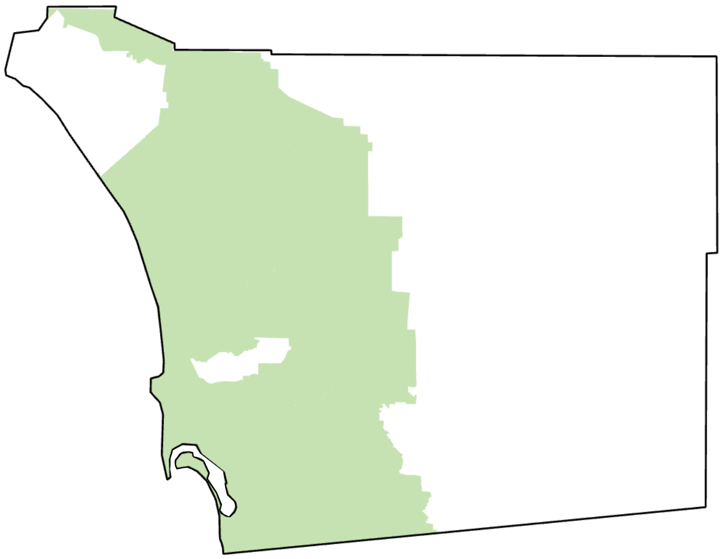

Figure 1. San Diego County, with the monitoring plan area of western San Diego County highlighted in green.

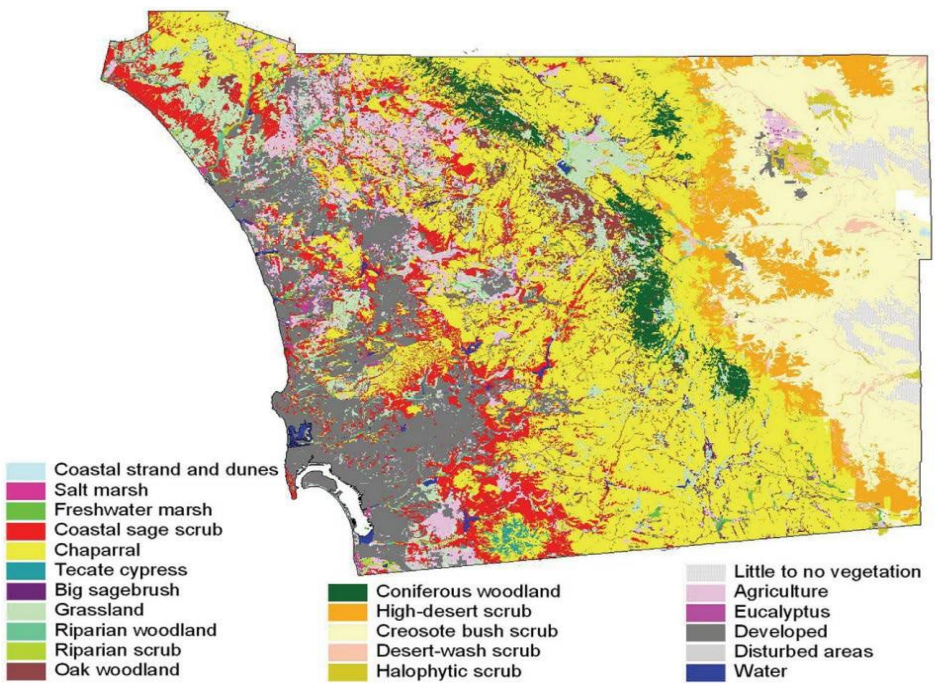

Figure 2. Vegetation communities in San Diego County (San Diego Bird Atlas available: https://sdplantatlas.org/ge_files/pdf/IntroSanDiegoHabitatBirds.pdf). The coastal sage scrub community (dark orange) will be the focus, including many smaller fragments within the urban (gray) matrix.

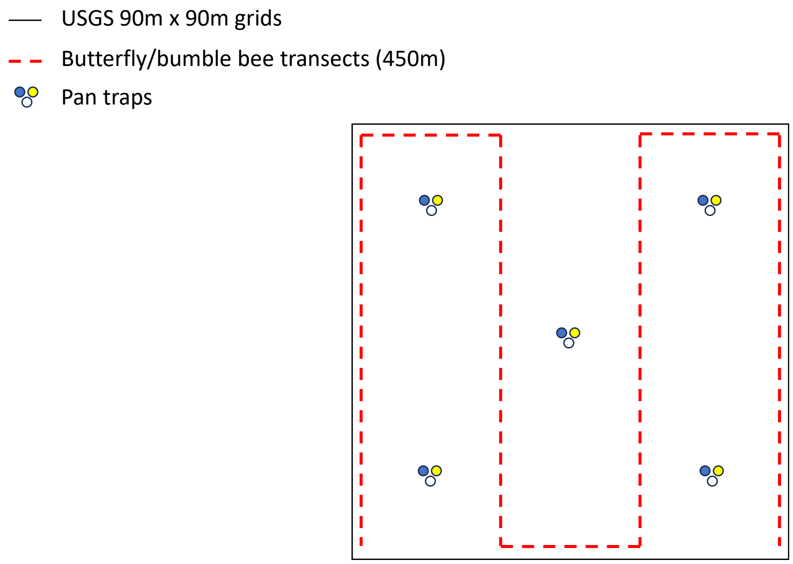

Figure 3. Sampling design for pollinators in the USGS delineated 90m x 90m plant sampling grids.

Alternatives

As explained above, there are several techniques for trapping or recording abundances of potential pollinators, each with advantages and disadvantages. And it is a combination of techniques that will more completely capture the pollinator assemblage at a given site. A comparison of sampling methods, conducted concurrently at the same sites and times, is needed to determine the most efficient protocol. This comparison must consider time, cost, natural variation in the pollinator community (daily, seasonal, annual), data replicability and reliability, and data/specimen processing and storage.

To assess a potential cost-saving data collection protocol, we will quantify the reliability and variability of data collected by community scientists in 2024. Multiple volunteers will conduct surveys at a subset of sites where the University of California – San Diego has conducted bee surveys and the 2024 SDMMP 90m x 90m plots for butterflies/bumblebees using the same standardized protocols as paid staff and experts. Community scientists have varying levels of ability and knowledge (Kremen et al. 2011; O'Connor et al. 2019) so it is important to understand any limitations their involvement with monitoring may present. For example, community scientists did not observe approximately half of the bee groups collected by professional scientists at the same sites (Kremen et al. 2011).

An assessment of different techniques and community science will provide important information and modifications to this draft pollinator plan. For example, the EU Pollinator Monitoring Scheme (Potts et al. 2021) initiated an initial assessment of pan traps, transects, and observer expertise (O'Connor et al. 2019). O'Connor et al. found: 1) pan traps and transects at the same sites yielded distinct pollinator assemblages, and 2) taxonomic experts netting along transects generated species accumulation data similar to pan traps, while non-pollinator researchers underperformed both. Based on these results, a certain level of taxonomic expertise will likely be required for an effective pollinator monitoring plan. With different taxa in southern California, it is important to compare these techniques in situ.

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